Mapping California
FROM THE EDITORS

If you ever strike up a conversation about maps with a vegetation scientist, get comfortable—you may be there for a while! If you’re a layperson, the discussion may seem a bit opaque at first, a little heavy on the jargon. But don’t be daunted. As this special issue will show, maps aren’t just for the data-savvy. They’re the most powerful tool we have for understanding, connecting to, and protecting California’s unique flora—and they are for everyone to create and use.

The aim of this issue is severalfold: First, to demystify conservation mapping and explain why generations of scientists have spent their entire careers doing it, often visiting the same areas over and over to understand how California’s unique landscapes are changing over time.

Second, to highlight how maps are deepening our understanding of California today, by helping us identify important areas to prioritize for conservation, for example, and tackling pressing issues like habitat loss and wildfire.

Finally, but most importantly, to show the power of maps to reveal unexpected, even revelatory connections between people and places, plants and animals, the values we promote and our actions on the ground. (Our special thanks to photographer Evan Keeler-Wolf for sharing the magnificent aerial images you’ll see in this issue, which show California’s landscapes in all their beauty and complexity.)

This is a critical moment for Californians. As we grapple with the impacts of climate change and development pressure, California is now the state with the highest concentration of imperiled species in the US. We belong to one of the world’s 36 biodiversity hotspots, and the stakes are high. Fortunately, vegetation mapping has emerged as one of the most cost-effective and strategic tools that we have to conserve this precious biodiversity. We hope you’ll view this issue not merely as a repository of information and data to be passively absorbed, but as an invitation to engage with a groundswell of local, statewide, and international efforts to map what matters to us most.

—Emily Underwood, Guest Editor, and Liv O’Keeffe, CNPS Senior Director of Public Affairs
INTRODUCTION: THE DEMOCRATIZATION OF MAPS & CALIFORNIA’S FUTURE 2
Ryan Perkl

VEGETATION MAPPING IN CALIFORNIA: RECENT HISTORY & INNOVATIONS 6
Julie Evens, Todd Keeler-Wolf, Jennifer Buck-Diaz, and Rachelle Boul

A VEGETATION MAPPING BOOM ACROSS THE BAY AREA 15
Danny Franco, Kass Green, and Mark Tukman

HISTORICAL ECOLOGY DEEPENS OUR UNDERSTANDING OF PLACE 20
Sean Baumgarten, Lauren Stoneburner, and Robin Grossinger

VEGETATION CLASSIFICATION & MAPPING—KEY DATA FOR CONSERVING CALIFORNIA’S UNIQUE BIODIVERSITY 26
Melanie Gagol-Prokurat, Evan Greenspan, Michael Hardy, and Kari Lewis

CALIFORNIA’S ROLE IN THE GLOBAL EFFORT TO PROTECT IMPORTANT PLANT AREAS 30
Sam Young

BOOK REVIEW
Field Guide to Manzanitas: California, North America, and Mexico, 2nd Edition
Michael Kauffman, Tom Parker, and Michael Vasey
Reviewed by Brett Hall

CNPS FELLOWS: DAN SONGSTER 36
Sarah Jayne

IN MEMORIAM
RON LANNER, Michael Kauffman 38
ROY BUCK, Gretchen Flohr, PhD, with contributions from Doug Stone, William Davilla, and Maya Khosla 40

Today, mapmaking is accessible to anyone with a smartphone, tablet, or computer. Nearly everyone can now use maps to connect with issues they care about, help them identify what they want to change, and see how that change can happen.

This democratization of maps is good news for California’s biodiversity because it provides a path to more effectively inventory, protect, and share what we value. We love much of what is local to us—the cold clear water in the pond where we learned to swim, the trees in the forest where we first climbed, the smell of desert air after a monsoon rain.

These things, their places, and the crucial processes and patterns that make them special motivate us to ensure that others will have the opportunity to experience, value, and love such treasures. As the Senegalese forester Baba Dioum said before the International Union for the Conservation of Nature and Natural Resources (IUCN) in 1968, “We will conserve only what we love, we will love only what we understand, and we will understand only what we are taught.”

Maps can serve as bridges that interconnect what we love, understand, and teach. Maps are also essential to 21st-century decision making.

Today’s mapping tools combine vast amounts of information, spanning both the built and natural realms, and include information about vegetation, wildlife, humans, and virtually every other facet of our world. Combining these layers of data unlocks insights about critical patterns and relationships, and holds

Above: Wintering ring-billed gulls over the Great Valley of California, a patchwork of modified and native endemic habitat occupied by cattle and agriculture along with vernal pools and swales. Photograph by Evan Keeler-Wolf
immense communicative power to spur action where it’s needed most.

It’s within this context that we must undertake the mapping of California’s biodiversity with fervor, inclusivity, and haste. As this special issue of *Artemisia* relates, there’s a long history of biodiversity mapping in California, starting with the first statewide systematic survey of vegetation that was completed in 1939 by Albert Wieslander.

Today, modern mapping techniques such as lidar, aerial imaging, and even artificial intelligence are being used to classify vegetation types and automate updates to maps that depict the changing landscape and plant and animal diversity, which now is among the most imperiled of any state. The resulting high-resolution maps capture detail crucial to informing everything from species management, wildfire risk analysis, collaborative conservation planning in the face of climate change, and equitable land use management.

Crucially, some of the latest efforts aim to address the colonial history of resource mapping and botanizing in California, which has been tragically intermingled with racism, genocide, and the displacement of Indigenous people. Far from being equitable, objective, or scientific, such history makes clear that modern-day maps, and the processes used to create them, require revisions to correct course. Maps, after all, can be used to reflect society’s values. Today, we must ensure that the maps we create do not merely serve the interests of a privileged few but benefit our most vulnerable communities, including those that have been historically forced out or excluded.

In California, we can find abundant examples of how maps can help to restore connections between people and places. On the Klamath River and its surrounding forests and mountains in Northern California, for example, the Karuk Tribe is leading an integrated fire management project to reintroduce fire as a tool to restore and maintain resilient ecosystems. The effort involves a shared map, careful work to document threatened species, and Indigenous knowledge to return the land to balance.

Another example of the power of maps to support communities comes from the devastated burn scar around Paradise, California, where the Bureau of Land Management has worked with the nonprofit American Forests to map out a climate-informed restoration plan that considers future climate. As is the case in Paradise and the growing number of communities tragically impacted by catastrophic wildfires, maps are central to supporting restoration work.

Related to equity, the California State Parks Foundation recently used a new mapping tool, CalEnviroScreen, to consider where to grant funding for more equitable investments in restoration and mitigation of environmental harms on disenfranchised communities. The foundation recognizes that climate change disproportionately affects low-income communities and communities of color. As a result, the foundation is collaborating with local organizations to address issues of climate resilience in underserved communities—and maps are central to this effort.

Democratized maps have been crucial for the Karuk Tribe’s use of fire to fight fire, the Bureau of Land Management’s replanting the Camp Fire burn scar for a changing climate, and the California State Parks Foundation’s application of an equity lens to prioritize replanting. These and other entities within the state have experienced the power of maps for equitable conservation, and now there’s even a galvanizing new mandate to do so, in the form of California’s 30x30 Initiative.

### A GLOBAL CONSERVATION MOVEMENT

In October 2020, an executive order from Governor Newsom committed California to conserve 30 percent of its land and ocean by 2030 (30x30) with the aim of stopping species loss and improving climate resiliency. Now, 30x30 efforts are gaining momentum around the globe with more than 50 countries implementing initiatives to date, including the United States and Canada.

California was the first state in the country to make this pledge and did so before the national commitment. While broadly sweeping in its scope, elements related to 30x30 include creating a baseline assessment of California’s biodiversity that builds upon existing data and information, utilizes best available science...
and traditional ecological knowledge, and can be updated over time.

In order to reach the 30x30 target, however, we must first understand where we are today. Maps are a critical element in establishing this baseline. Land and coastal water areas that are “durably protected and managed to sustain functional ecosystems, both intact and restored, and the diversity of life that they support” count toward the state’s goal. Applying this definition, approximately 24 percent of California’s total land area and 16 percent of its total coastal waters currently count toward the state’s target. Maps provide a clear picture of where these areas are located. Perhaps more importantly, they are critical in illuminating other locations that can be conserved to help close the remaining gap.

These durably conserved areas, coupled with other area-based conservation measures such as hedgerows, urban canopy cover, and riparian buffers, will be critical in achieving 30x30 goals. Of the dozens of potential measures, efforts to restore degraded landscapes, prioritize habitats, and invest in actionable science to inform decision making are perhaps the most critical for Artemisia readers.

Specifically, these strategies aim to work with local and regional stakeholders to identify and ensure the use of appropriate local native plants and seed sources in restoration projects. Such attention is critical not only to the restoration of landscapes such as those in Paradise, noted above, but in other restoration efforts around the state such as those along the LA River and Banning Ranch. All strategies that encourage stakeholders to identify monitoring gaps to support adaptive management of lands and coastal waters for biodiversity protection and climate resilience hold relevance for Artemisia readers.

CALIFORNIA LEADS WITH CA NATURE
To support statewide, regional, and local implementation of 30x30 and related conservation efforts, California has created a new web-based, publicly available geographic information system (GIS), called CA Nature (californianature.ca.gov). CA Nature consolidates biodiversity, access, and climate change resources into a single repository, presenting various layers of data in a single system to help identify multi-benefit conservation opportunities and advance strategic actions. CA Nature therefore serves as a central location for information, planning, and tracking progress.
toward the state’s goal—and it’s available for everyone to use in charting their own, locally applicable conservation efforts. By improving access to environmental data on California’s lands and coastal waters, CA Nature democratizes and supports 30x30 and local conservation decision making in exciting new ways.

The examples shared above, and the others to follow in this volume, are but a few exciting instances of how democratized maps are being used to shape our state. Just as CA Nature maps are being used to shape California, we encourage you to join us in creating and sharing your next map, and in turn, helping to shape our collective future with maps.

—Ryan Perkl leads green infrastructure and related industry practice for Esri, the global market leader in geographic information system (GIS) software, location intelligence, and mapping. Founded in 1969 in Redlands, California, Esri software is deployed in more than 350,000 organizations globally and in over 200,000 institutions across the globe, including Fortune 500 companies, government agencies, nonprofits, and universities. RPerkl@esri.com

Online map of conserved terrestrial and marine areas in California on the CA Nature website (californianature.gov). These and other maps, powered by Esri, support the state’s 30x30 initiative to conserve 30 percent of its land and ocean by 2030.

Thank you

CA Natural Resources Agency, for a 30x30 Plan that prioritizes:

• CONSERVATION • EQUITY • BIODIVERSITY

Together, we can protect 30% of California’s lands and coastal waters by 2030.

Get involved today at PowerInNature.org @PowerInNatureCA | #30X30CA | #PowerInNature
For decades, California has been a testing ground for ecologists and geographers interested in developing accurate and efficient methods to map vegetation. Vegetation maps provide essential information for land managers, whether for forestry, agriculture, conservation, or recreation, and are used to inform decisions about maintaining or restoring threatened habitats, as well as predicting and adapting to changes in California’s ecosystems.

In this article, we’ll describe how vegetation mapping has evolved over the past 150 years in California and provide some examples of how vegetation maps guide conservation at the state and local levels. The economic and ecological significance of the decisions arising from vegetation mapping have been powerful drivers of innovation. Today's vegetation maps involve a wide array of sophisticated tools to distill information from the ground and air, including satellites, ever-faster computer processors, advances in geographic information systems (GIS), and machine learning. Even with these technological advances, however, every vegetation map made today is the product of human effort and collaboration.

**HISTORY OF CALIFORNIA VEGETATION MAPPING**

Early efforts to map California’s vegetation relied on much simpler tools, and they were directed more at extracting natural resources than conserving them. In the late 1880s to mid-1900s, for example, timber companies and both state and federal government agencies began mapping forested portions of Northern California to delineate the location and grades of timber products (Leiberg 1902, Nash 1965). Over time, the companies and mappers developed a system of symbols for commercial conifers and certain hardwood stands to indicate dominant species in township maps, a practice that continued into the 1960s and emphasized the most valuable timber trees.

In 1928 and continuing until the early 1940s, the United States Forest Service (USFS) began a series of efforts collectively called the Vegetation Type Map Survey (or VTM Survey), which remains to this day one of the most exhaustive and detailed efforts to map vegetation in California. Dr. Albert Everett
Wieslander, a botanist and forester with USFS, was the coordinator of this very large project, which was originally intended to aid the development of statewide land use and fire protection policies. Long before the widespread availability of aerial photos, Weislander and his colleagues mapped almost half of the state, covering about 40 million acres. Field crews worked from prominent peaks and ridges to gain the perspective needed to draw and label the individual patches of vegetation onto 1902 topographic maps (Kelly et al. 2005; see Figure 1).

The VTM Survey created a relatively fine-grained snapshot of California’s natural vegetation during a period when California had a population of less than one-fifth of what it has today. Using creative coloring, shading, and labeling, the VTM Survey depicts both broad vegetation types—those with similar uses, economic importance, or fire hazard characteristics—and more specific vegetation types labeled by dominant plants such as oaks (*Quercus*), pines (*Pinus*), sagebrush (*Artemisia*), and manzanitas (*Arctostaphylos*). Colors show the general or broad vegetation types, and each separately colored area may have one or more subtypes labeled by dominant plant.

Despite their impressive scope, these hard-copy maps had limited capacity for detail, and much of the information was conveyed in code. Over the past century, the USFS, United States Geological Survey (USGS), and other agencies have made many improvements in both classification and mapping of vegetation. Modern aerial maps inform resource assessment, fuels reduction, restoration, and other land management efforts. They include large-scale maps of forested lands using satellite-based remote sensing, led by the US Forest Service Remote Sensing Lab (Levien et al. 1998, 1999) and national and regional projects such as the USGS GAP Analysis and LANDFIRE data products. Coarse in scale, these maps are reproduced at regular intervals, transmit many layers of data in digital form, and are available online to the public (see www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap and landfire.gov/).

At a finer scale, the US Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) provides detailed mapping of wetland and riparian vegetation across the United States (Dahl 2011, USFWS 2021). Their sixth decadal NWI update is under way for analyzing changes in the 2009–2019 period, while allowing users to identify plant communities surrounding surface and subsurface rivers, streams, lakes, and drainages. The NWI data informs policymakers and the public on the status of, and changes to, wetland habitats.

Today’s maps are based on GIS analysis, air-photo interpretation, and extensive field checking and are an essential tool for land managers (BIOS 2021, Evens and Klein 2006, SCAPOSD 2019, Thorne et al. 2004). As contemporary vegetation maps become ever more granular, however, questions frequently arise about how to define different vegetation types. This brings us to one of the central challenges of current vegetation mapping: how much detail to include, and how to classify, categorize, and present that detail in an accurate, useful manner.

**CLASSIFICATION VS. MAPPING**

Without fully defining an area’s vegetation, it is difficult to map it. Since vegetation is not just identifying a single species but determining the “community” or assemblage of species that tend to co-occur, it is important to establish rules for determining each vegetation type. For example, if one is attempting to determine what kinds of scrubland are present, one must decide whether “chaparral” scrub should be labeled separately from “coastal sage” scrub. If we agree that they are different, then we might decide that blue blossom (*Ceanothus thyrsiflorus*) chaparral is sufficiently different from coyote bush (*Baccharis pilularis*) coastal scrub to merit a different label. But if ceanothus and coyote bush are
Both present, should we deem it coastal scrub or chaparral? Alternatively, if we encounter a new scrub that does not meet any description in our existing classification scheme, do we ignore it, and “force” it into an existing category? Or do we develop a new name for it? (See Figure 2 for examples of this complexity.)

Such questions arise regularly when classifying vegetation types, a process fundamental to, yet distinct from, vegetation mapping. Unlike mapping, classification provides the necessary framework to name and describe vegetation types and ultimately wildlife habitats. If we use the same standard terms and definitions across the state—and even the nation—then we have a common language to assess, compare, and track vegetation.

One important difference between vegetation classification and mapping is that, while a particular vegetation classification may apply to all patches or “stands” of vegetation, small or large, a map is limited by its scale. A map is a snapshot of vegetation taken at a given distance with various parameters that limit its resolution. GIS is a flexible format allowing viewers to zoom in and out of a map, and query “stands” or polygons with various attributes such as the percentage of tree cover or mortality. But the constraints imposed by cost and accuracy still mean that GIS maps usually cannot capture a 1:1 representation of all the stands of vegetation that we see on the ground. Some fine-scale patterns will not be represented such as small vernal pools that are

Figure 2: Complex vegetation patterns exemplify what classifiers and mappers need to decipher. The upper left image shows the Mojave National Preserve, where complex semi-desert scrub and pinyon-juniper woodland coexist with Wright’s buckwheat scrub, pinyon pine woodland, and Sonoran scrub oak shrubland. In the upper right image, post-fire dynamics play out in Bishop pine forests in Point Reyes, along with blue blossom ceanothus and coyote bush scrub. Finally, the complexity of vegetation along the North Coast is evident in the Landphere Dunes, where dune mat vegetation occurs on the trailing ridges. Upper photographs by Julie Evens, bottom photograph by Andrea Pickart.
often embedded in a larger grassland matrix. Thus, an informed choice must be made by the cartographer(s) on which habitats are mappable.

Vegetation mapping and classification also serve distinct purposes. A vegetation map’s purpose goes beyond identifying and cataloging all the vegetation types in an area. Rather, it graphically displays the location of the different vegetation types, emphasizing their spatial relationships, including extent (area) and relationship to other geographic factors such as soil types, roads, geological features, elevation, and development threats. Modern GIS technology allows us to use maps to display and analyze such features in relation to one another, and to monitor the same areas over time, if the maps are updated using the same rules applied to the original product.

In contrast to vegetation mapping, vegetation classification requires describing each vegetation type (e.g., by plant species, associated species, environmental condition, site history, disturbance impacts, etc.) and devising a means to differentiate one type from another.

Since the early 1900s, vegetation ecologists all over the world have spent entire careers determining which criteria should be used at various scales for classifying vegetation. Is it enough to stop at distinguishing between communities that are dominated by conifers versus hardwoods, or is more detail needed? For instance, a blue oak (Quercus douglasii) woodland is floristically and ecologically distinct from black oak (Q. kelloggii) forests or white fir (Abies concolor) forests. Likewise, localized serpentine manzanita (Arctostaphylos hooker or A. montana) chaparral is distinct from the more general chamise chaparral.

As taught in US grade schools, different plant communities form habitats that harbor specific animals as well as plants. By differentiating between communities that contain a particular set of tree species and/or understory shrubs and herbs, for example, vegetation classification provides floristic and environmental information for resource assessment and management actions. These distinctions require on-the-ground data collection throughout the region of interest, and repeated surveys in all possible vegetation community types at the finest level possible. When this data is analyzed using multivariate statistics, we can determine which species occur together repeatedly across the landscape, to categorize the recurring assemblages as distinct “plant communities.”

In addition to defining plant communities at the highest resolution possible, which are typically at the alliance and association levels, vegetation classification reveals how spatially, floristically, and environmentally related different plant communities are to each other. For example, in a vernal pool–grassland matrix of the Central Valley (see Figure 3), you will find the smooth goldfields (Lasthenia glaberrima) alliance at the deepest part of the pool, while you
can find the Fremont’s goldfields (Downingia [Las-thenia fremontii–Downingia spp.]) alliance at the edges of the pool that experience fewer days of flooding. Adjacent to that, you may find upland grassland and wildflower alliances such as wild oats–brome; needlegrass–melic grass; popcorn flower, California poppy–lupine; and California goldfields–dwarf plantain–small fescue flower fields alliances (Bar- bour et al. 2007, CNPS 2021).

Simply put, small ephemeral patches of annual flowers are generally much more difficult to map at any scale than stands of trees or shrubs. Hence, these vernal pool and upland herbaceous alliances are typically depicted in maps at a broader level of the classification hierarchy, typically group or macrogroup level (e.g., Californian Vernal Pool Group, and Californian Annual & Perennial Grassland Macrogroup) per the US National Vegetation Classification (USNVC 2021). Our classification can provide this fine-scale detail, while a map typically cannot. The appropriate use of the hierarchical classification system is important. Users need to understand that not all vegetation is easily mapped. They should also be able to query the classification and associated map data at different spatial scales (see Figure 4).

Compared to species taxonomy, vegetation classification is a young, dynamic field of study. Researchers at both the state and federal levels are working to standardize a national classification system. It may surprise some readers to learn that we have not quantified all the forests, scrubs, or grassland patterns in California, and we still regularly modify and add new definitions based on field data collection and analysis. As ecologists acquire more ground-based datasets and analyze them within and across ecological regions, they apply their growing knowledge of the relationships between vegetation types to this system, and, in turn, produce more accurate maps.

Many parts of the state do not have a quantitative classification; mapping and quantitative classification of vegetation are regularly done in a stepwise approach. After botanists take a field inventory, ecologists derive a classification scheme, which is used to label a map of a given area. Application of this stepwise approach across California has slowly ramped up over the past 22 years. Since 1998, various local,
state, and federal agencies and mapping firms have produced over 100 new vegetation maps using the quantitatively based Manual of California Vegetation (Sawyer et al. 2009, CNPS 2021), and the Survey of California Vegetation methods (VegCAMP 2020, 2021). As of September 2021, standardized, relatively fine-scale maps (Alliance-level classification hierarchy [VegCAMP 2020]), cover over 60 percent of the state.

Unlike older, static vegetation maps such as the original hard-copy Wieslander VTM Survey project (http://vtm.berkeley.edu/#/data/vegetation), these online maps can be digitally queried and overlaid on other data layers to enhance our understanding of the relationships between vegetation and environmental variables such as soils, geology, slope, aspect, precipitation, etc. Now that the Weislander maps have been digitized, they can also serve as a “snapshot” in time for us to analyze change from past to present (Kelly et al. 2016). With the establishment of rigorous classification and mapping standards, all recently produced maps can be updated over time using the same standards that were used before, to compare future and past vegetation patterns (see Figure 5). Thus, repeat vegetation mapping holds great promise in clarifying trends in climate change and other ecological effects.

FITTING A MAP’S SCALE TO ITS PURPOSE
Vegetation maps are increasingly used in forest management, fire and fuels modeling, carbon sequestration measurement, climate modeling, conservation planning, and many other applications. With the growing need for such maps, however, comes the imperative to standardize classification nomenclature, so that accurate representations of vegetation can be compared from place to place. As with most things, however, one size rarely fits all.

To be useful, a vegetation map’s scale must fit its purpose. Coarse maps may be sufficient to answer general questions about the extent of major forests, grasslands, or shrublands across the United States. Yet more detailed maps are necessary to define the rarity and extent of locally restricted vegetation types.

Scale can refer not only to a map’s spatial scale—how fine or coarse it is, or the spatial extent of its geographic area—but also its theme, including the names of the mapped types, or the level of detail in a vegetation classification. In a thematically scaled map, the vegetation units are commonly nested within a hierarchy arranged from the broadest classes, such as woodlands, forests, shrublands, and deserts, down to the finest floristically defined categories. A map’s physical scale constrains the thematic scaling that can be used. For example, a global map depicting general locations of all tropical forests could be useful for determining the distribution of this broad category but would not be useful for local management (see Figure 6).

Determining the thematic scale that appropriately fits a map’s geographic scope as well as its purpose is crucial. A wildlife biologist might need a broad map to determine the habitat and range of species such as mule deer or spotted owls, which have large geographic
ranges, to identify and maintain wildlife corridors for these species. Conversely, a local land manager in Marin County might need a fine-scale map to identify and protect habitat for a narrowly endemic species such as a rare jewelflower.

An example of coarse-scale vegetation mapping is the USGS and the USFS collaborative effort to create a national land cover map to support landscape-level management of wildlands for fire fuels and other natural resources (LANDFIRE 2013). Created by combining the LANDFIRE and Gap Analysis Program (GAP) mapping efforts, the map uses a simplified, standardized vegetation classification (NVCS Group level) at a large spatial resolution that is useful when applied nationally.

Mid-level mapping, such as mapping across California or the West, has taken many paths depending on the need and purpose. For example, Region 5 of the US Forest Service has produced detailed vegetation maps of nearly 75 percent of California, as part of its United States Fish & Wildlife Service program (USFS 2016). Their map datasets are organized by ecoregion, and their medium-scale detail is often adequate for regional or state-wide analyses.

Fine-scale mapping is typically used for local land management at the county, city, property, and/or project level. These efforts require a fine thematic resolution to address local management concerns such as distribution and locations of sensitive natural communities, habitat for rare species, or areas of restoration potential, as well as finer spatial resolution to refine restoration or conservation priorities. The California Department of Fish and Wildlife’s Vegetation Classification and Mapping program (VegCAMP 2021) curates this level of detailed vegetation map data through the Biogeographic Information and Observation System (BIOS).

MAP ATTRIBUTES: WHY ARE THEY SO IMPORTANT?
With the advent of geodatabases that store geographic information and other attributes, it is now possible to store significant information in a vegetation map that surpasses even the most detailed pre-GIS maps.

Fine-scale maps produced today contain polygons (spatial shapes that delineate an area and store information about that area) coded with a suite of attributes such as vegetation type, the proportion of non-native species, the average height of trees, or even the relationship to wildlife habitat for animal species of interest. At the beginning of a project, the mapping team and key stakeholders determine the core attributes they want to capture, beyond standard ones such as vegetation type and acreage. Based on the project’s budget and applications, a map can indicate the growth, function, or health of an ecosystem, including the cover, size, or height of trees, the amount of tree or shrub mortality; or impacts such as the sudden oak death pathogen, presence of invasive plants, or amount of clearing. A map display can shift to visually represent and highlight different aspects of the map (see Figure 7).

These attributes provide powerful data that can be used to answer questions such as: What proportion of an oak woodland consists of conifers versus hardwoods? Where are the tallest trees in these coastal watersheds of redwood and Douglas-fir forests? What areas support shrublands at 40 to 60 percent cover? Where along the coast has the most significant die-back occurred from sudden oak death?

These fine-scale maps provide users with a wealth of information for conservation and restoration planning. The most common uses include identifying ecosystem-based conservation targets, including core habitats for wildlife and wildlife corridors; pinpointing areas of high-fire fuels for prescribed fire or thinning; and identifying areas of high weed invasion or high tree and shrub mortality.

A CLOSER LOOK AT APPLICATIONS
An excellent example of stakeholders coming together to create and use a fine-scale map comes from the North Coast of California, where CDFW agency staff and CNPS chapter members and staff collaborated on

---

Figure 6. Like classifications, vegetation maps can be constructed at different scales depending on their perceived needs and desired uses. This diagram shows three geographic or spatial scales, ranging from the general mapping of major patterns (forest, woodland, shrubland, grassland, etc.) to a more detailed approach to the accurate depiction of the location and shape of specific stands of trees and shrubs, for local use. Courtesy of Rachelle Boul with map screenshots from USGS GAP Analysis, LANDFIRE, and VegCAMP.
a project to determine the remaining extent of Mendocino cypress stands and related plant communities on oligotrophic (nutrient-poor) soils, which continue to be impacted by ongoing development.

More than 25 people helped collect field data to define the vegetation units and verify the fine-scale delineation of cypress, coastal pine, and maritime chaparral stands. The resulting map denotes approximately 5,000 acres of remaining Mendocino cypress woodlands and provides essential data for conservation efforts of the area’s highly threatened natural communities, illustrating that at least 20 to 40 percent of their historic extent has been lost to development (see Figure 8).

Because we are experiencing noticeable shifts in climate, fire behavior, urbanization, and other impacts, vegetation maps and the embedded attributes provide vital data for evaluating past and future change. For example, we are seeing significant shifts in coastal scrub, chaparral, and oak woodlands in Southern California near urban centers, particularly in areas where too-frequent fire is converting woodlands and shrublands to grasslands. Thus, repeated mapping is an integral tool to determine restoration actions for impacted habitats (see repeat mapping article in *Fremontia* 45(1–2):18–24, Keeler-Wolf et al. 2017).

Although vegetation mapping has come a long way since Weislander, we continue to improve mapping standards and techniques and refine our statewide vegetation classification in the *Manual of California Vegetation* (CNPS 2021) to accommodate the growing need for this valuable land management tool. Government and NGO mapping partners aim to complete fine-scale mapping of vegetation across the state, then repeat mapping in 10- to 20-year intervals.

As our breadth of knowledge of vegetation across the state increases, it will be easier to define and identify rare and threatened vegetation, as well as vegetation that hosts higher amounts of biodiversity, stores more carbon, and sustains clean air and water. This process requires expertise and support from hundreds of local, state, and federal agencies and organizations, along with millions of stakeholders.
Ultimately, a complete, standardized, fine-scale vegetation map for the state will allow for more thorough and informed management and conservation of the diverse and unique natural resources that California supports, equipping communities to better protect vital ecosystems and wildlife corridors, restore impacted habitats of plant and animals, and monitor and mitigate the impacts of global climate change.

—Julie M. Evens is the vegetation program director of the California Native Plant Society (CNPS). Todd Keeler-Wolf is the retired senior ecologist from the California Department of Fish and Wildlife — Vegetation Classification and Mapping Program (VegCAMP). Jennifer Buck-Diaz is the vegetation ecologist of CNPS. Rachelle Boul is the senior environmental scientist with VegCAMP.

REFERENCES


A VEGETATION MAPPING BOOM ACROSS THE BAY AREA
Danny Franco, Kass Green, and Mark Tukman

Following the Mt. Vision Fire at the Point Reyes National Seashore (PRNS) in 1995, which burned 9,000 acres and 45 homes, the National Park Service, United States Geological Survey, and California Department of Fish and Game partnered to develop what was eventually termed the Plant Community Classification and Mapping Program. The goals of the project were to create a map with supporting documentation that would provide managers with information about the distribution of vegetation communities and inform opportunities for future ecological inventory, monitoring, and research activities. In their final report, the group found that, "at the time of the fire, PRNS did not have a vegetation map. Had a map been available, it would have been of great assistance in making the crucial decisions associated with suppression of a major fire . . . in implementing logistics and planning, and in ensuring firefighter and public safety" (Keeler-Wolf 2003).

Twenty-five years later, as the impacts from climate change–driven wildfires, historic droughts, and other ecological stressors reverberate across the state of California, the need for comprehensive vegetation maps as identified by PRNS has become only more urgent. The 1996 to 2003 NPS-led vegetation mapping in Point Reyes was an early version of what has become a full-blown, formal effort to produce a comprehensive and standardized statewide vegetation classification and map, led by the California Department of Fish and Wildlife Vegetation Classification and Mapping Program (VegCAMP) and California Native Plant Society (CNPS) Vegetation Program.

The framework and justifications for that program are described in a prospectus for the Shared Vision for the Survey of California Vegetation, which underscored that “completion of a statewide, high-resolution vegetation map is crucial for effectively managing California’s natural resources and for fostering conservation of those resources; without it, the government entities

Gerbode Valley in the Marin headlands. Photograph by Mark Gunn
tasked with these responsibilities cannot operate efficiently” (Bram 2015). While this statewide effort is robust and ongoing, the urgent need for these data has only increased as land managers grapple with the cascading effects of a changing climate and many related planning and management challenges.

This need is what inspired land managers in Sonoma County, led by the Sonoma Agriculture and Open Space District (Sonoma Ag + Open Space), to initiate a fine-scale vegetation and landcover mapping program. Beginning in 2013, dozens of local, state, federal, and non-governmental organizations have come together to advance fine-scale vegetation and landcover mapping projects in Sonoma, Marin, San Mateo, Santa Cruz, Santa Clara, Alameda, and Contra Costa counties.

The four consortia funding this work have organized themselves around a central challenge: to effectively care for the ecosystems and infrastructure they manage. To prepare for natural disasters and climate change, citizens, landowners, politicians, scientists, and government agencies must know the location and distribution of resources across the landscape over time. Managing and monitoring carbon stocks, fire and flood hazards, critical habitat, and climate resiliency require up-to-date, fine-scale maps and databases of the area’s vegetation and topography. Without accurate maps, there is no way to plan for and comprehensively measure and monitor the impact of human decisions and natural disasters on the environment.

The significant level of public and private partnership and collaboration surrounding the fine-scale mapping effort in the Bay Area clearly reflects a unifying need for these maps and data.

It is, therefore, not surprising that the current locally driven Bay Area efforts to fund and implement countywide and/or regional mapping efforts have gained so much traction. Prior to this effort, existing vegetation maps were piecemeal, out of date, or at a statewide scale incapable of supporting local decision making. Topographic data were coarse or nonexistent. As a result, managers and decision makers were forced to labor with maps that did not support cross-jurisdictional collaboration, were out of date, crude, and often incorrect. To address this challenge, managers sought to co-fund and produce fine-scale vegetation maps with other local or regional land management agencies.

The Sonoma County effort introduced two key features that would remain a part of subsequent initiatives across the region. First was the utilization of lidar data to improve the accuracy and breadth of vegetation and other mapping products. And second was a partnership with the CNPS Vegetation Program and CDFW VegCAMP to support the field sampling and floristic classification components of the Sonoma County Fine-Scale Vegetation Map (Green 2021), which was completed in 2017. Both CDFW VegCAMP and the CNPS Vegetation Program are key partners and proponents of parallel efforts in neighboring counties, ensuring consistency with state standards and best management practices for conducting field surveys to support floristic classification.

Following in Sonoma’s footsteps, the Tamalpais Lands Collaborative (One Tám)—a coalition of land management agencies in Marin that includes Marin County Parks, the Marin Municipal Water District, the National Park Service, and California State Parks—initiated development of the Marin Countywide Fine Scale Vegetation Map and Landscape Database Project in 2018. This effort was profiled by CNPS in *Flora* (Morrison 2018) in December of that year. The Marin map has now been completed, and for the first time, land managers there have access to a vegetation community map that is consistent across jurisdictional boundaries.

Yet the maps themselves do not achieve their true purpose until they are put to use by the audience they are intended to serve. The teams producing the maps, led by Mark Tukman (Tukman Geospatial) and strategic consultant Kass Green, are quick to underscore that the map belongs to the stakeholders who helped to fund it, rather than to the mappers: “It’s not *our* map.
it’s your map” is a common refrain repeated by Ms. Green during stakeholder meetings. To understand the value of the maps and data, therefore, it’s instructive to highlight several examples of their recent use.

EXAMPLE APPLICATIONS
On the night of October 8, 2017, a historic wind event led to one of the worst firestorms in Sonoma County history. In total, the Nuns, Tubbs, and Pocket fires (together comprising the Sonoma Complex Fire) burned over 110,700 acres in Sonoma and Napa counties over the course of three weeks. Twenty-four lives were lost as a result of the fires and 6,997 structures were destroyed. Sonoma Ag + Open Space estimates that 26.6% of the 87,000 acres burned in Sonoma County was public or protected open space lands, including parts of Trione Annadel State Park, Sugarloaf Ridge State Park, Mark West Creek Regional Park & Open Space Preserve, Hood Mountain Regional Park & Open Space Preserve, Sonoma Valley Regional Park, and lands held by Sonoma Land Trust, Pepperwood Preserve, and Audubon Canyon Ranch, among others.

Catastrophic as these fires were, they also presented a unique opportunity to put into use the county’s fine-scale vegetation map and landscape dataset, completed just five months prior to the Sonoma Complex Fire. Sonoma Ag + Open Space applied for and received NASA Rapid Response Research funding to employ the fine-scale vegetation and landcover datasets to study the relationships between weather, vegetation type, fuel loading, land use, and land management patterns, identifying land management practices that “enhance ecosystem and human community resiliency to wildfire.” (Green et al. 2020).

The study would not have been possible without the pre-fire, fine-scale vegetation map and landcover data generated by the Sonoma consortium. It revealed several important considerations for managers, including the contribution of ladder fuels to canopy burn severity in forests and woodlands, and the ability of riparian areas to act as barriers to fire spread. The Santa Cruz Mountains Stewardship Network has since been awarded CAL FIRE funding to conduct a similar analysis of the 2020 CZU Lightning Complex Fire that burned 86,000 acres in the Santa Cruz Mountains, including Big Basin State Park. The Stewardship Network hopes to integrate post-fire analysis findings into land management, fuels reduction approaches, conservation efforts, and land use planning.

In Marin County, the One Tam collaborative is working to integrate data from the recently completed countywide fine-scale vegetation map into a strategic planning effort to assess forest health at a landscape scale and identify areas that may benefit from a restorative approach to fuels reduction that will both increase wildfire resiliency and preserve or enhance key ecosystem services such as carbon sequestration and wildlife habitat. The One Tam Regional Forest Health Strategy for Public Lands has identified five key forest types to focus on for the ecological forest health assessment aspect of the work, including bishop pine, coast redwood, open canopy oak woodlands, and Sargent’s cypress stands. Without the countywide, fine-scale vegetation map, it would have been impossible to locate stands of these forest types spatially at any meaningful resolution across jurisdictional boundaries.

To do this work, One Tam is developing add-ons to the countywide fine-scale vegetation map that can serve as indicators of forest health. One is a percent mortality for forest stands, which will help managers identify areas with concentrated impacts from Phytophthora ramorum, the pathogen that causes sudden oak death, in several hardwood tree species. Other known pests include pitch pine canker disease, caused by the fungus Fusarium circinatum. Mortality indices, combined with lidar analysis of the structure of forest stands, can give managers a clearer picture of where mortality overlaps with other important attributes such as dense ladder fuels or seral stages. This allows managers to prioritize areas for treatment, stratify field monitoring plots, complete compliance documentation,
and communicate the need for forest resiliency work to potential funders and members of the public.

In San Mateo County, project stakeholders, with support from the San Mateo Fire Safe Council and District 3 Supervisor Don Horsley, initiated development of a countywide five-meter fuels model as an add-on to their countywide fine-scale vegetation mapping project. Similar mapping of surface fuels has been completed in Napa County and is under way in Santa Clara and Santa Cruz counties. These fuel models provide a fine-scale map of fuel conditions on the landscape and are a required input for fire behavior and fire spread simulations. Five-meter fuel models provide a higher spatial resolution than existing, publicly available fuel models such as LANDFIRE data derived from 30-meter Landsat satellite data. They are a key application of fine-scale vegetation data and allow managers to conduct wildfire hazard risk assessments as well as prioritize fuel reduction efforts in the wildland urban interface.

**COLLABORATIONS IN ACTION**

The coalition built in Marin County by One Tam and facilitated by the Golden Gate National Parks Conservancy (Parks Conservancy) has served as a fundraising template for parallel work in San Mateo, Santa Cruz, Santa Clara, Alameda, and Contra Costa counties. Key to this fundraising success was working to identify potential project partners facing similar obstacles, and then to highlight the benefits of tackling this challenge comprehensively, including capturing large economies of scale and the ability to co-fund the most expensive project components such as lidar acquisition. This model leverages individual agency and stakeholder resources collectively, and fosters buy-in by involving agencies in the map-making process, both of which ultimately lead to an increased sense of ownership of and trust in the end products. Sharon Farrell, the Parks Conservancy’s executive vice president of projects, stewardship, and science, underscores that the Marin effort “reflects the impact that the Conservancy can bring to leverage and scale work through our public-private partnerships to create a consistent data set that will be used by many organizations and agencies” (Farrell 2021).

Ultimately the Parks Conservancy would bring together stakeholders such as the National Park Service, San Mateo County Parks, Midpeninsula Regional Open Space District, San Francisco Public Utilities Commission, Peninsula Open Space Trust, and others to fund a countywide, fine-scale vegetation map and numerous related landcover datasets in San Mateo County. The San Mateo fine-scale vegetation map was completed in March of 2022.

The success of the Parks Conservancy’s public-private partnership and fundraising model in Marin...
and San Mateo has inspired parallel efforts in other counties. In 2019, Dylan Skybrook, manager of the Santa Cruz Mountains Stewardship Network, began building a different but similar consortium to map the Santa Cruz Mountains ecoregion. The Stewardship Network–led consortium has succeeded in funding countywide mapping of all of Santa Clara and Santa Cruz counties. According to Mr. Skybrook: “We were able to raise the money for this project because Santa Cruz Mountains Stewardship Network (SCMSN) members recognize how crucial the data is to steward their lands, especially in the face of climate change and catastrophic wildfire, yet no single organization had to bear the burden of all the costs. The project is only half done and already many members of the SCMSN are finding that the data that has been produced is invaluable for making land management decisions.”

The Santa Cruz/Santa Clara map, funded by more than a dozen stakeholders, will encompass over 1.2 million acres of land. It is scheduled to be complete in 2023 and has encouraged land managers in Alameda and Contra Costa counties to seek and obtain CALFIRE grant funding to acquire foundational data and conduct wildland fuels and wildfire risk index mapping, a key first step toward a fine-scale vegetation map project.

CONCLUSION
Mike Vasey, a longtime Bay Area conservation biologist with San Francisco State University and researcher with the San Francisco Bay National Estuary Research Reserve [and member of the Artemisia editorial board], was an early advocate for GIS-based mapping of vegetation, having proposed a project to the South Bay–based nonprofit Sempervirens Fund in 1991 to conduct a GIS-based map analysis of biodiversity in the Santa Cruz Mountains. At the time, Dr. Vasey indicated that such a map would “provide a common denominator that can be easily accessed by all interested parties for the management purposes while fitting into a broader, biogeographical context” (Vasey 1991).

Visionaries such as Dr. Vasey and others foresaw the value of regional fine-scale vegetation maps, and the technology needed to produce these maps at an effective cost has finally caught up. Now, 30 years later, Dr. Vasey is participating in the current regional effort as an expert reviewer and advisor and was a key proponent for adding more detail to the maps in tidal wetland vegetation communities—a project add-on that has been funded in part by the NOAA Coastal Change Analysis Program. In Dr. Vasey’s view, “new technologies involving remote sensing, geographic information systems, and field-informed machine learning have created the opportunity to take an economical yet regional approach to evaluating landscape change over time in the Bay Area. Fine-scale vegetation mapping using these tools is the key” that will help “develop optimal conservation management strategies.” (Vasey 2021).

Looking ahead it is clear that the technical methodology and cost-sharing model developed in the Bay Area could be replicated in other unmapped portions of the state. This would move us closer to the long-sought statewide fine-scale vegetation map, deemed by the Shared Vision for the Survey of California Vegetation as “critical for assessing current conditions, monitoring long-term changes, and determining land management options.”

—Danny Franco is project manager at the Golden Gate National Parks Conservancy, Kass Green is the president of Kass Green and Associates, and Mark Tukman is the owner of Tukman Geospatial. The fine scale vegetation, fuels, and landcover data referenced in this article is publicly available at https://pacificvegmap.org courtesy of CALFIRE, the Santa Cruz Mountains Stewardship Network, and Tukman Geospatial.

REFERENCES
Farrell, S., June 14, 2021, personal communication.
The land is the real teacher. All we need as students is mindfulness.”—Robin Wall Kimmerer, *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants*

Ecosystem restoration is an endeavor inextricably tied to specific places. While general ecological principles and information from analogous sites can help guide restoration efforts, every place is unique. Any site thus presents restoration practitioners with a novel combination of opportunities and constraints, some grounded in the land’s physical characteristics and ecological legacy, and some dictated by anthropogenic modifications.

Understanding past ecological conditions consequently forms a key part of the foundation underpinning efforts to restore native ecosystems. Information about historical landscape patterns and processes deepens our understanding of contemporary landscape functioning, provides the basis for identifying locally appropriate restoration targets, and helps us to predict the effects of environmental variability (Swetnam et al. 1999, Jackson and Hobbs 2009). While contemporary ecosystems face many novel constraints and stressors, maintaining or reintegrating ecological functions provided by historical landscapes is, in many cases, not only practical but critical to building future ecological resilience. Those characteristics that enabled ecosystems to persist and respond to dynamic conditions in the past—for example, native vegetation communities adapted to the local setting, intact physical processes and disturbance regimes, connectivity between habitat patches, and a diversity of habitat and landscape features—will also confer ecological resilience in the future (Safford et al. 2012, Beller et al. 2015).

For over two decades, the nonprofit San Francisco Estuary Institute (SFEI) has led historical ecology studies in ecosystems around the Bay Area and throughout California. Drawing on old maps, photographs, textual accounts, and other sources, researchers piece together...
clues about how the landscape looked and functioned before European and American settlement. A central element of this work is creating maps to represent the historical landscape and how it has changed over time. In addition to providing a visual representation of historical habitat mosaics, these maps can be analyzed in myriad ways to help us understand how ecological patterns relate to underlying physical gradients, and how different features of the landscape work together to support native biodiversity.

Here we discuss the methods and findings from two recent historical ecology studies of landscapes on the San Francisco Peninsula, and explore some of the restoration applications of the research. Hidden Nature SF reconstructs the historical landscape of San Francisco before the city, while the Peninsula Watershed Historical Ecology Study examines terrestrial vegetation change in the Peninsula Watershed in San Mateo County. Although both studies rely on a diverse array of historical data sources and spatial analyses, they employ distinct approaches tailored to the unique goals and landscapes associated with each project.

**HIDDEN NATURE SF**

Hidden Nature SF reconstructs the historical landscape of San Francisco with two interrelated objectives. One is to engage the public in our scientific journey and foster curiosity about San Francisco’s past, present, and future landscapes through accessible stories. Building on this excitement about San Francisco’s natural history, we also aim to inspire local residents and decision makers alike to imagine how the city’s past can help us create a healthier and more resilient future.

To meet these goals, Hidden Nature SF’s historical ecology has focused on a single engaging and accessible map representing San Francisco’s past landscape prior to Spanish colonization in 1776. The recently completed initial phase of the research mapped the historical landscape of the northern portion of the San Francisco Peninsula, and subsequent phases will extend the mapping south to remaining portions of the city.

The map below shows the results of this initial phase of the research, depicting the habitat types and waterways that existed prior to Euro-American modification. Rolling sand dunes extended across much of the fog-shrouded peninsula, blanketed in many places by grasses and low-growing shrubs. Groves of dwarf coast live oak (Quercus agrifolia), their growth stunted by the wind and the infertile soils, clung to the mounds of sand. Hardy maritime chaparral sprung from the shallow soils of bedrock outcrops, while wildflowers carpeted the cliffs and bloomed in the valleys. Wet, low-lying places across the landscape were marked by a diverse array of freshwater wetlands and lakes, while tidal marshes wrapped around the shoreline.

This one-of-a-kind landscape, with its unlikely diversity of ecological communities, was the product of...
a unique combination of physical conditions. Braced between the Pacific Ocean and the San Francisco Bay, the San Francisco Peninsula experienced heavy fog cover, harsh winds, drifting dune sands, nutrient-limited soils, and cycles of drought and flooding that selected for highly specialized plants and animals adapted to survive in these challenging conditions.

Within the sand dunes, areas of loose, shifting sand were sparsely vegetated, but supported pioneer species like coastal sand verbena (*Abronia latifolia*) and beach evening primrose (*Camissoniopsis cheiranthifolia*). Low-lying areas within these mobile dunes supported dune slacks, or various types of ponds and wetland habitats dominated by plants like willows (*Salix* spp.) and rushes (*Juncus* spp.). Older, stabilized dunes supported more established and densely vegetated plant communities such as dune scrub, dune grassland, and oak woodland.

Beyond the sand dunes, serpentine soils (and related greenstone soils) supported a range of unique plant communities such as serpentine maritime chaparral, serpentine grasslands, and serpentine slope wetlands. These communities included a number of very narrowly distributed species such as Raven’s manzanita (*Arctostaphylos montana* ssp. *ravenii*), Franciscan manzanita (*Arctostaphylos franciscana*), and Presidio clarkia (*Clarkia franciscana*).

Among the most unusual habitats that existed in historical San Francisco were fens, which occurred within the present-day SOMA District in low-lying areas between dune ridges and along the borders of tidal marshes. Described as “a kind of Arctic oasis amidst a vegetation of California type” (Behr 1896), the fens supported a highly distinctive flora, including species like bogbean (*Menyanthes trifoliata*), marsh sandwort (*Arenaria paludicola*), and stream orchid (*Epipactis gigantea*).

The landscape of San Francisco has been forever transformed, shaped, and reshaped over generations. The city today bears little resemblance to the land once dominated by sand dune habitats and dwarf oaks. However, among the busy streets and tall buildings, there is still a complex network of “hidden nature,” including remnant habitats that have persisted amid the centuries of change. There are also many opportunities to reintroduce and support native biodiversity through urban greening efforts at a range of scales.
In this highly modified urban environment, building ecological resilience relies on restoring healthy native ecosystems, as well as restoring the public’s connection to the city’s natural landscape. An understanding of historical habitats—their distribution, composition, structure, ecological function in supporting native wildlife, and relationship to physical controls and processes—can provide all residents with insights into how to fold these elements into our urban ecosystem.

Informed by historical ecology, urban greening efforts, such as planting street trees, landscaping yards and schools, designing green stormwater infrastructure (GSI), and restoring native ecosystems in larger open spaces, will support both natural and human communities. For example, SFEI is currently partnering with a number of local agencies and community groups on a project called Next Generation Urban Greening: Integrating Water Quality, Biodiversity and Resilience to apply findings from the historical ecology research, in conjunction with urban biodiversity science and GSI monitoring, to develop green infrastructure tools, strategies, and implementation projects that deliver multiple benefits in southeast San Francisco. Weaving San Francisco’s historical ecology back into the urban realm reinforces a natural heritage and deeper connection to place, while also promoting urban biodiversity and providing other important benefits such as flood risk reduction, improved water quality, heat resilience, and sea level rise adaptation.

**PENINSULA WATERSHED HISTORICAL ECOLOGY STUDY**

Just to the south of San Francisco, a very different sort of landscape characterizes the rugged coastal mountains of San Mateo County. Home to mountain lions (*Puma concolor*), marbled murrelets (*Brachyramphus marmoratus*), towering old-growth Douglas-firs (*Pseudotsuga menziesii*), and an immense diversity of other plants and animals, the Peninsula Watershed is a unique and wild expanse of open space just minutes from one of the most urbanized parts of California. Here too, historical ecology is helping us to better understand the contemporary landscape and how we can promote ecological resilience in the future.

The Peninsula Watershed Historical Ecology Study focuses on reconstructing patterns, trajectories, and drivers of change among the terrestrial vegetation types—grasslands, shrublands, hardwood forests, and conifer forests—that dominate the watershed. As with *Hidden Nature SF*, mapping plays a central role in synthesizing the historical data, but with a new twist. Rather than representing the historical landscape with a single map, we created a series of maps showing “hotspots” of vegetation change. These maps illustrate the dominant vegetation trends in different parts of the watershed, as shown below. They show generalized areas of vegetation loss, gain, and persistence across the watershed, synthesizing information from a wide range of data sources. A series of quantitative analyses that estimate the extent of each vegetation type at several different time periods complements the hotspot maps.

Over time, the maps show a clear trend toward decreased grassland and shrubland cover and increased forest cover within the watershed. This is consistent with observed vegetation changes in many other parts of coastal California; in the absence of major land use modifications or regular disturbances such as fire or grazing, vegetation communities in the region have frequently shifted from more open vegetation types such as grasslands, to more closed vegetation types such as shrublands or woodlands (McBride 1974, Williams...

However, closer examination shows that within this broad trend, there has been a complex trajectory of vegetation change over time and a heterogeneous pattern of change throughout the watershed. For instance, serpentine grasslands have been more persistent than non-serpentine grasslands. Coyote brush (*Baccharis pilularis*)–dominated shrublands have increased in some areas and declined in others, while more diverse coastal scrub and chaparral communities have experienced considerable loss. Hardwood forests dominated by eucalyptus (*Eucalyptus* spp.) and acacia (*Acacia* spp.) have expanded, while oak woodlands and other native hardwood forests have been lost in some areas and expanded in others. Conifer forests, including planted stands of Monterey pine (*Pinus radiata*) and Monterey cypress (*Hesperocyparis macrocarpa*), as well as stands of Douglas-fir, have expanded in many areas.

Complex, interconnected processes and land use changes have driven these patterns. Through the regular use of fire, Indigenous communities on the Peninsula likely maintained open mosaics of grassland, shrubland, and oak savanna to increase habitat for favorable game animals and the abundance of favored plants, among other purposes. Spanish colonization led to a period of both fire suppression and extensive livestock grazing on the eastern side of the watershed, which had mixed effects on vegetation communities. Extensive logging in the early to mid-19th century reduced the extent of redwoods in the southwestern portion of the watershed, while clearing for agriculture and grazing altered vegetation cover in the San Andreas Valley and elsewhere. Plantings of non-indigenous tree species displaced grasslands, shrublands, and hardwood forests. Highways, urban development, and reservoirs have led to additional displacement or loss of a number of vegetation types.

Information about historical ecosystem functioning and patterns of landscape persistence and change in the Peninsula Watershed provides an important framework for management and restoration decision making (Hobbs et al. 2014, Higgs et al. 2014). In many locations.
throughout the watershed, current ecosystem function still approximates historical function in many respects, and protection of these ecosystems should be prioritized. In some locations, landscape change has drastically altered ecosystem function, and major constraints make restoration of the historical ecosystem infeasible. Many other locations fall somewhere between these two extremes, and restoration efforts in these areas may succeed in recovering some of the lost ecosystem function. Managers should thus consider a site’s historical trajectory, as well as site limitations, social and environmental context, and potential future changes, when prioritizing conservation and restoration efforts and deciding about potential interventions.

LOOKING TO THE PAST TO INFORM THE FUTURE

One of the primary applications of historical ecology is to identify the restoration and urban greening targets and strategies appropriate to a specific place. Information about historical habitat mosaics—their distribution, structure, and composition—as well as the plant and animal species that they supported and the physical and ecological processes that sustained them, provides a functional understanding about the potential of the landscape to support native habitats and provide desired ecological functions and ecosystem services. In addition, an understanding of the ecological processes that supported habitat diversity and complexity in the past, and of the drivers of ecosystem changes, can help in anticipating future landscape change and identifying the factors that will maximize ecological resilience in the response to climate change and other factors. While the potential for ecological restoration and stewardship is clearly much more constrained in an urbanized setting such as San Francisco than in a large expanse of open space such as the Peninsula Watershed, both settings have the potential to support native biodiversity and contribute to a healthy environment. The work of sustaining and caring for the many species we share these landscapes with will never be completed, but rather a perpetual work in progress. Yet, generations from now, insights from the historical ecology of these places can continue to teach and inspire us.

—Sean Baumgarten, Lauren Stoneburner, and Robin Grossinger support the Resilient Landscapes Program at the San Francisco Estuary Institute. 
Emails: seanb@sfei.org, laurens@sfei.org, robin@sfei.org.


REFERENCES

Vegetation Classification & Mapping: Key Data for Conserving California’s Unique Biodiversity
Melanie Gogol-Prokurat, Evan Greenspan, Michael Hardy, and Kari Lewis

Bordered by ocean, mountaintops, and desert, much of California is functionally an ecological island, isolated from the rest of the North American continent. Living on this ecological island are more endemic species—those found nowhere else in the world—than can be found in any other state.

The diverse geology and topography of the landscape, ranging from the coast to the high Sierra mountaintops, from desert to sagebrush steppe, makes California one of the most biodiverse places on Earth. With less than 5 percent of the land area of the United States, California is home to 32 percent of the total vascular plant flora. The richness, rarity, and endemism of the state’s species have resulted in California’s recognition as a global biodiversity hotspot (Stein et al. 2000). To conserve this unique biodiversity, scientists and conservation planners must understand how it is distributed across the landscape. Vegetation maps are a key component of mapping and understanding biodiversity, not only because they capture how plant communities are distributed across the landscape but because they show the vegetation structure and plant species composition that make up the habitats on which animals depend.

The California Biodiversity Initiative Roadmap defines biodiversity as “the variety of life at all scales, ranging from genes to species to whole ecosystems.” This action plan for conserving California’s biodiversity describes the need to conserve species, habitats, and vegetation types at regional and state scales, and the need to conserve genetic variation within and among species’ populations. To support these biodiversity conservation efforts, scientists and decision makers need maps that show not only the distribution and diversity of species, habitats, and vegetation types, but...
maps of habitat connectivity that allow species to move and genes to flow between populations, maintaining genetic diversity.

Vegetation maps provide detailed and accurate information on the distribution of vegetation and habitat types, including the locations of rare and unique plant communities, and provide underlying habitat data used to map and model species distributions and habitat connectivity. There are a number of different ways to measure species biodiversity. Most simply, one can count the total number of species in a given area. However, a simple count overlooks some of our most unique habitat areas in California, which don't support large numbers of species but are home to endemic species found nowhere else on Earth. A metric that factors in how restricted each endemic species is can be used to capture the uniqueness, or irreplaceability, of habitat areas. Areas that support a high diversity of rare or at-risk species (endemic and non-endemic alike) are also important.

Maps that show how individual species are distributed across the landscape allow us to calculate each of these biodiversity measures. Species distribution maps can also be used to model habitat connectivity to determine how to best support plant and animal species movement through the landscape, a necessity to mitigate impacts from climate change and anthropogenic influences.

**AREAS OF CONSERVATION EMPHASIS (ACE) BIODIVERSITY MAPS**

The Areas of Conservation Emphasis (ACE) project (www.wildlife.ca.gov/data/ACE), developed by the California Department of Fish and Wildlife’s (CDFW) Conservation Analysis Unit, brings together species habitat distribution models and species occurrence, vegetation, and connectivity data to map biodiversity in California. The ACE viewer can be used to explore maps of species richness, rarity, and irreplaceability for seven major taxonomic groups—amphibians, aquatic invertebrates, birds, fish, mammals, plants, and reptiles—as well as overall biodiversity. (Note: Data on the rarity and irreplaceability of aquatic invertebrates is not currently available.)

Scientists and armchair naturalists alike can use ACE to obtain a list of species with documented occurrences or modeled distributions within 2.5-square-mile hexagons across the state. Each hexagon also shows the relative species counts and biodiversity scores, the presence of significant habitat types, and habitat connectivity information. First published online in 2009, ACE was among the first biodiversity map tools of its kind.

The species richness maps in ACE are based on habitat distribution models that draw directly from vegetation maps developed by the CDFW’s Vegetation Classification and Mapping Program (VegCAMP), the CNPS Vegetation Program, and others. The vegetation maps also provide locations of sensitive natural communities—rare and unique vegetation types—and other vegetation and habitat types of conservation concern used in the ACE significant habitats map. The CDFW updates the ACE maps regularly as new data and vegetation maps become available. For example, the plant species richness maps in ACE Version 3 are based on coarse-scale plant distribution information cataloged in the Jepson Manual; the CDFW is partnering with researchers to include more refined distribution models in ACE.

Scientists have developed a number of habitat connectivity models for California, and the currently available models are summarized in the

---

ACE Native Species Richness map showing the count of potential species per hexagon based on species habitat models. Courtesy of Ryan Hill, CDFW
ACE terrestrial habitat connectivity dataset. Regional habitat connectivity models identify habitat linkages and movement corridors needed for daily and seasonal movement, to maintain genetic diversity, and to allow for shifts in species’ distributions in response to climate change. Building regional habitat connectivity models requires highly accurate land cover data to assess the juxtaposition of habitats when identifying potential corridors; fine-scale vegetation maps provide the necessary high spatial and thematic accuracy needed for such assessments.

USES OF FINE-SCALE VEGETATION MAPS IN MODELING

Animal distributions are largely defined by the availability of habitats on which they depend. In California, an effort by a consortium of agency and university wildlife biologists defined wildlife habitats by the dominant plant species, cover, and tree size, all of which are included in vegetation maps. Species experts have compiled information on the suitability of each of these habitats to support wildlife species over the past four decades, creating the California Wildlife Habitat Relationships (CWHR) system, which the CDFW maintains (CDFW 2018). The CWHR contains information on the suitability of each habitat for California’s animal species, assigning it a score for reproduction, cover, and feeding. These habitat suitability values can be directly applied to vegetation maps to create species habitat maps. The CDFW has developed species habitat maps for 522 terrestrial vertebrate species using this information. These maps are used in ACE biodiversity mapping and conservation planning and are available for download in the BIOS map viewer (www.wildlife.ca.gov/data/BIOS).

Can vegetation data be replaced by other environmental variables in conservation modeling? Sophisticated statistical methods and machine-learning algorithms can incorporate a wide array of environmental variables such as temperature, precipitation, elevation, water availability, and geology to determine where a plant or animal species is most likely to occur on the landscape. A study by the CDFW evaluated simple vegetation-based habitat models and statistical models built with a variety of variables for 30 species in the Sierra Nevada foothills. Species experts selected the model that best represented the species distribution in the landscape. Vegetation was among the top two variables with highest importance in 80 percent of the final models selected by species experts and had some explanatory power in all of the final models, even when 14 other environmental variables were considered (Krause et al. 2015). These results underscore the importance of vegetation maps in species distribution modeling.

From a modeling perspective, detailed vegetation maps are often more desirable than coarser land cover classifications because they allow for more sophisticated models, which in turn facilitate more effective conservation and management outcomes. For example, a recent analysis by CDFW biologists combined vegetation maps with data from automated recording devices that capture bird calls, to map the predicted distribution of 89 bird species in the Modoc Plateau of northeastern California. A model that used detailed vegetation classifications from the Manual of California Vegetation (MCV) identified subtle variations in habitat relationships among bird species that would
not have been evident from a model using coarser habitat data.

For example, the black-throated sparrow (Amphispiza bilineata) and vesper sparrow (Pooecetes gramineus) used only a subset of the sagebrush alliances that make up the more general sagebrush habitat class; the more detailed MCV vegetation classification thus predicted the birds’ distribution in the landscape more accurately than a model that used a single, broad sagebrush habitat class. The finding demonstrates the importance of detailed vegetation classification and mapping to identify habitats that support species of special concern, pinpoint habitats that promote bird diversity, and inform regional conservation and management planning.

Vegetation mapping can also help to predict species’ home ranges and movement corridors. Researchers are working to collect fine-scale GPS data on the movements of species such as mule deer, elk, pronghorn, and mountain lion in California. However, the cost and labor required to implement large-scale collaring projects, as well as the invasive nature of such efforts, mean that large knowledge gaps persist. When collar data are absent, researchers can sometimes use statistical models that incorporate empirical movement data to fill in these gaps.

Fine-scale vegetation data, which also show where species may find cover or food, inform these models. The CDFW is currently working on predicting likely mountain lion movement paths in areas that may be impacted by new infrastructure projects. These models can also predict the migration corridors of ungulates such as mule deer without the need to collar dozens of animals per herd, saving valuable resources for conservation measures such as vehicle crossing structures, which may benefit migratory populations, and reducing stress on the animals.

Detailed and accurate vegetation mapping allows researchers to detect and document change over time, and to assess the impacts of slow, incremental changes as well as sudden changes from major events such as wildfires. Because vegetation maps are directly tied to measures of biodiversity and habitat connectivity in ACE, vegetation change detection can also be used to assess the directionality, magnitude, and spatial extent of these changes and their impacts on biodiversity and habitat connectivity, including evaluating changes that have already occurred, and forecasting future change. Thorne et al. (2016), for example, used vegetation data to project the impacts of future climate scenarios on vegetation. The CDFW then used those projected impacts to assess possible effects on animal species (Gogol-Prokurat and Hill 2019).

CONCLUSION

The State of California and partner organizations are investing in the completion of a full vegetation classification and detailed vegetation map for the entire state. This map will provide essential data to develop and refine models for use in conservation planning and biodiversity conservation. Tools such as satellite imagery, GPS tracking devices, and genetic analyses are rapidly increasing the ability of scientists to track and analyze different types of biodiversity data.

These approaches, together with field monitoring data and a complete vegetation map of the state, allow us to tie together knowledge of species, vegetation, and habitats on the landscape and to monitor change over time—all of which aids large-scale conservation efforts throughout the state. More work will be needed to incorporate information on less well-known taxonomic groups such as lichen, fungi, mycorrhizal fungi, and invertebrates. Through partnerships to collect, develop, and analyze this information, we will further our understanding of California’s unique biodiversity and preserve our irreplaceable natural heritage for generations to come.

—The authors are affiliated with CDFW’s Biogeographic Data Branch (BDB). Melanie Gogol-Prokurat is the lead ecologist and supervisor of the Conservation Analysis Unit (CAU) and Vegetation and Classification and Mapping Program; Michael Hardy is a spatial ecologist in the CAU, Evan Greenspan is a senior GIS specialist in the CAU, and Kari Lewis is the BDB branch chief.

REFERENCES


CALIFORNIA’S ROLE IN THE GLOBAL EFFORT TO PROTECT IMPORTANT PLANT AREAS
Sam Young

The nations of the world are gathering this year in China to plan for the next decade of global biodiversity conservation. The Convention on Biological Diversity is 30 years old this year, and representatives from 196 countries will meet at the 15th Conference of the Parties (COP15) in 2022 to negotiate strategies to combat the global extinction crisis. While California cannot sign the convention on behalf of the US, the state has become a sub-national observer to the Convention and has indicated that it will participate in COP15 in China. California belongs to one of the world’s 36 global biodiversity hotspots, making it a significant player in these upcoming conversations.

Scientists have been documenting global biodiversity decline for more than half a century, prompting the United States to sign the Endangered Species Act in 1973. In the year 2000 at COP5, the international community adopted conservation provisions specific to plants, recognizing them as the foundation of our terrestrial life support systems. This article traces the origins of Important Plant Areas (IPAs) as global conservation targets, and describes the California Native Plant Society’s work to identify IPAs in California as another tool to preserve the state’s unique biodiversity. Tools such as IPAs are becoming increasingly important, especially as California has the highest concentration of imperiled species in the US.

In 2002, Plant Life International, an NGO based in the UK, published criteria for identifying and mapping important areas for the conservation of plant biodiversity. At the most general level, the criteria for plant areas are:

A – The site holds significant populations of one or more plant species that are of global or regional conservation concern.

Above: Aspen fall colors at Lake Sabrina, Inyo County, CA. Photograph by Sam Young
B – The site has an exceptionally rich flora in a regional context to its biogeographic zone.
C – The site is an outstanding example of a habitat or vegetation type of global or regional plant conservation and botanical importance.

By 2020, a COP report found that 27 countries had completed IPA maps. The report also noted significant overlap between IPAs and Key Biodiversity Areas (KBAs), a designation of biodiversity importance developed by the International Union for Conservation of Nature (IUCN), which considers the presence of rare species of all types (not only plants), endemism, biological processes, irreplaceability, and ecological integrity. The report notes that 106 countries have begun identifying KBAs thus far.

CALIFORNIA IPA IDENTIFICATION
In 2006, the California Native Plant Society began to develop criteria for identifying IPAs within California. The effort began when the Bay Area Open Space Council, a network of 65 conservation organizations and agencies (now Together Bay Area), requested input from the CNPS East Bay Chapter for the development of the Bay Area Upland Habitat Goals. The chapter developed area-based conservation priorities for plants in Alameda and Contra Costa counties called Botanical Priority Preservation Areas (BPPAs) of the East Bay.

To designate these areas, the chapter used California Natural Diversity Database (CNDDB) records and Consortium of California Herbaria collections for rare species; rare habitat types identified in the CNDDB and VegCAMP; indicators of unique habitat driven by substrate such as alkaline, sandy, and serpentine habitats from USDA Natural Resources Conservation Service soil surveys; and United States Geological Survey geological data. They combined this data with Farmland Mapping and Monitoring Program (FMMP) data and land management datasets to identify which areas have likely been converted to other land uses such as agriculture, and which were already protected such as state and regional parks lands. BPPAs informed the Upland Habitat Goals, which in turn were translated to Priority Conservation Areas in the Bay Area Greenprint, a publicly available online resource that maps and measures local natural resources. Today, the CNPS East Bay Chapter continues to use BPPAs for conservation advocacy.

In 2017, building on these efforts, CNPS initiated a statewide Important Plant Areas Pilot Project to address regional conservation prioritization, launching the full-fledged program in 2018. The CNPS approach to Important Plant Areas combines data analysis, using as many existing botanical datasets as can be compiled, with charrette-style meetings in which experts and stakeholders gather to review the data and suggest where conservation efforts should be prioritized in the landscape.

Statewide, the regional conservation prioritization for plants has become more important as regional planning has shifted from a singular focus to being more holistic in recent decades. Emerging issues crossing jurisdictional boundaries, such as climate change, have created a need for regional planning efforts which are inclusive of multiple management issues.

Voluntary programs such as the CDFW’s Resource Conservation Investment Strategies allow for comprehensive resource planning at the regional scale. Even efforts such as 30x30 are being developed to synergize, enable, and accelerate existing conservation actions, climate change adaptation and mitigation mandates. This presents an opportunity to insert botanical biodiversity data where it would otherwise be largely absent. Many environmental review activities only require consideration of a fairly narrow range of species and habitats relative to California’s overall botanical
biodiversity. It is therefore critical that tools and datasets, such as IPAs, are included in these emerging comprehensive regional planning efforts as they become more commonplace.

Furthermore, a centralized assessment of biodiversity conservation priorities allows conservation planners and advocates to protect priority areas (like IPAs) before financial resources have been invested in development projects.

The IPA program has been coordinating with an international IPA network organized by Plantlife International on promoting IPAs as part of the post-2020 Global Biodiversity Framework. The CNPS IPA Program is also actively participating in a large working group of environmental stakeholders working to elevate California’s role as a leader. The California Global Biodiversity Working Group, as the group has been named, is currently collaborating with the California Natural Resources Agency (CNRA) on participation in COP15, leading by example showcasing efforts at home like 30x30. Potential collaborators and stakeholders are already requesting input from the IPA program on individual projects, and the demand is apparent for IPA maps at multiple scales, from local projects and state initiatives to global conservation efforts.

—Sam Young is the CNPS IPA Program Manager
METHODS

CNPS staff categorized the input data for its California IPA program based on criteria developed by Plant Life International for IPAs: Rare Plant Data (Criterion A), Significant Native Plant Biodiversity (Criterion B), and Rare Vegetation and Habitat Types (Criterion C). While the IPA program’s modeling approach differs from Plant Life International’s checklist approach in important ways, at least some, if not all, modeled IPAs will be recognized in the international IPA database, highlighting the importance of conserving these areas.

The CNPS IPA mapping program differs from a more traditional objective or stochastic modeling approach in that the model output constitutes a “heat map” of conservation values that are relative to one another. We chose this relative value system because it allows for compilation of a wide variety of biodiversity attributes, including the presence of rare species, rare habitat types, and measures of native biodiversity such as phyloendemism and native species richness to a common scale, while remaining adaptable to regional expert input and regional data availability.

Relative-scale modeling also allows us to maintain a standardized model structure that allows for unique inputs and adjustments to weights and thresholds based on biodiversity factors that are important to a particular ecoregion. Rare species occurrences are important drivers for IPAs in California’s desert regions. However, as overall rare species richness is less than in the North Coast regions, we adjust thresholds to account for a relative rather than an objective measure of importance for biodiversity conservation. Rare vegetation types may be bigger drivers in the Sierra Nevada foothills and the Central Valley compared to the Mojave Desert where rare species occurrences may drive output values. A relative-scale approach also lends itself more easily to collaborative input from a large number of regional stakeholders and experts who have participated in the IPA modeling process from the start.

To ensure the data underlying the CNPS IPA program were of high quality, we asked regional experts and stakeholders to review input data, draft models, and results in workshops for each modeling region. IPA program staff initially conducted workshops in person over two days, but COVID-19 forced us to move to a two-hour webinar format. A two-week review period followed each workshop, where participants could submit comments on suggested changes to the model or additional datasets to be used as inputs. IPA program staff reviewed all new datasets, comments, and recommendations provided by participants, and updated regional models. Revisions will be distributed for a final round of comment and reiteration prior to public release in 2022.

For any questions on IPAs, interest in using IPA data, or to be a part of reviewing IPA products, please contact Sam Young, IPA program manager, at syoung@cnps.org.

Field trip following an IPA workshop in Bishop, CA. Amy Patten, Dean Tonenna, Jim Morefield, Spike Jackson, and Mark Bagley investigate areas highlighted as important during the mapping portion of the workshop. Photograph by Sam Young.
BOOK REVIEW

Field Guide to Manzanitas: California, North America, and Mexico, 2nd Edition
by Michael Kauffman, Tom Parker, and Michael Vasey

Brett Hall

The second edition of the Field Guide to Manzanitas by Kauffman, Parker, and Vasey retains the 2015 edition’s refreshing approach to botanical field guides. Yet it has many enhancements, expanding our understanding and appreciation of manzanitas from many intriguing perspectives. It is a disciplined, enjoyable, and adventurous guide to identifying species and subspecies in the genus Arctostaphylos, and provides important information and insight to the evolution, ecology, and biogeography of this group.

The authors’ stated purpose is to “lift the veil on this quintessentially California shrub genus so that professional and amateur botanists alike are able to more fully appreciate the beauty, complexity, diversity, distinctive habitats and conservation value of wild manzanita populations.” Concisely, they convey compelling, relevant taxonomic, morphological, ecological, and evolutionary information. They describe the story of the California Floristic Province in relation to Arctostaphylos across millions of years, showing how tectonic activity, climate changes, botanical migrations, and subsequent evolutionary events have played out. They also discuss Mediterranean climates and their role in shaping global biodiversity hotspots.

The species and subspecies within the book are organized alphabetically, which makes the experience of using it easy and enjoyable. Conveniently, the table of contents also serves as an index to the taxa, with page numbers for quick reference to spin directly to the pictures and descriptions for the taxon of interest. After Michael Kauffman’s friendly and intelligent biogeographic reflections in his preface, the authors provide a short preview of what’s inside the field guide with salient comments about the forthcoming sections.

The “Origin, Ecology and Diversification” section takes us back into the early Cretaceous (~110mya) and entices us to imagine the Heath Family, Ericaceae, with a global footprint on all continents, slowly evolving along its diverse lineages into subfamilies and genera, species and subspecies, and their many variants. This evolutionary discussion goes into the morphological adaptations of fruits and vegetative responses to fire (burls and soil seed banks) and drought, along with the ebb and flow of glacial events throughout the Pleistocene, indicating how these events and adaptations affected the dispersal and current ranges of manzanita taxa. They introduce topics including edaphic (soil-related) endemism and oligotrophic (low nutrient) soils, neo-endemics and paleo-endemics (“recent” vs. ancient), and mutualistic fungi that produce mycorrhizae (fungal roots), all of which are central to the ecology and evolutionary biology of manzanitas.

A small section on “Conservation Implications” describes the California Coastal Act protecting Environmentally Sensitive Habitat Area (ESHA), leading to a brief discussion on maritime chaparral, which of course is mostly manzanitas. We learn that the coast ranges are where we find the greatest diversity of manzanitas, shaped by past events, fog, and geology.

After this we arrive where the burls hit the ground, so to speak: the physicality of manzanitas themselves. “Manzanita Characteristics” takes a deep dive into the morphology of the taxonomic characters that enable us to differentiate species from one another. Stems, leaves, stomata, bark, hairs, glands, bracts, nascent inflorescence, fruits, drupes, and nutlets, or stones, are described in an ecological context involving fire, rodents, hummingbirds, bees, and other beings.

Next are the keys. First, a map is presented to select from one of seven regions and then you proceed to that specific region’s key. These smaller regions reduced the number of species to navigate through in the key. With manzanitas, geography is destiny.

Ahead of the first regional key, the authors present a helpful paragraph titled “A note before keying.” Keying, they argue, is a bit more like an art than
quantitative science, and takes practice, like playing a musical instrument. They give us a method to follow, so be sure to read it! Each regional key includes the same major departure points or crossroads. Burls or not? Prostrate or mounding? Leaves with stomata only on the lower surface...or leaves with stomata on both surfaces, surfaces similar in color and/or hairiness? If you can get a handle on these characteristics and a few others, including a good visual understanding of inflorescence branching, you will be well on your way to successful manzanita identification. The authors have made a great effort to develop keys that work and to provide good guidance in their use.

The next section, including 107 species and subspecies plates, is the core of the field guide. The authors developed a standard template designed for easy comparison. It includes six characters (form, stem, leaves, inflorescence, fruit, and habitat), remarks, and, as in the original, Bisbee’s amazing illustrative photographs.

Toward the end of the book is a glossary of terms, including sections on manzanita destinations to visit, including Baja; and a list of manzanita species by county as well as other states and countries outside of the Western US. There’s a list of suggested readings with updates, a description of manzanita relatives and lastly, a bit about the authors.

HIGHLIGHTS OF THE 2ND EDITION INCLUDE:

- A beautiful, water-resistant cover with an alluring photo of the Big Sur Coast, water-resistant pages, and as in the first edition, exquisite photographs by Jeff Bisbee. Rounded edges allow for smooth sliding in and out of pockets and backpacks; this book is designed to be taken out into the field.
- Updated regional keys, including the addition of Arctostaphylos uva-ursi subsp. cratericola (from Guatemala) in Regional Key 7 (Manzanitas Outside the California Floristic Province). There are two additional subspecies within the CFP and these are Arctostaphylos patula subsp. gankinii and Arctostaphylos purissima subsp. globosa.
- Descriptions for each of the 107 manzanitas include a description of their inflorescence characters with accompanying photographs. These were often missing in the first edition and are an important diagnostic trait for the genus.
- Updated county lists.

So give the gift that keeps on giving, a Field Guide to Manzanitas. Give it to yourself! As the authors say, “like playing a musical instrument, practice yields proficiency and your skill at identifying manzanitas will eventually make sweet music indeed.”


—Brett Hall is program director of the UC Santa Cruz Arboretum and director of the CNPS board: brett@ucsc.edu
Dan Songster grew up with gardens and gardeners. As a young man, he absorbed, studied, and practiced ornamental horticulture. While working on the ground crew at Golden West College in Huntington Beach in 1975, he says, “I was asked to design a native garden for the science department and realized I knew nothing about native plants! So began a most rewarding journey discovering amazing plants and people along the way.”

Dan gave himself a crash course in native plants and embraced the project. Later, he and fellow groundsman Rod Wallbank co-directed the garden until Rod’s untimely death in 2010. Their hard work and persistence made it the garden it is today.

In 1998, Dan established a nonprofit foundation to raise funds for the garden’s support. Around that time, the CNPS Orange County Chapter became a regular supporter of the garden through volunteering on work days and putting a little cash in the pot.

When Dan retired in 2013, he became the volunteer garden director. Now, he and his volunteer maintenance crew meet every Tuesday and Thursday morning, year-round. Work is always followed by coffee hour and animated discussions. In early 2020, the campus closed due to the pandemic. Weeds grew freely and shrubs went without their annual trimmings. Fortunately, after several months, Dan got permission to work in the garden and later volunteers were allowed to join him. While the campus is still not fully active, the garden and its volunteers are going strong.

Dan Songster first appeared on the CNPS Orange County Chapter’s radar early in 1990, when he took on the plant sale. Whether or not he’s on the plant sale committee, Dan is always our top salesman, with his extensive knowledge of horticulture and keen sense of garden design. He generously shares his knowledge in other ways, too. For years his column “Native Gardeners Corner: Members’ Tips, Tricks, and Techniques” has been a popular feature in the Orange County Chapter newsletter. His many articles on native plants and gardening with natives could fill a book. He promotes native plants far and wide with presentations and plant care workshops.

A founding member of Cal IPC, then known as Cal EPPC, Dan has been on our invasive exotics team since 1994. He has also acted as treasurer (1996–1999), president (1999–2003), co-president (2013–2015), and president again from 2016–2017.

One of Dan’s most enduring contributions to our chapter has been his one-person public programs team. For 20-plus years, Dan has capitalized on his many connections in the native plant world to bring consistently outstanding speakers to our chapter meetings, including Bart O’Brien, Carol Bornstein, Greg Rubin, Naomi Fraga, Sula Vanderplank, and Jon Keeley. While president, he attended quarterly state CNPS board meetings and served on the state horticulture and education committees from 2000 to 2010. While on the horticulture committee, he helped develop a list of plant nurseries statewide that feature a significant number of native plants. He also worked on wildland interface issues.

Dan is always coming up with better ways to engage people, manage the chapter, and enlarge the world...
of native plants. In 2008, Dan designed, set up, and led our first native plant symposium, At Home with Natives, which was held at Golden West College and included tours of the garden. Dan and Bart O’Brien were the chief presenters. When it was decided that the chapter needed bylaws, Dan led the team.

Dan is a fan of used book stores and has collected many out-of-print books on native plants, which he occasionally gives the chapter for a silent auction or bestows upon a volunteer. For many years Dan was in charge of selecting and ordering books for chapter book sales. He was a content reviewer for *California Native Plants for the Garden* (O’Brien, Bornstein, and Fross, 2005). From 2009–2013, Dan was the chapter lead in the efforts to publish *Wildflowers of Orange County and the Santa Ana Mountains*. After the book finally came out, he led a project to donate a copy to all 23 Orange County public libraries.

Extrovert that he is, Dan also recognizes the human element in carrying out the mission of CNPS. He created the chapter’s Perennial Award, our top honor given each year to an outstanding chapter volunteer, and is himself an awardee. Among the grants we offer, Dan developed the Travelers Grant to help students attend CNPS and other conferences. He also initiated the Acorn Grant that provides start-up funds for school gardens.

The “rewarding journey” that Dan Songster set off on so long ago has opened paths of discovery for all who visit the Golden West College Native Plant Garden. Its plantings, arranged by community and accented with color, its outdoor classrooms with places for learning and for contemplation, and its people-friendly walkways and resting spots all reflect Dan’s true dedication to the enjoyment and preservation of native plants.

—Sarah Jayne is a CNPS Orange County Chapter board member. She became a CNPS member in 1985.

---

**CALL FOR PROPOSALS!**

Interested in writing for CNPS’ scientific journal *Artemisia*?

We are accepting proposals and brief summaries for upcoming issues of *Artemisia*.

Proposals should contain a topic, theme, and be relevant to the CNPS mission. This is a great opportunity for new and seasoned writers, and those looking to get their work published in a scientific journal.

Submit proposals to Krystle Ramos at kramos@cnps.org

---

**REGIONAL PARKS**

**BOTANIC GARDEN**

Dedicated to conservation, education, and horticulture in a beautiful landscape of California native plants

Due to COVID-19 and the need for social distancing, Botanic Garden programs as well as days and hours of operation may vary

Please refer to www.nativeplants.org for the most current information on Garden access, tours, classes, programs and plant sales

Wildcat Canyon Road at South Park Drive in the Berkeley Hills
Ronald Martin Lanner, 91, passed away peacefully at home on January 6, 2022, with his family by his side. A native of Brooklyn, New York, Ron developed his love of the natural world early in life on the shores of the Hudson River and in the Catskill Mountains. His parents, Louis and Esther, both immigrated from Eastern Europe to the US to escape persecution. Ron, therefore, fought hard to remove bigotry and prejudices of all kinds. His thoughtful and carefully worded letters to the editor of local newspapers over the decades sought to raise the consciousness of its readers.

He earned his BS and MF from the State University of New York’s College of Forestry and his PhD from the University of Minnesota. He led a distinguished career at Utah State University as a professor, researcher, and nature writer. Prior to joining the faculty of USU, Ron worked as a research forester for the US Forest Service in California and Hawaii. He pioneered research on pinyon pine, taking his family on extended back road adventures throughout the West and Mexico to conduct his fieldwork. He lived his final years in Placerville, California, on two acres of beloved forest in the Sierra Nevada foothills.

This forest was well-endowed with conifers—Ron’s favorite plants. While he loved to travel, usually for research that took him all over the world, he always returned to the mountains of the American West and his beloved haunts among the bristlecone and foxtail pines.

Ron entered my life in 1996, when I received his book, Conifers of California, as a gift. At this point, I was a tree-hunting tenderfoot and new to California. The book almost immediately changed my relationship with California and its natural history. I knew I loved conifers, but I didn’t really know why. After reading Ron’s book cover to cover (many more times since then in fact) my conifer obsessions began in earnest.

I now had a reference manual for understanding how these ancient plants fit within California’s diverse landscapes. Ron describes the natural history of every conifer in California while also sharing a few destinations for each one. I now also had a guide for finding, as Lanner calls them, “arguably the nation’s most fascinating trees.” Thus began a series of adventures to the most beautiful places in the West; after reading Conifers of California I explored his other books, including Made for Each Other: A symbiosis of birds and pines and The Bristlecone Book. In all, Ron has published nine books and over 50 scientific papers.

It was an honor to finally meet Ron at the Northern California Symposium of Botanists meeting in 2012 when we came together to create the first working group for whitebark pines in California. I was also intimidated as hell—as he was a harsh critic of my work. I was both honored that he read my writing and humbled when he would reach out to challenge me and my hypotheses. But with Ron’s mentorship my writing grew, as did my love of conifers. I also learned from these exchanges that Ron had a strong belief in the importance of rigorous science and an indeterminate love of the conifers of which we both wrote. Ron made me a better science communicator and for that I will always be thankful.

I encourage you to pick up and read (reread) one of his many richly illustrated books, dive into the complex stories he tells about their roles and relationships in these beautiful ecosystems, and relish his poetic gift for explaining complex biological systems to the lay reader. Reading Ron Lanner is a must for anyone interested in understanding one of the most ancient and interesting lineages of plants on Earth.

—Michael Kauffmann is a research ecologist and owner of Backcountry Press.
A Klamath Mountain foxtail pine (Pinus balfouriana ssp. balfouriana). Photograph by Michael Kauffmann
Dr. Roy Buck, one of California’s most brilliant botanists, passed away on January 9, 2019, at the age of 66. Roy was born in Arlington, Virginia, as the first son of David and Elizabeth Buck on June 9, 1952. He attended Colby College in Waterville, Maine, majoring in psychology, and in 1972 was expelled for protesting the draft to the Vietnam War.

After leaving Colby, Roy bounced around for a few years; he hitchhiked across the US, lived in Boston for a time, drove a taxicab, and worked on a riverboat as a deckhand. Eventually he went to Kentucky, where his parents and younger brother, Nat, had moved in 1972. There, he picked up a book on the wildflowers of Kentucky and decided to study botany. Roy made his way to California, where he attended the University of California, Santa Cruz. His senior project was a botanical flora of the UC Santa Cruz campus.

Roy received his BA in 1981 from UC Santa Cruz where he double majored in environmental studies and biology. His PhD dissertation at Cal Berkeley (1995) was on the systematics of Caulanthus (in the Brassicaceae or mustard family), and he was also the lead or sole author of the Caulanthus, Guillenia, and Streptanthus treatments for the first edition of The Jepson Manual (Hickman, 1993). Little of Roy’s doctoral work ever appeared in print, yet in light of recent DNA analyses (Ivalú Cacho et al., Molecular Phylogenetics and Evolution 72: 71–81. 2014), his recognition of Guillenia appears to have been prescient, as was his finding that Caulanthus as previously delimited is an unnatural (i.e., paraphyletic) group.

The rare Santa Cruz clover, Trifolium buckwestiorum (Isely, Madroño 39: 90–97. 1992), commemorates Roy and James A. West, who first discovered the plant. Roy was also a coauthor of two new species, the long-fruit jewelflower (Streptanthus longisiliquus) and the giant checkermallow (Sidalcea gigantea) (Clifton and Buck, Madroño 54: 94–98. 2007; Clifton et al., Madroño 56: 285–292. 2010). He contributed extensively to the California Natural Diversity Database, serving as the primary author of 171 source records and a coauthor to an additional 71 records consisting of specimens, letters, and notes. From 1999 to 2007, Roy also served as treasurer of the California Botanical Society.

Roy first began working with BioSystems Analysis, Inc., an environmental consulting company, in 1986. There, he met senior botanist Bill Davilla, who noted that Roy was already an accomplished plant taxonomist and field botanist. Roy’s skills were well-suited to the botanical surveys and rare plant studies that BioSystems was conducting for project-level studies and planning assessments. His keen taxonomic knowledge of California’s flora resulted in comprehensive plant species lists, observations, and documentation of rare plant populations, resulting in better mitigation and conservation actions.

During his time at BioSystems, Roy also worked collaboratively with field botanist and taxonomist Glenn Clifton. They often met for a lively discussion of phylogeny and plant taxonomy and as a result, generated several local floras. Roy continued to work with Bill and Glenn at EcoSystems West from 1996 to 2012, further dedicating himself to advancing our knowledge of the flora of California.

I first met Roy in 1994 on the bombing ranges of Fallon Naval Air Station, where he and Glenn came toddling up in a Plymouth Voyager minivan on donut wheels. I was trapping small mammals at the time, and
the two of them were conducting botanical surveys. In 2012, Roy joined my newly established company, California Environmental Services. He was much beloved as the country music–loving botanist who mentored all the staff, whom he adored in return. He was always game to conduct field work with any of them, taking the opportunity to teach budding wildlife biologists.

Roy and I had a very special bond. I remember him as the best person I ever met, and a genius at all things botanical. He would often sit and muse with his hand lens, and in a deep, distinctive baritone, say, "HmmmmmMMM" or "Well…" and suggest that the plant species we thought the specimen to be, did not fit the key. He was not one to rush to judgment and was often correct in his counter observations.

Another colleague, Maya Khosla, remembers Roy sitting in a patch of sun and shade with the massive Jepson volume on his lap. "It was springtime, and we were in Stanislaus National Forest, by the side of Highway 120, west of Yosemite National Park. He confirmed the presence of a rare monkeyflower: ‘So now we go to the next key break: calyx generally with red-brown spots; ding-ding-ding-ding-ding! I think we have a winner here folks! That looks like *Mimulus filicaulis*, slender-stemmed monkeyflower’.”

That memory captures Roy as a serious academic, an instructor, and a comedian. He frequently expressed his strong preference for the world of plants “because they don't run, swim, or fly away from you.”

Earlier that same spring afternoon, Maya recalls that Roy led the team to a location in Stanislaus where he confirmed the continued presence of *Clarkia australis*, Small’s southern clarkia. The diminutive flowers showed their bright splashes of fuchsia in the green hillside, and Roy said, “Like the Small’s southern clarkia, the slender-stemmed monkeyflower is a species that is known to be favored by fire…. Fire affects the seedbed; it influences the mosaic of the forest vegetation, which creates a variety of what we call microhabitats—very localized, specialized areas of habitat that many native plants require.”

Roy loved to be among plants and studied them whether he was compensated or not. He gave his spare time to assist with weed removal and management in the Golden Gate Natural Resource Area (GGNRA), including Point Reyes National Park, nearly his entire adult life. He was close friends with Maria Alvarez at GGNRA and viewed her daughter, Phacelia, as a god-daughter.

Roy was down to earth and valued his integrity over all else. He was the most honest, ethical, kind, and funny person we have ever known and a genius in his field. He is survived by his younger brother, Nathaniel M. Buck, who resides in Kentucky and says that Roy was “always there for his little brother.”

Please view the last “Field Days with Roy” here: https://youtu.be/t9Ho-u7Y3NQ

—Gretchen Flohr, PhD, is principal biologist at Helix Environmental Planning; Doug Stone is an associate rare plant botanist at CNPS; William Davilla is principal and senior botanist at EcoSystems West; and Maya Khosla is a wildlife biologist, independent documentary filmmaker, and an award-winning poet and naturalist.
Spring Into Action

Now is the perfect time to get organized and tackle those life tasks you’ve been avoiding. As you begin your spring cleaning, there’s one more item you can check off your to-do list: creating a will or trust to support your loved ones — and the future of the native plants that make California so special.

CNPS has partnered with FreeWill to offer our members a free resource to protect the ones they love. In just 20 minutes, you can create a will or trust with our online tool.

If you want to make an impact on California’s native plants and their habitats without paying a cent today, you can create an optional legacy gift to CNPS in your plans. Creating your will and defining a charitable plan helps your loved ones understand your wishes, and continues your legacy by giving to the causes you care about.

Get started at FreeWill.com/CNPS

Questions? Contact Christine Pieper at legacy@cnps.org or (916) 738-7622
SAGING THE WORLD

“I ask everybody to learn about the sage...before thinking that taking a match or a lighter to it is the way to go.”

-Nick Rocha, Gabrielino-Shoshone

A film by
Rose Ramirez
Deborah Small
The California Native Plant Society

Directed by
Rose Ramirez
Deborah Small
David Bryant

For a listing of screening events, film festivals and viewing opportunities visit cnps.org/sagingtheworld

Photo: Kendra Macle Johnson, Gabrielino-Temane

SPRING OFFERINGS FROM YOUR CNPS STORE
STORE.CNPS.ORG

SHOW YOUR CNPS STYLE!
T-shirts for everyone in black and latte, featuring native plants of California

Take 20% off with discount code tshirt20

Shop for field guides, posters, photo books, and more at store.cnps.org
ENDANGERED PLANTS NEED YOUR HELP

PLEASE DONATE AT TAX TIME - LINE 403 - CALIFORNIA RETURN

Funds directly support efforts to prevent the extinction of imperiled plant species
Please spread the word - www.wildlife.ca.gov/conservation/plants

ENDANGERED PLANTS NEED YOUR HELP

PLEASE DONATE AT TAX TIME - LINE 403 - CALIFORNIA RETURN

Funds directly support efforts to prevent the extinction of imperiled plant species
Please spread the word - www.wildlife.ca.gov/conservation/plants

HELIX
Environmental Planning

Looking for a new career opportunity? We’re hiring!

We are a growing, employee-owned California-based firm, we’re passionate about what we do, and we have a casual and collaborative work environment. Our employees describe us as family-oriented, supportive, and focused on integrity and high-quality service for our clients.

We’re hiring for many positions in habitat restoration, biology, botany, and archaeology including project managers, field staff, and as-needed staff to support our teams across California.

Learn more about life at HELIX. www.helixepi.com/careers

SAN DIEGO | LOS ANGELES | ORANGE | RIVERSIDE
SACRAMENTO | PLACER

Get The Dirt on gardening

Find gardening inspiration in The Dirt, Irvine Ranch Water District’s quarterly electronic newsletter promoting beautiful, water-efficient SoCal landscaping.

Visit RightScape.com/The-Dirt.
Bloom! California is a campaign to help you discover, explore, and find native plants near you. Keep your eye out for the Bloom! California logo in nurseries! Learn more at:

bloomcalifornia.org
Join us for the largest conference in California devoted to native plants!

October 20-22
San Jose, California

Giant Sequoia Sponsor

Manzanita Sponsors

Environmental Science Associates
Moulton Niguel Water District
Sacramento Valley Chapter, CNPS
Santa Barbara Botanic Garden
Santa Clara Valley Chapter, CNPS

There is still time to become a Conference sponsor! For sponsorship inquiries, please contact Lindsay Dula at ldula@cnps.org