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THE FUTURE OF CALIFORNIA SAGE SCRUB
THE ARICA MOUNTAINS
LIFE INSIDE PLANT GALLS
THE NEED FOR SITE-SPECIFIC MAINTENANCE MANUALS
SEQUOIA: CONTINUATION OF THE SAGA

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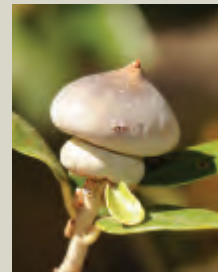


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ABOVE: View of intact California sage scrub in spring bloom at Fremont Canyon in Irvine County, California. Photograph by Stephen Francis for the Irvine Ranch Conservancy. • FACING PAGE: View of California sage scrub in summer, dominated by California buckwheat (*Eriogonum fasciculatum*), a semi-evergreen species. All photographs by Erin C. Riordan unless otherwise noted.

THE FUTURE OF CALIFORNIA SAGE SCRUB IN AN ERA OF INCREASING URBANIZATION AND GLOBAL CLIMATE CHANGE

by Erin C. Riordan and Philip W. Rundel

California sage scrub (CSS), one of California's most threatened vegetation types, faces a tenuous future marked by rising threats from human land use and climate change. This distinct vegetation type spans coastal and semiarid interior regions of the state from Santa Barbara south to El Rosario in northwestern Baja California, as well as scattered

patches along the central California coast. In Southern California, it occurs almost entirely in the wildland-urban interface in a complex and delicate mosaic of chaparral, grasslands, and riparian corridors amidst the region's sprawling human population. This vegetation lends a unique beauty to the Southern California landscape with its drought deciduous shrubs, such as the name-

sake aromatic sages (*Salvia* spp.), and a rich understory of herbaceous native plants.

California sage scrub is rapidly disappearing in California under a variety of human pressures, and a large proportion of species associated with CSS are categorized as sensitive, rare, threatened, or endangered. Land development, invasive species, changes in fire regime, and

air pollution have all contributed to the widespread loss, fragmentation, and degradation of CSS, which currently occupies a tiny fraction of its original extent (Westman 1981). Moreover, human activities that increase disturbance facilitate the conversion of CSS to exotic grasslands, a change that is further reinforced by soil nitrogen inputs from air pollution.

To make the situation worse, CSS faces additional threats from both projected global climate change and human population growth in Southern California. A rapidly warming climate this century could cause species range shifts, species losses, and declines in diversity as individual species respond to climate change, while increasing human populations will likely cause additional loss of wildlands. By the end of this century, scientists expect California's climate will shift substantially with temperatures rising by 1.7–5.8°C (3.0–10.4°F) statewide, depending upon the level of mitigation of greenhouse gas emissions (Mastrandrea and Luers 2012).

One study predicts dramatic range losses in as many as two-thirds of California's endemic species by 2100 (Loarie et al. 2008). Such findings are particularly concerning for California, where endemic taxa contribute greatly to the state's biodiversity, accounting for nearly 35% of the 6,500 native taxa. California's characteristic Mediterranean-type climate of mild, wet winters and warm, dry summers may be at risk in coastal areas of Southern California and northwestern Baja California (Ackerly et al. 2010; Klausmeyer and Shaw 2009). Warming and drying conditions could cause the loss of Mediterranean-type conditions in these areas, which harbor high CSS diversity and endemism.

In the face of these mounting changes, we set out to assess the potential impacts of both 21st century climate change and land use on CSS shrub species in California.

ADDRESSING FUTURE ENVIRONMENTAL CHANGE

Incorporating scenarios of future environmental change into conservation and resource management is challenging but increasingly necessary. Evidence of the negative ecological ramifications of climate change has accumulated over the last decades, spurring a growing community of scientists to investigate the current impacts of climate change and predict likely future impacts as the climate continues to warm.

Unfortunately, California sage scrub exists inside a highly urbanized region with a growing human population. For this vegetation, future land use may pose at least as big a threat as climate change. California is, of course, not the only region facing such threats. It is one of the world's five Mediterranean climate regions, and in each one human land use followed by climate change are expected to cause some of the highest biodiversity losses worldwide by 2100 (Sala et al. 2000).

Innovative modeling now makes it possible for scientists to predict the potential impacts of future climate change on biodiversity. The magnitude and trajectory of climate change depends heavily upon human greenhouse gas emissions, which will be determined by population growth, economic development, technological development, and land use. The Intergovernmental Panel on Climate Change (IPCC) has released a set of widely used possible future emission scenarios based upon different patterns of human growth and development. Sophisticated global climate models are then used to generate predictions of future climate patterns under these future emission scenarios.

Species distribution models can provide hypotheses of how species may respond to climate change. These models define a species range with respect to climate and other

environmental variables. Scientists then use these models to map potential habitat for a species under future conditions. Species distribution models have been used for a variety of purposes, including to identify species at risk of habitat loss and extinction and to predict changes in biodiversity.

In our study, we used a species distribution modeling approach to predict changes in habitat for a number of key CSS species under 21st century climate change. We used location data from herbarium records to model the current climate requirements for CSS species (Riordan and Rundel 2009). Then we mapped areas meeting species requirements under two possible trajectories of projected climate change in California: a warmer, wetter future and a warmer, drier future.

In order to weigh the impact of future climate change against that of future human land use, we used pro-





jections of future land cover and land use released by the United States Geological Survey (USGS) Land Carbon project, the first-ever of such projections for the conterminous United States (Sleeter et al. 2012). These projections, built upon the same future emission assumptions as the future climate projections, allow us to directly compare the two main causes of environmental change

TOP: Conversion of California sage scrub to agricultural land uses in Baja California, Mexico. Photograph by Benjamin T. Wilder, 2010. • BOTTOM: Black sage (*Salvia mellifera*) with a view of sprawling urbanization in the Los Angeles basin outside of Pasadena, California, 2010.

for the first time in Southern California. Our model of future CSS extent was based on a future of high economic growth, high urbanization, and high greenhouse gas emissions.

MOUNTING DEVELOPMENT PRESSURES

California sage scrub's primarily Southern California distribution coincides with areas of high human impact.

Southern California's history of land use dates back to the Spanish ranchos of the late 18th century and subsequent Euro-American settlement during the 19th century. Following World War II, rapid eco-

nomic and population growth in Southern California fueled extensive settlement and urbanization of low-land coastal areas, much at the expense of the native shrublands such as CSS. Today, nearly half (45%) of California's 38 million residents live in the coastal counties of Southern California (Ventura, Los Angeles, Orange, and San Diego), which together comprise just 7% of the state's total land area. High land values and development pressure across the region pose a significant threat to remaining fragments of CSS, making conservation both costly and challenging. These pressures will continue to grow with California's population, which is projected to increase to as high as 147.7 million by 2100 (Sanstad et al. 2011).

Approximately 25% of coastal and western Southern California has now been developed primarily as a result of urban and suburban growth, transportation infrastructure, and agriculture. This percentage could rise to over 40% by late century (2080s) under a future marked by high economic growth and urbanization. Under such a scenario, the single greatest type of land conversion in the region will be the loss of shrubland habitats to development.

Such high rates of future habitat conversion will likely impact future CSS persistence. For the 20 dominant species considered in our study, we predict that species may lose, on average, 30% of remaining unconverted and suitable habitat in California to land use alone by late century. We predict habitat losses of greater than 40% in coastal species with southern distributions, such as the coast prickly pear (*Opuntia littoralis*) and San Diego sunflower (*Bahiopsis laciniata*). We predict approximately 20% of habitat conversion for some of the more widespread species, such as California buckwheat (*Eriogonum fasciculatum*) and sticky monkeyflower (*Mimulus aurantiacus*).

A FUTURE OF CLIMATE CHANGE

By the end of the century, we predict that dominant CSS species will lose considerable habitat in Southern California due to climate change alone. If we assume that CSS species are unable to disperse and track favorable conditions outside of their current ranges, the species we studied may lose on average 30% of their remaining suitable habitat due to climate change alone, but the loss increases to 50–60% after we factor in habitat conversion under projected land use. Some species, such as mission manzanita (*Xylococcus bicolor*), may lose up to 88% of suitable habitat due to land use and climate change. These predictions are particularly troubling, given the high diversity and high number of threatened species associated with CSS in Southern California.

Along the Central California coast, however, we predict a strikingly different pattern. Here, climate change may cause the environment to become more favorable for CSS shrubs. Assuming CSS species can spread to newly suitable areas, we predict species will experience an overall net *gain* of habitat in California by an average of 15% (in a warmer, wetter future scenario) to 21% (in a warmer, drier future sce-

Under future climate scenarios, the evergreen shrub lemonade berry (*Rhus integrifolia*), is projected to gain climatically suitable habitat along California's central coast by late century (2080s), assuming species can disperse or spread into newly suitable areas. Photograph by Alan B. Harper.



Characteristic CSS species, FROM TOP TO BOTTOM: coast prickly pear (*Opuntia littoralis*); sticky monkeyflower (*Mimulus aurantiacus*); California buckwheat (*Eriogonum fasciculatum*) and golden yarrow; and the San Diego sunflower (*Bahiopsis laciniata*). Coast prickly pear and San Diego sunflower are predicted to experience large losses in habitat to human land uses by 2080. Sticky monkeyflower photograph by Michael W. Tuma. San Diego sunflower photograph by Benjamin Smith.

nario), even after accounting for future land use change. These habitat gains, much of which will occur in the Central Coast, could offset some of the habitat losses predicted in Southern California, and cause a general shift northward in CSS distribution.

We predict considerable net habitat gains in California of over 90% for three species: California bush sunflower (*Encelia californica*), lemonade berry (*Rhus integrifolia*), and coast prickly pear (*Opuntia littoralis*).

Even assuming species can move and spread under climate change, California sage scrub will likely face significant obstacles to future range expansion into areas of new habi-



tat. The considerable land development and habitat degradation that characterize coastal Southern Cali-

fornia pose formidable barriers to species movement. Competition with already established species could also prevent CSS from colonizing areas of new habitat without additional human assistance. A mosaic of chaparral, CSS, and grasslands dominate much of the central coast, with local patterns of CSS distribution governed by a number of factors in addition to climate, such as fire, topography, soil type, and species interactions.

IMPLICATIONS FOR CONSERVATION

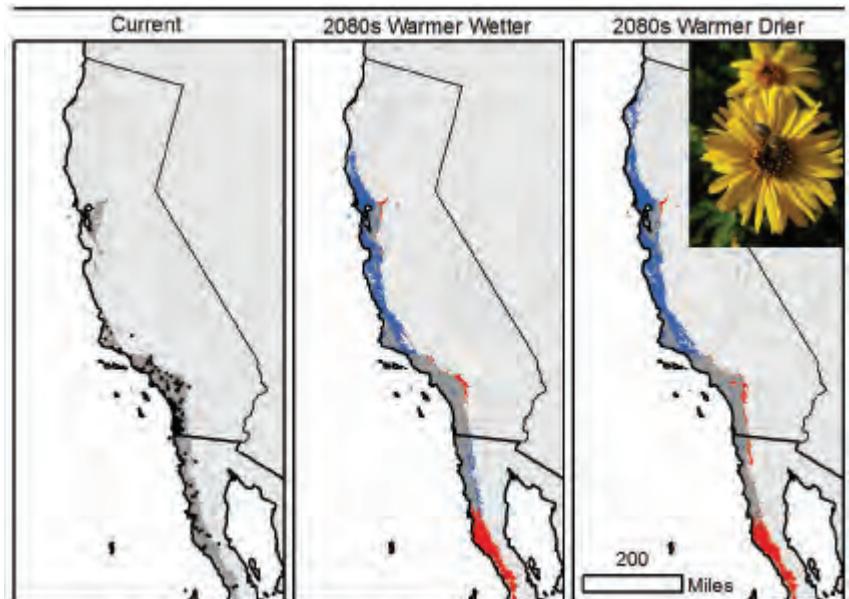
As climate conditions change, the future persistence of species may well hinge upon their ability to move to areas with favorable environmental conditions. Our models underscore the importance of dispersal in moderating CSS habitat losses. However, human activities such as habitat conversion through land use and altered disturbance regimes pose a major barrier to plants realizing their full dispersal potential. Additionally, the factors influencing a species' successful establishment are numerous and nuanced. Thus, the future dynamics of CSS expansion will likely be complex, governed by many processes that can also be influenced by human activities.

When species respond individually to climate change, we can expect patterns of diversity to change as well. We predict considerable declines in CSS shrub diversity in coastal Southern California. Vegetation composition will change, which could have implications for the large number of threatened and endangered animals that depend upon CSS for habitat. If CSS species are able to shift northward in response to climate change, we can expect changes in vegetation along the Central California coast. In Southern California, remaining high quality CSS vegetation needs to be protected from development and new approaches to resource management may be

needed to mitigate habitat loss from both future land use and climate change.

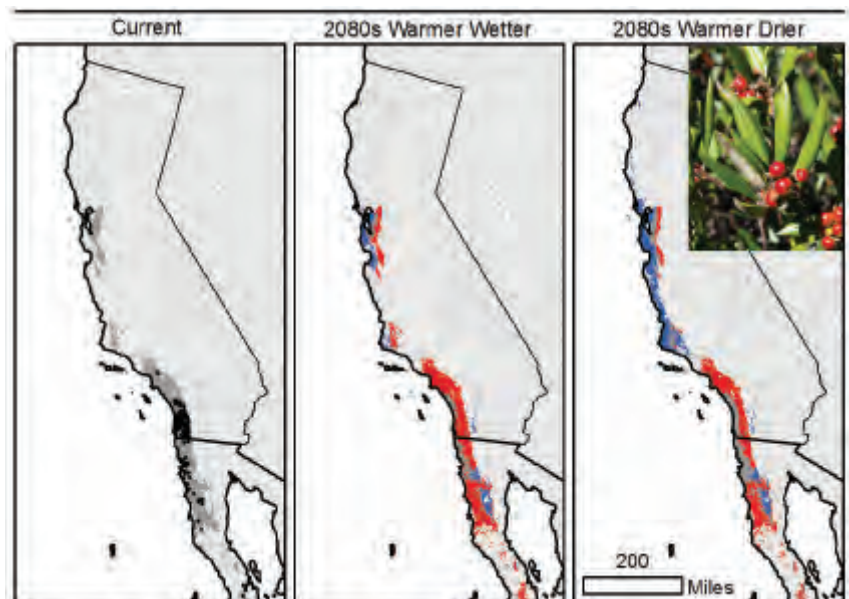
The future persistence of CSS will also hinge upon the successful establishment of species along

FIGURE 1. FUTURE HABITAT GAIN UNDER CLIMATE CHANGE BY LATE CENTURY (2080S) FOR CALIFORNIA BUSH SUNFLOWER (*ENCELIA CALIFORNICA*).



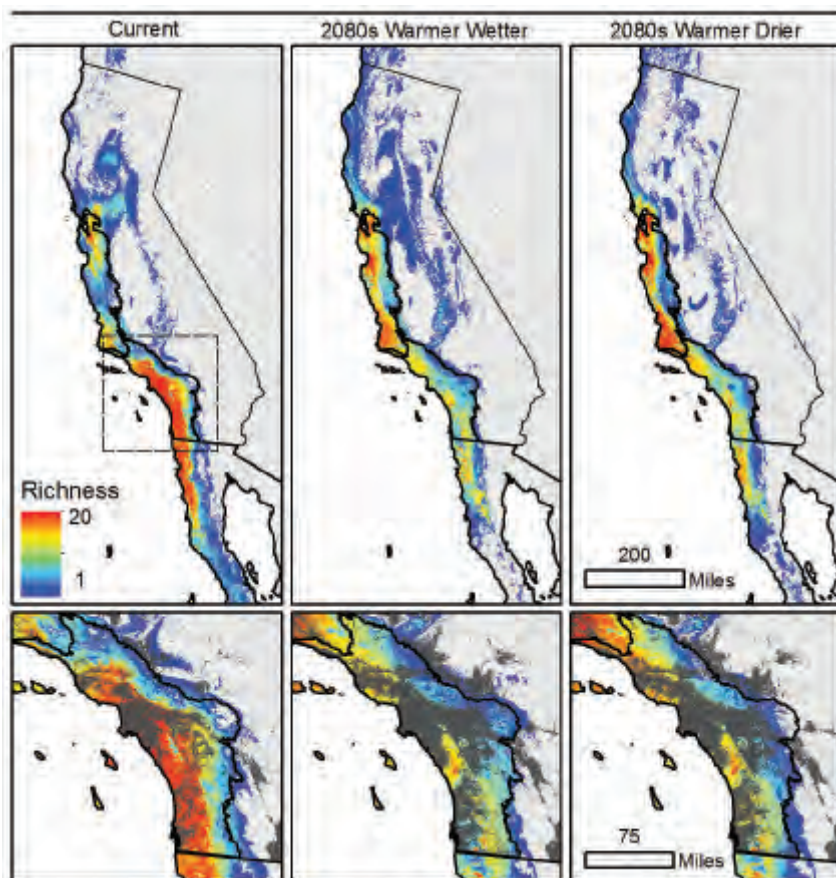
First panel shows current modeled suitable habitat (gray) and locations where the species has been recorded. In future panels, blue represents habitat gain, red habitat loss, and gray remaining climatically suitable habitat. Photograph by Erin C. Riordan.

FIGURE 2. SEVERE HABITAT LOSS UNDER CLIMATE CHANGE BY LATE CENTURY (2080S) FOR MISSION MANZANITA (*XYLOCOCCUS BICOLOR*).



First panel shows current modeled suitable habitat (gray) and locations where the species has been recorded. In future panels, blue represents habitat gain, red habitat loss, and gray remaining climatically suitable habitat. *Xylococcus bicolor* photograph by Keir Morse.

FIGURE 3. COMPOUNDING IMPACTS OF FUTURE CLIMATE CHANGE AND LAND USE ON CALIFORNIA SAGE SCRUB SHRUB DIVERSITY.



Modeled species richness ranges from 1 (blue) to 33 (red). Areas of habitat conversion to human land uses in Southern California are shown in dark gray in the bottom three panels and overlap with areas of species loss driven by climate change. The coastal central western and southwestern California ecoregions are shown in a black outline.

coastal Central California. In this case, the role for managers is more complex. How actively should managers facilitate species movements? Does the northern expansion of CSS species come at the expense of local natives or other vegetation types, such as chaparral? One approach, which is not specific to CSS and is likely to benefit a variety of species, is to promote species movements through the protection of strategic migration corridors.

Finally, we offer a word of caution in applying species distribution modeling to conservation and resource management. Our findings represent one possible future trajectory of change for CSS and should be viewed as a hypothesis of how

CSS may be impacted by future climate and land use changes. They can best be applied in combination with careful monitoring of CSS and climate change and land use impacts in an adaptive management context.

Conservationists—including CNPS members, land managers, agency personnel, and environmental advocates—need to start thinking about whether it is proper to allow and/or facilitate the expansion of species from southern climates into more northerly areas to prevent the extinction of local plant populations. Policymakers need to consider the costs of avoiding massive local die-offs and habitat conversions as part of their preparation for climate change. The costs of adapting to cli-

mate change may be more painful than the costs of curbing our carbon emissions. Hopefully grim predictions, such as those from our modeling effort, will spur action rather than grief or resignation.

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The west side of the Arica Mountains within the Palen/McCoy Wilderness with carpets of cinch weed (*Pectis papposa*).

THE ARICA MOUNTAINS: BOTANICAL EXPLORATIONS OF A PHYTOGEOGRAPHICAL BLACK HOLE

by Duncan S. Bell

Located in eastern Riverside County about 30 miles west of Vidal Junction and south of Highway 62, the Arica Mountains are what botanists refer to as a “phytogeographic black hole” because there is little to no floristic information from the area (see map, page 9). Prior to my explorations of the Arica Mountains, the only collections known from the area were a few roadside specimens from Highway 62 to the north and along the eastern side of the mountain range. What I found when I explored the area more thoroughly, however,

were many rare plant communities and several hundred different species, most of which had never before been reported.

FROM ROCK AND SAND COME LIFE

I first visited the Aricas in December 2008 and found a harsh rocky mountain range nearly devoid of life except for a few near-dormant shrubs and cacti. The area receives little annual rainfall (variable at <1-5 inches) and contains many sand

dunes. The summit elevation of the highest peaks is around 2,100 feet. Curious about this unexplored range, I returned just a few months later in March of 2009. The difference was striking. Thousands of flowering plants had sprung forth from the harsh rocky mountains that had initially looked barren.

Being new to the world of botany, the Arica Mountains became my classroom. Essential training included how to make plant collections, how to take notes on habitats and plant communities, and how to identify plants. I started my explo-

rations in the center of the range, and over the course of four years worked my way into all corners of this vast section of desert that makes up the Arica Mountains and its drainage. Presented here are just a few discoveries from this botanic education adventure.

HABITATS AND THEIR INHABITANTS

Canyons and Ridges

The center of the Arica Mountains is made up of rugged canyons and ridges holding many plants that somehow persist despite the heavy and continuous erosion of the range. Found here in abundance are ghost flower (*Mohavea confertiflora*), parachute plant (*Atrichoseris platyphylla*), and notched-leaved phacelia (*Phacelia crenulata*) which during good years can number in the thousands.

Hiding on limestone cliff faces in the center of the Arica Mountains is the yellow liguled Godding's aster (*Xanthisma spinulosum* var. *gooddingii*). It is not currently on the CNPS inventory but potentially could be since it is only known to occur in a few California mountain ranges in the upper northeast section of our Colorado Desert. Closer inspection of these cliffs and break-neck slopes reveals many hidden wonders neatly tucked away and nearly unreachable by any botanist without climbing gear.

Washes/Microphyll Woodland

The Arica Mountains are populated with great stands of microphyll woodland, a plant community comprised of small-leaved, subtropical leguminous trees that are fairly tall in height and grow along desert washes. The representative species found here include paloverde (*Parkinsonia florida*), smokebush (*Psoralea argemone*), and ironwood (*Olneya tesota*). Ironwood is one of the densest and heaviest woods

LOCATION MAP OF THE ARICA MOUNTAINS.



growing on our planet, and with its dramatic white bark and intensely purple flowers is one of the most beautiful trees of our California deserts. Many of the paloverdes here grow over 30 feet tall and often have large quantities of fallen branches at their bases, which provide home and shelter to many desert mammals, reptiles, and invertebrates. Ocotillo (*Fouquieria splendens*) can be found occasionally on benches above these washes. All of these plants represent one of the northernmost sections of Colorado Desert in California.

One of the more unique inhabitants of these desert washes is the desert Christmas tree (*Pholisma arenarium*), also referred to as sand food, because the Native Americans would roast and eat this plant (Moerman, 1998). It is often found parasitizing the roots of burrobrush (*Ambrosia dumosa*). Of similar uniqueness and oddity is Cooper's broomrape (*Orobanche cooperi*), also a parasitic plant and also found in washes punching skyward through hard compacted soils with great force.

Desert Pavement

On the large alluvial fans along the east side of the Arica Mountains is an extensive "desert pavement"—an unusual geological formation that looks something like a massive jigsaw puzzle put together over thousands of years. This habitat is so rocky and rugged that at first it may appear devoid of life, but on closer inspection one can find tough desert annuals such as the elegant lilac sunbonnet (*Langloisia setosissima*) or the devil's spineflower (*Chorizanthe rigida*), along with showy perennials like white ratany (*Krameria grayi*) and the colorful harshly

Solar projects threaten populations of crucifixion thorn (*Castela emoryi*) and other rare species in Rice Valley.





Continuous erosion requires plants to be tough to survive. Two such rugged species include desert Christmas tree (*Pholisma arenarium*) (left) pushing up through compacted soils in one of the many washes of the Arica Mountains, and notch-leaved phacelia (*Phacelia crenulata*) (right) growing out of a limestone cliff face near the summit.

spined cottontops (*Echinocactus polycephalus*). All these plants are so painful to the touch that most of the fauna in the area seem to ignore them completely.

Valley Floor

Over 70% of the Arica Mountains drainage runs out into Rice Valley on the east side of the range and is an area of great biodiversity. Here is a desiccated valley floor that is being overtaken by sand dunes and some patches of microphyll woodland. This mixing of sand and rockier soils is a preferred habitat for the rare pink funnel lily (*Androsteph-*

TABLE 1. SOME RARE PLANTS OF THE ARICA MOUNTAINS.

Species	Common Name	California Rare Plant Rank (CRPR)	Habitat and Distribution
<i>Androstephium breviflorum</i>	Pink funnel lily	CRPR 2.2	Sandy/rocky places on ridgeline of range and scattered widely in Rice Valley.
<i>Astragalus insularis</i> var. <i>harwoodii</i>	Harwood's milkvetch	CRPR 2.2	On sand ramp on west side of range and scattered uncommonly in sandy places of Rice Valley.
<i>Astragalus lentiginosus</i> var. <i>borreganus</i>	Borrego milkvetch	CRPR 4.3	Loose sand and compacted sandy places in the northern section of the Arica Mountains.
<i>Castela emoryi</i>	Crucifixion thorn	CRPR 2.3	Large scattered population of over 2,500 individuals in Rice Valley.
<i>Chamaesyce abramsiana</i>	Abrams' spurge	CRPR 2.2	Summer annual. Found only in a few localized populations in Rice Valley.
<i>Cryptantha costata</i>	Ashen forget-me-not	CRPR 4.3	Sandy places from north section of the Aricas out into Rice Valley.
<i>Funastrum utahense</i>	Utah swallow wort	CRPR 4.2	A few large populations found in washes and canyons on west side of Aricas.
<i>Ditaxis claryana</i>	Glandular ditaxis	CRPR 2.2	A single population found on rocky outcropping being taken over by sand dunes on west side of Aricas.
<i>Ditaxis serrata</i> var. <i>californica</i>	California ditaxis	CRPR 3.2	A localized population found in rugged rocky canyon in center of the Arica Mountains.
<i>Eriastrum harwoodii</i>	Harwood's eriastrum	CRPR 1B.2	Sandy places on west side of Aricas and in extended dunes from north of range out into Rice Valley.
<i>Nemacaulis denudata</i> var. <i>gracilis</i>	woolyheads	CRPR 2.2	A few localized populations on sand ramp on west side of Aricas, and a single population in Rice Valley.
<i>Proboscidea althaeifolia</i>	Devils claw	CRPR 4.3	A few localized populations in small drainages in Rice Valley.
Source: Duncan Bell, 2013.			



LEFT: Ghost flower (*Mohavea confertiflora*) growing out of rocky scree on an open ridgeline in the Arica Mountains. RIGHT: Harwoods eriastrum (*Eriastrum harwoodii*), one of the rare plants growing in the sand dunes of the Arica Mountains.



ium breviflorum) and, after the summer monsoonal storms, devils claw or unicorn plant (*Proboscidea althaeifolia*).

Of great interest and importance is the large and widely scattered population of crucifixion thorn (*Castela emoryi*). With approximately 2,500 plants, this is currently the largest population in California and the world. This large robust shrub has very long, spiny branches that are often tipped with robust seed clusters. If you want to see this plant in flower you will have to brave temperatures of 110° F or more, since it only flowers in the middle of summer. Because it is one of the only plants on the valley floor to flower regularly during the summer, it can often be found with a cacophony of insect life from native wasps to intrepid climbing ants.

Sand Dunes and Sand Ramps

A great many of the rare plant species of the Arica Mountains can be found in its sandy habitats. The sand dunes that blow in from the north into Rice Valley on the east are a continuation of those blowing in from Cadiz Valley to the northwest, and together this dune system

is one of the largest in the California deserts. The amount of life in these dunes is staggering. On a wet year the area is blanketed with millions of flowering annuals that are covered by hundreds of different invertebrate species. Hastening to take advantage of this seasonal, lush green desert bounty, many fly frantically from plant to plant collecting as much nectar and pollen as possible, while others crawl in zigzags or circles to gather their food.

These dunes are home to many populations of rare desert plants such as Harwood's milkvetch (*Asragalus insularis* var. *harwoodii*), growing at its most northwestern limit here; the bristly ashen forget-me-not (*Cryptantha costata*), which prefers deep shifting sands; the gentle woollyhead (*Nemacaulis denudata* var. *gracilis*), which is becoming increasingly rarer in California due to development that has destroyed most of its historic populations; and Harwood's eriastrum (*Eriastrum harwoodii*), a curious little plant that often seems to grow leaning to the east.

Sand ramps, which are inclined or vertical sand dunes that have formed by wind blowing sand up

onto rocky slopes and mountain sides, can be found on the west side of the mountain range. These are similar to the other sand dunes of the range except that everything is distributed much more vertically. In the center of the Arica Mountains a sand ramp blows ever so slightly over the ridgeline onto its eastern side, which is so steep that the sandy sections often collapse upon themselves. Many of the plants that grow here have roots three to ten times the length of their terrestrial bodies that help to anchor the ever shifting and unsteady slopes they call home.

SEASONS

The Arica Mountains have two distinct flowering seasons: the spring season that follows the winter rains, and the summer season that follows the monsoonal storms. The spring season is more consistent, and the abundance of flowering plants varies from year to year depending on the amount of rainfall.

My first spring season in the Aricas was blessed with a profusion of wildflowers. Thousands of strongly scented notch-leaved phacelias covered the rugged slopes of



The main western drainage of the Arica Mountains with its many peaks and ridgelines in the background.

the mountain range. In between the phacelias, many other showy annuals were to be found such as the delicate desert star (*Monoptilon bellioides*), purple mat (*Nama demissum*), Parry's dalea (*Marina parryi*), a dozen different species of popcorn flower (*Cryptantha*), desert dandelion (*Malacothrix glabrata*), and everywhere desert fivespot (*Eremalche rotundifolia*). That so many delicate desert annuals can spring up from the rocky rubble of such a rugged mountain range is a wonder indeed.

In marked contrast, the summer flowering season happens very irregularly, and decades can go by

without a sign of summer annuals. After exploring this range for two years, I was under the impression that no summer annuals grew there, as I had not seen a single one. However, in the summer of 2011 during my third year of exploration, I went out after a storm blew over from Arizona, and to my amazement found what seemed like a billion annuals in bloom. There were literally thousands of spiderlings (*Boerhavia*) of three different species, brightly colored fringed amaranth (*Amaranthus fimbriatus*), and the viney prostrate caltrop (*Kallstroemia californica*). The prostrate windmills

(*Allionia incarnata*), at times growing six feet long, were so abundant that one's feet and legs would regularly get entangled in them. There was also the strong scented cinch weed (*Pectis papposa*) numbering in the millions, and so abundant that after several days of exploration my boots and lower pant legs were bright yellow with its pollen.

Summer annuals require the ground to be a certain temperature and they require monsoonal rains. That these seed banks can lie in wait for so many years is amazing. And when the event happens, it all happens so fast. The temperature at the

LEFT TO RIGHT: The parasitic desert broomrape (*Orobanche cooperi*) growing among shrubs in Rice Valley. • Devils claw (*Proboscidea althaeifolia*) in flower in Rice Valley following some heavy monsoonal storms. • The pendulous seed pods of Harwood's milkvetch (*Astragalus insularis* var. *harwoodii*) growing in sand dunes of the Arica Mountains. • Borrego milkvetch (*Astragalus lentiginosus* var. *borreganus*) growing in compacted sandy soils in the northern part of the range. • Delicate desert fivespot (*Eremalche rotundifolia*) growing out of the harsh rocky slopes of the Arica Mountains. • Woolly heads (*Nemacaulis denudata* var. *gracilis*) at sunrise growing in the sand dunes of Rice Valley.





Cottontop cactus (*Echinocactus polycephalus*) growing on a rocky alluvial fan on the east side of the Arica Mountains.

time of flowering is still around 100° or warmer so that some of these annuals can germinate, grow, flower, and go to fruit in just a few weeks, and sometimes faster.

THREATS AND CONSERVATION NEEDS

Unfortunately the Arica Mountains and Rice Valley face many threats of varying degrees, from invasive non-native species to development pressures. Sahara mustard (*Brassica tournefortii*) is very problematic and is most prolific in the sandy habitats, where it is crowding out our native annuals. Off highway vehicles (OHV) continue to destroy and degrade habitat. While Rice Valley was an open OHV area over a decade ago, it is now closed to vehicles, but people are still showing up to drive on the dunes. Rice Valley is also open to livestock grazing, which creates a lot of destruction in

the form of trampling and herbivory to the native vegetation.

The most recent threat to the area is the renewable energy projects that target open flat areas of the desert where large solar fields are being installed. One such project that has already been approved will be installed at the northern section of Rice Valley. The plan includes digging wells in Rice Valley and pumping water from the ground. This could be detrimental to the large population of crucifixion thorn and many other plants that grow here.

The sand dunes of Rice Valley and to the north of the Arica Mountains are home to many rare plant communities that need greater protection. While the western section of the Arica Mountains and the southernmost section of Rice Valley lie within the Palen-McCoy Wilderness under the jurisdiction of the Bureau of Land Management (BLM), the large expansive sections in-between are open areas susceptible to destruction and development. Expanding the wilderness boundaries north of the Arica Mountains to include all sandy areas between the mountain range and the California aque-

duct, and south of Highway 62 to the current Rice Valley Wilderness boundary area to include all sandy sections, would greatly assist in the conservation of these rare plant communities, including a large stand of approximately 2,500 crucifixion thorn individuals.

The Arica Mountains also have a very diverse fauna and include other sensitive species such as desert tortoise, fringed toed lizard, kit fox, badger, burrowing owl, prairie falcon, and the cheeseweed owlfly (CNDDDB and personal observation). With all other common and rare species included, the Arica Mountains and Rice Valley comprise a very unique, special, and fragile ecosystem that deserves greater attention.

It was actually while camping in the Arica Mountains that my wife found out she was pregnant for the first time. I hope that 50 years from now I'll be able to take my grandchildren out to this amazing mountain range and show them the same things I found when I was their age. And hopefully they will be able to do the same with their grandchildren, so that many generations going forward can also enjoy the beauty and diversity of this special place in our California deserts. This will only be possible if we formulate and put into action an effective conservation plan to address threats to this wild area.

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INDUCERS, PARASITOIDS, AND INQUILINES: LIFE INSIDE THE PLANT GALL

by Peter Bryant

Most people are familiar with the round growths on oak trees that we call oak apples. However, oak apples are just one example of a diverse set of related structures called galls that are induced on various plants by mites, fungi, bacteria, and small insects including wasps, sawflies, midges, and aphids. Ron Russo (2007) has produced a wonderfully comprehensive field guide to the galls of California and other western states, and in *Fremontia* (38:4/39:1, Oct. 2010/Nov. 2011) he has described his discovery of even more plant galls.

Gall formation is often thought to reflect a defense mechanism on the part of the plant, but this interpretation does not fit the facts very well, since in the process of “defending itself” the plant provides a protected, nutritious chamber that allows the growth and development of a new generation of gall inducers. Since the plant usually appears to suffer no harm, the insect/plant relationship here fits the definition of commensalism (one partner benefits, the other is not harmed or benefited) rather than parasitism or mutualism. But what attracts biologists to galls is that they support a fascinating micro-ecosystem that is easily accessible for study. Here we

are concerned mainly with galls induced by insects.

INHABITANTS OF THE GALL

Galls are convenient to study since they can easily be collected and kept in containers until something emerges. But in doing this I soon found that what emerges is only sometimes the expected progeny of the insect that induced the gall; in fact there are three quite different types of gall inhabitants.

Inducers: Galls form when the female insect (of the inducer species) lays her eggs in or on the plant, and the plant responds by encapsulating the developing larva or larvae in a growing chamber called the gall. In some cases the gall contains only one individual of the inducing species (it is monothalamous), whereas in other cases it contains many larvae of the inducing species (it is polythalamous).

Insect galls can form at various sites on the plant: leaf, stem, bud, root, catkin, or acorn. Some types stay attached, whereas others fall off. Those on leaves and stems are the most conspicuous.

Parasitoids: Galls provide a home for the inducing species, but most of them are also invaded by a wide variety of other insects. After a gall starts to form, very often another type of wasp, a parasitoid (differing from a parasite in that it kills its host, whereas a parasite does not) lays one or more eggs inside the growing gall. The resulting larva kills and consumes the original inhabitant of the gall, then goes through metamorphosis and emerges from the gall to propagate the parasitoid species. In some cases the parasitoids have evolved extraordinarily long ovipositors (egg-laying appendages) that allow them to deposit eggs far inside the gall and close to the target which is the inducer larva. This is especially important in large galls such as oak apples, which can, in fact, be as big as apples. David Attenborough calls these parasitoids “burglars” and in his BBC documentary, “Life in the Undergrowth,” he shows amazing video of a long ovipositor finding its way through the gall tissue to the target insect.

Inquilines: Several types of wasp, beetle, and moth larvae, called inquilines, live inside galls induced by other insects and feed mainly on

LEFT TO RIGHT: Red, bean-like “apple galls” on the leaf of arroyo willow (*Salix lasiolepis*) induced by the willow leaf gall sawfly *Pontania pacifica*. • The sawfly is named after the saw-like ovipositor that the female uses to deposit eggs. • Larva revealed in a bisected apple gall.



the nutritive tissues. Although the inducer larva is not the main target, it sometimes also gets killed by the inquiline as it feeds on the gall tissue.

The situation can get much more complicated with the arrival of additional parasitoids, leading to the idea of a community of insects associated with the gall. Some are hyperparasitoids, meaning that they are parasitoids on parasitoids, and there can be parasitoids on the inquilines. It is commonplace for a gall type to support parasitoids from five or six families, but there are reports of much more complicated communities, including in one case a report of an oak gall with over 75 associated species (Wiebes-Rijks and Shorthouse 1992)! In well studied cases it has been shown that distinct generations (often sexually and asexually reproducing generations) of the inducing species, parasitoids of different types (some attacking each other), and inquilines all arrive at specific different times during the life of the gall (Wiebes-Rijks and Shorthouse 1992).

GALLS ON ARROYO WILLOW

One plant that is well known for its galls is the arroyo willow (*Salix lasiolepis*). The red beans that develop in the leaves of this plant are

among the most conspicuous of galls, and they harbor a microecosystem as fascinating as it is complicated. The inducer is the willow leaf gall sawfly (*Pontania pacifica*), named after its saw-like ovipositor that it uses to penetrate the leaf for deposition of the egg. But the resulting galls can be occupied by parasitoids from several different families of wasps, and they are also invaded by inquilines including larvae of a moth and a weevil.

Another common willow gall, the willow rosette gall, looks like a cabbage and is induced by a peculiar mechanism quite unlike the growth stimulation that appears to be involved in the formation of most other galls. Instead, the larva of the inducing species takes up residence in the shoot tip and lives in the exact position normally occupied by the dividing cells necessary for shoot elongation. This ap-

pears to prevent the shoot from growing any more in length, while it continues to produce shortened but swollen leaves that pile up on one another to produce the cabbage-like gall. The inducer can be attacked by parasitoid wasps from at least four families, and the gall can be invaded by at least two kinds of inquiline beetles and an inquiline moth. These galls stay on the tree and can often be seen as blackened remnants the following season.



Parasitoid wasps that emerged from willow apple galls. TOP TO BOTTOM: Wasps from the families: Pteromalidae (*Pteromalus* sp.), Eurytomidae, Ichneumonidae (*Lathrostizus* sp.), and Eulophidae (*Pnigalio* sp.).

GALLS ON WILD ROSE

California wild rose (*Rosa californica*) develops at least three kinds of galls, all induced by wasps in the family Cynipidae. The most spectacular are the spiny leaf galls that are induced by the wasp *Diplolepis polita*. These are monothalamous, as can be seen in the photo on page 16



TOP TO BOTTOM: The willow rosette gall. • Bisected to show the inducer, the larva of the willow rosette gall midge (*Rabdophaga salicisbrassicoides*). • The adult midge.

where one very small larva has induced a gall that is huge compared with the inducer. The single larva induces a gall containing enough nutrients to allow it to grow to full size, after which it will go through meta-

morphosis in the pupal stage and emerge as an adult (unless it has been attacked by parasitoids!).

Wild rose produces at least two other galls, both polythalamous, in addition to the spiny leaf one. These

are a swollen stem gall induced by *Diplolepis nodulosa*, and a large, terminal, round leafy gall induced by *Diplolepis californica*. My DNA barcoding studies show that the three wasps responsible for inducing these



TOP LEFT: Intact spiny leaf gall induced by the wasp *Diplolepis polita* on California wild rose (*Rosa californica*). TOP RIGHT: Bisected spiny leaf gall with a single larva inhabiting the gall. MIDDLE LEFT: Intact swollen-stem gall, probably induced by the wasp *Diplolepis nodulosa* on California wild rose. MIDDLE RIGHT: Bisected swollen-stem gall with multiple inducer larvae. BOTTOM LEFT: Intact terminal leafy gall induced by the wasp *Diplolepis californica* on California wild rose. BOTTOM RIGHT: Bisected terminal leafy gall showing multiple inducer larvae.

three distinct gall types are close relatives of each other, much more closely related than they are to other cynipid wasps. This suggests that these three species are descended from a common ancestor that was already a gall inducer associated with wild rose.

OAK GALLS

For some reason our local scrub oak (*Quercus berberidifolia*) develops an impressive variety of galls, each one induced by a different species of wasp in the family Cynipidae. Some of the galls boggle the mind, with form and color that seem totally foreign to the host plant. How can one small larva completely reprogram the plant tissues?



GALLS ON OTHER OAK SPECIES

Just as scrub oak produces a spectacular variety of galls, other species of oak produce their own collection of gall types. For example, California live oak (*Quercus agrifolia*) produces a pumpkin gall and a two-horned gall, and canyon live oak (*Quercus chrysolepsis*) produces a two-story gall. Both species also produce oak apples and other more common galls, all induced by specific cynipid wasps. Joyce Gross has compiled photographs of a huge collection of oak galls at http://joycegross.com/galls_ca_oak.php.

Two of the many gall types on California scrub oak (*Quercus berberidifolia*). LEFT: Multiple spined turban galls on a single leaf. RIGHT TOP: The inducer of spined turban galls, *Andricus douglasii*. • RIGHT MIDDLE: Disc gall on a leaf. RIGHT BOTTOM: The inducer of disc galls, *Andricus parmula*.

ing gall, which forms on the leaves of valley oak (*Quercus lobata*) and other oaks in Central California. They are among the smallest galls to be found, measuring only about 1mm across, and they are unusual in that they are formed in huge numbers and are dehiscent (they fall to the ground rather than remaining attached). But what makes them the

most amazing of all galls is that, for some unknown reason, they jump! As with Mexican jumping beans, the larva inside the gall is able to make the shell click with enough energy that the whole structure leaves the ground. The jumping gall soars many times its own height before coming in to land again. When the larva is removed from the gall it does continue to make some jerky movements, and these must be responsible for causing a rapid click movement in the shell.

Another mystery is why these galls jump. When they fall onto pavement, they seem to be responding to the heat of the surface where they have fallen, but when they fall into a more normal



THE NOTORIOUS JUMPING GALL

One of the most interesting galls is the jump-

LEFT: A beaked twig gall on California scrub oak. The internal structure of galls can be surprisingly well organized. In this gall, the inducing larva resides in a chamber which is connected to the shell of the gall by numerous thin fibers. RIGHT: Two larvae inside this gall were identified by DNA barcoding. The larger larva is the inducing cynipid, and the smaller one is a parasitoid from the Eupelmidae family.



COTTONWOOD PETIOLE GALLS

One more example of a gall must be mentioned because its inducer is so different from all the rest. The gall forms at a very specific location—the petiole at the base of the leaf on Fremont cottonwood (*Populus fremontii*) trees—and the inducer is an aphid called *Pemphigus populi-transversus*. An egg produced by sexual reproduction in the spring initiates the gall, and inside the gall the fat, wingless “stem mother” (the fundatrix) grows and gives birth to a family of fatherless juveniles. These feed on the growing tissues of the gall, eventually develop wings, and fly off to colonize the roots of secondary plant hosts in the mustard family including turnip and cabbage. They reproduce asexually on the secondary hosts, where they can cause economic losses and are known as cabbage root aphids.



Galls on canyon live oak (*Quercus chrysolepis*). TOP AND MIDDLE LEFT: Steeple gall, intact and bisected to show the single inducer larva. BOTTOM LEFT: The inducer, *Heteroecus sanctaeclarae*. BELOW: A parasitoid eupelmid wasp (*Reikosiella* sp.).



SAGE AND COYOTE BUSH GALLS

Galls developing on other plants are induced by midges in the family Cecidomyiidae. One can be found on white sage (*Salvia apiana*) where the galls are tubular in shape and protrude from both upper and lower leaf surfaces, and another on coyote bush (*Baccharis pilularis*) where the gall forms a rounded swelling at the tip of a branch. Yet another is found on honeysuckle (*Lonicera subspicata*), where it resembles a small bud.



environment, their jumping movements might help them to retreat into the shelter of leaf litter rather than staying exposed at the surface.

SEX LIFE OF GALL INSECTS

A common strategy among the cynipids is an alternation between asexual and bisexual (sexually reproducing) generations, each generation often being associated with a different type of gall or host plant. In most cases the galls of the asexual generation appear during late summer and fall, while galls of the sexual generation can be found in spring and/or early summer (Pujade-Villar et al. 2001). Two of our local species (*Andricus quercuscalifornicus* and *Disholcaspis plumbella*) appear to have given up on sexual reproduction altogether, since only females and no males have been found.

QUESTIONS FOR FUTURE RESEARCH

Galls may not be very significant in the grand scheme of nature, but they do raise some fascinating questions. The most intriguing is the na-



Jumping galls, induced on valley oak(*Quercus lobata*) by the wasp *Neuroterus saltatorius*. The galls are aligned with a 1 mm scale.

ture of the signal that induces gall formation and maintains its growth. Much is known about the hormones, including auxins, cytokinins, and gibberellins, that control growth in plants. But whether the gall inducers are using these growth-control pathways or others has been a mystery until recent ground-breaking work by Yoshihito Suzuki and colleagues in Tokyo.

Their work indicates that, for willow leaf galls induced by sawflies, the inducing signal is, indeed, a cytokinin precursor produced by the sawfly and injected into the plant at the time of egg laying. Furthermore, they showed that subsequent growth of the gall is maintained by the production of an auxin by the larva. They also showed that in the growing gall tissue there was increased activity of genes that are known to be regulated by auxin and cytokinin. So in a remarkable evolutionary process, the gall inducer has found a way to hijack the plant's normal growth regulatory mechanisms.

More intriguing still is the question of what controls the amazing

morphology and color of many plant galls. Often it appears that the insect has completely reprogrammed the plant tissue to make structures—including discs, stars, hairy balls, spotted balls, and some in bright colors—that are quite specific for the inducing species but are completely novel for the plant. I have often heard the comment that this must mean that the gall inducer works by introducing new DNA into the plant cells. If so, this would be an almost unprecedented horizontal transfer of genetic information from one species to another.

Horizontal gene transfer is almost, but not totally unprecedented, since the crown gall bacterium (*Agrobacterium tumefaciens*) is known to transfer a small piece of DNA (a plasmid) into the plant cell where it integrates into the chromosomal DNA. The introduced DNA contains genes for the production of auxin and cytokinins, and these hormones cause the affected cells to grow rapidly and produce a gall on the root crown (Costacurta and Vanderleyden, 1995). The crown gall bacterium affects plants in the rose

family and it represents an economically serious plant disease. Whether other gall inducers also work by “genetically engineering” their hosts is perhaps the most important question in gall biology, and new techniques in molecular biology should make it possible to answer this question in the near future.

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LEFT: The petiole gall induced by the aphid *Pemphigus populitransversus* on Fremont cottonwood (*Populus fremontii*). RIGHT: The easily recognizable fundatrix and her progeny inside the gall.

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THE NEED FOR SITE-SPECIFIC MAINTENANCE MANUALS FOR PUBLIC AND PRIVATE NATIVE PLANT LANDSCAPES

by Ellen Mackey and Nancy L.C. Steele

Most of us who are gardeners have probably faced this predicament at one time or another. We were at a plant sale or nursery and couldn't resist buying some of the beautiful plants we saw that were not on our list. But now we're stumped. How big will they get? Where should I plant them and how do I care for them?

Now imagine that you work for a public agency or community group and have been handed a newly installed landscape to maintain. It happens to be a drought tolerant native plant garden, and maybe you have little experience caring for this type of landscape. How do you keep things growing and looking good?

Several years ago Ellen Mackey, together with Bart O'Brien and Betsey Landis, coauthored the book, *Care & Maintenance of Southern California Native Plant Gardens* (hereafter referred to as the *Care & Maintenance Manual*) (O'Brien, Landis, Mackey 2006). It is designed to assist homeowners and beginning maintenance staff with caring for native plant landscapes, and addresses these very issues. The *Care & Maintenance Manual*, however, is encyclopedic, and requires a certain level of expertise. We realized that many workers involved in the day-to-day maintenance of landscapes did not have the time to read the book, even though it was printed in both English and Spanish, and often lacked the background required to make good use of it.

So following several impromptu discussions with landscaping workers at different parks in 2007 and 2008, and thinking about some landscapes under development, we decided to use the *Care & Maintenance Manual* to develop customized manuals and checklists for new native landscapes. Our thinking was that workers would be much more likely to use checklists tailored to the needs of the landscapes where they were working, than to refer to generalized information from a book.

BACKGROUND

The Council for Watershed Health, which promotes sustainable water management in the Greater Los Angeles area, has been involved in writing or editing a number of landscaping support documents over the past ten years, including the *Los Angeles River Master Plan Landscaping Guidelines and Plant Palettes* (LADPW 2004). Unique to the Guidelines is the requirement that an ecologist work with the landscape professional to choose and place the appropriate *locally* native plants selected from an extensive list. (The document can be accessed at: <http://dpw.lacounty.gov/wmd/Watershed/>. Then click on Major Watersheds/Los Angeles River/Master Plan/Landscaping Guidelines.)

Beginning in 2006, the Council for Watershed Health offered sustainable landscape seminars to train landscape professionals working on public landscapes. Through these seminars we gathered feedback on what information and approaches were working and what was not.

In addition, the Council was required to develop manuals and con-



Looking south across Old Marengo Park in Altadena, California: the first spring, showing rock signage, poppies, native shrubs, and trees. All photographs by Nancy Steele unless otherwise noted.



A dry well inlet in Old Marengo Park was discovered after a pile of mulch that had been covering it was removed. The underground dry well detains and infiltrates stormwater that flows across the site. Photograph by Ellen Mackey.

duct trainings for the Elmer Avenue Neighborhood Retrofit, a project that uses bioswales and an infiltration gallery under a street to collect stormwater on-site. We were concerned about how to apply the information in the *Care & Maintenance Manual* to a residential setting. Serendipitously, we had the opportunity to test out our ideas on another native landscape, a new pocket park developed with funding from Metropolitan Water District of Southern California.

What follows is a chapter-by-chapter description of key information that should be included in a site-specific maintenance manual so that others can develop their own. Links to custom manuals we have created appear in the sidebars accompanying this article. We used the *Care & Maintenance Manual* as the primary source of information, but also referred to *California Native Plants for the Garden* (Bornstein, Fross, and O'Brien 2005) and to numerous websites, including Tree-of-Life, Theodore Payne Foundation, Las Pilitas, and CNPS.

1: Introduction. We think it is helpful to memorialize and include a history of the project, along with design approach, project elements, and

goals. You should provide details on the partners, design concept, and eventual maintenance responsibilities. Additional information, such as grant contracts and press releases, could be included in appendices.

2: Soils, Planting, Fertilization, and Mulch. Document how you tested the project site soil, how to plant and stake trees, when and how much to fertilize, and how to apply mulch. You might want to include photo documentation of the plant installation to track the changing landscape as plants grow, die, and are replaced. The soils report should be included either here or in the appendices.

3: Watering, Irrigation, Stormwater. Other than the planting plan, no documents seem to disappear more quickly than the stormwater and irrigation plans. We recommend that you include both 11" x 17" construction documents as part of the manual.

4: Plant Maintenance. You will want

to include the original plant list as well as the 11" x 17" planting plan, followed by species-by-species information on the sun exposure, soil, pruning, pests, etc. To aid landscape personnel in identifying species, we include a picture of each plant in a garden landscape (as opposed to a wild situation) and a close-up of the flower. We've heard too many horror stories of maintenance crews removing the wrong plant—killing the natives and leaving more familiar weeds in place.

5: Weed Management. We conduct a survey in late winter for weeds within the project area, and include in the maintenance manual additional weeds that have been found in the area and might show up later in the project site. This additional information helps maintenance crews separate the weeds from the expensive native plants. We primarily use *Weeds of California and Other Western States, Vol. 1 & 2* (DiTomaso and Healy 2007) for descriptions and



Closeup of native wildflowers in bloom at Old Marengo Park. Pictured are California poppies (*Eschscholzia californica*), Eaton's penstemon (*Penstemon eatonii*), tidy tips (*Layia platyglossa*), and elegant clarkia (*Clarkia unguiculata*).

Maintenance Checklist Schedule

pg. Task	January	February	March	April	May	June
3 Soil testing						
4 Fertilization	no	never	not	no	never	not
5 Mulch replacement		check/add				check/add
6 Irrigation equipment - check	weekly	weekly	weekly	weekly	weekly	weekly
8 Soil moisture monitoring	as	needed	as	needed	as	needed
7 Backflow preventer certification	X					
9 Stormdrain inlets - keep clear of gravel/mulch	as	needed	as	needed	as	needed
16 Tree maintenance	check guy wires	check guy wires	check guy wires	check guy wires	check guy wires	check guy wires
18 <i>Cercis occidentalis</i> (western redbud)		prune if needed	prune if needed			
19 <i>Platanus racemosa</i> (western sycamore)	prune if needed	prune if needed				
20 <i>Quercus agrifolia</i> (coast live oak)						
21 <i>Quercus engelmannii</i> (Engelmann oak)						
22 Shrubs and perennials						
23 <i>Ceanothus</i> 'Dark Star' (Dark Star ceanothus)		prune/pinch back	prune/pinch back			
23 <i>Eriogonum grande</i> var. <i>rubescens</i> (red buckwheat)						dead head
24 <i>Lessingia</i> 'Silver Carpet' (Silver Carpet California aster)						
24 <i>Mimulus aurantiacus</i> (red monkeyflower)		pinch lightly		pinch lightly	prune flwr stems	
25 <i>Muhlenbergia capillaris</i> (pink hairgrass)					prune if needed	
25 <i>Penstemon eatonii</i> (Eaton's penstemon)						
26 <i>Penstemon spectabilis</i> (showy penstemon)						
26 <i>Ribes aureum</i> (golden currant)				prune		
27 <i>Salvia</i> 'Bee's Bliss' (Bee's Bliss creeping sage)						
27 <i>Salvia clevelandii</i> (Cleveland sage)	prune					
28 <i>Salvia mellifera</i> 'Terra Seca' (Terra Seca black sage)	prune					
29 <i>Salvia spathacea</i> (hummingbird sage)			dead head ?	dead head ?	dead head ?	dead head ?
30 <i>Trichostema lanatum</i> (woolly blue curls)	dead head ?	dead head ?	dead head ?	dead head ?	dead head ?	dead head ?
30 <i>Zauschneria californica</i> (California fuchsia)	prune	prune			remove seedlings	
31 Annuals (all)						
31 <i>Eschscholzia californica</i> (California poppy)						pull by hand?
31 <i>Nemophila menziesii</i> (baby blue eyes)						pull by hand?
3 Replace dead or dying plants	plant					
35 Weed management						
36 hand pulling	weekly	weekly	weekly	weekly	weekly	weekly
42 oil sprays	as	needed	as	needed	as	needed
43 Pest management						
43 Vertebrates (rodents, etc.)	weekly	weekly	weekly	weekly	weekly	weekly
43 Invertebrates (ants, slugs)	weekly	weekly	weekly	weekly	weekly	weekly
44 Hardscape management	as	needed	as	needed	as	needed
45 Graffiti	weekly	weekly	weekly	weekly	weekly	weekly
46 Litter management	weekly	weekly	weekly	weekly	weekly	weekly
46 Greenwaste management	as	needed	as	needed	as	needed

July 2010 by Ellen Mackey

? - optional

recommended management techniques. Be sure to obtain permission to reproduce photos in your manual from the UC Regents. This chapter should also include the weed control methods you want to be used.

6: Pest Management. This chapter addresses possible animal pests that

could harm native plants. Describe invertebrate and vertebrate pests and control methods, but also define and describe beneficial animals, such as lizards and insects (e.g., ladybug larvae, praying mantis, and common black ground beetle).

7: Hardscape, Site Amenities, and

Graffiti. All these elements require maintenance as well since, for example, rocks in a seating wall can become loose, or a water fountain can break. For graffiti removal you will want to specify acceptable methods (e.g., steaming), and information about who to call and whether surfaces have an anti-graffiti coat-

July	August	September	October	November	December
no	never	not	no	never	not
			check/add		
weekly	weekly	weekly	weekly	weekly	weekly
as	needed	as	needed	as	needed
as	needed	as	needed	as	needed
check guy wires	check guy wires	check guy wires	check guy wires	check guy wires	check guy wires
					prune if needed
prune if needed	prune if needed	prune if needed			
	prune if needed	prune if needed			
dead head	dead head	dead head	dead head		
			dead head	dead head	pinch lightly
					pinch lightly
cut back hard	cut back hard				
cut back hard	cut back hard				
					prune
dead head ?	dead head ?	dead head ?	dead head ?	dead head ?	dead head ?
remove seedlings					
pull by hand?				seed	
pull by hand?				seed	
				plant	plant
weekly	weekly	weekly	weekly	weekly	weekly
as	needed	as	needed	as	needed
weekly	weekly	weekly	weekly	weekly	weekly
weekly	weekly	weekly	weekly	weekly	weekly
as	needed	as	needed	as	needed
weekly	weekly	weekly	weekly	weekly	weekly
weekly	weekly	weekly	weekly	weekly	weekly
as	needed	as	needed	as	needed

Checklist and Schedule

ing. This chapter could also include information on any public art that is located on the site and the 11" x 17" hardscape plan.

8: Litter management. Our public landscapes seem to attract throw-away items such as couches and mattresses. Be sure to list who is

responsible for removing these articles, as well as for removing litter.

9: Green Waste Management. With advance planning and staff training, maintenance crews can shred green waste into mulch and keep it on site. However, be sure to include a warning about weeds that should

OLD MARENGO PARK

The Old Marengo Park is an 8,000-square-foot, gently sloping triangle that lies on the southwest corner of Woodbury Road and Marengo Avenue, bordering the cities of Altadena and Pasadena. For 40 years this parcel was a dirt and gravel unimproved eyesore. Neighbors living on the "Old Marengo" cul-de-sac have long lived with this dirt lot across from their homes.

In 2007 the Arroyos & Foot-hills Conservancy, a 501(c)(3) nonprofit corporation, and the Altadena Watershed Committee, a community organization, completed a waterwise oak woodland pocket park for this old county right-of-way. The oak woodland references nearby mountains and appears to pull a piece of upland habitat down to the urban Altadena/Pasadena border.

The park reflects the historical and natural heritage of Altadena and Pasadena, and acts as an informal gateway between the two communities. The Council, with support from Barbara Eisenstein, crafted a maintenance manual for the park in 2008. The lot size and limited planting list was the perfect venue to develop our maintenance manual and checklist templates. Our target audience was the volunteers' supervisor who needed support through an individualized manual and monthly checklist (<http://mm.watershedhealth.org>).

not be mulched because their seeds are likely to spread infestations on site. Describe what equipment may be needed, and list contacts.

Appendices. This is the place to in-



Rock and gravel-lined swale on Elmer Avenue fills up with stormwater on a rainy day. Note the meandering sidewalk and dymondia (*Dymondia margaretae*) in the 18" next to the curb for passengers exiting cars. The landscaped area includes Douglas iris (*Iris douglasiana*), spreading rush (*Juncus patens*), sanddune sedge (*Carex pansa*), autumn sage (*Salvia greggii*), and germander sage (*Salvia chamaedryoides*).

clude copies of the soils report, all detailed drawings of the irrigation and stormwater components, as well as the planting details for trees and shrubs. We also include emergency contacts for the police and fire department, trash collectors, and local graffiti removal resources. You also

might want to list nonprofit organizations (with their permission, of course) that can provide educational information, such as the California Native Plant Society and the California Invasive Plant Council, and volunteer groups, such as the community service organization Big Sunday.

Monthly Checklist. Our monthly checklist consists of an 11" x 17" spreadsheet that lists all tasks, both general and species-specific, for a particular landscape. This way a crew supervisor can quickly assess which tasks are necessary for the month and allocate time accordingly. Since the plant list is also included, this eliminates any guesswork about how to take care of these native plants.

We hope that this *site-specific* and *species-specific* maintenance manual for native landscapes will serve as a template for professionals (ecologists, landscape architects, designers, and contractors) to create their own. Such a resource will increase the probability of success and the long-term beauty of these native landscapes. We're also interested in hearing from readers about any improvements that you discover which will make maintenance manuals even more useful to landscape practitioners.

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ELMER AVENUE NEIGHBORHOOD RETROFIT

The Elmer Avenue Neighborhood Retrofit is the first complete "green street" in the City of Los Angeles, creating a walkable street that conserves more water than residents use, on average. The Council for Watershed Health and its partners retrofitted a one-block section of Elmer Avenue in Sun Valley with state-of-the-art storm water best management practices to capture and infiltrate runoff, reduce flooding, improve water conservation, reduce pollution to the Los Angeles River, restore habitat, provide green space, and beautify the community.

Specific techniques include bioswales and subsurface galleries for infiltration, native drought tolerant landscapes, smart irrigation controllers, permeable surfaces, and solar streetlights. In 2012 the Council completed construction on the Elmer Paseo, a mid-block permeable walkway with biowales that were planted with all natives.

This neighborhood-scale project provides a real-world model of sustainable design and serves as an example of how to provide multiple benefits along with community enhancement. In addition, the Council has been monitoring Elmer Avenue before the project began and has accumulated a wealth of information on plant survival, water quality improvements, and soil accumulation. The Council gave each resident a customized maintenance manual and checklist, in Spanish and English, designed for a non-professional audience (<http://mm.watershedhealth.org>).

THE COUNCIL FOR WATERSHED HEALTH

The Council for Watershed Health is a hub for watershed research and analysis in Southern California. It is uniquely positioned to influence and inform policy by convening forums and conducting applied research that is reliably fair, objective, and rooted in science.

Founded in 1996, the Council uses an inclusive process to improve the economic, social, and ecological health of our watersheds through applied research, education, and planning. The Council promotes Vision 2025—a model of sustainable, urban watershed management for Southern California. This collaborative vision promotes clean water, reliable local water supplies, restored native habitats, ample parks and open spaces, integrated flood management, and revitalized rivers and urban centers.

The Council's Sustainable Landscape Seminars offer workshops on sustainable landscape design and management practices, with experts from the fields of landscape architecture, ecological restoration, ornamental horticulture, arboriculture, and land care. Speakers share current research, best practices, and case studies, and facilitate field sessions.

To further its goals, the Council has initiated the Native Seed Resources Coalition (NSRC). The goal of this stakeholder process is to nurture an ethically obtained, reliable supply of locally native plants for public landscaping and restoration projects and residential gardens.

For more information on the seminars, go to: <http://watershedhealth.org> (Symposia & Seminars/Sustainable Landscape Seminars). For more information on NSRC, go to <http://nativeseed.watershedhealth.org>.



Elmer Avenue vegetated swale with maturing plants veiling the gravel-lined swale on a sunny day. Sanddune sedge (*Carex pansa*), spreading rush (*Juncus patens*), Germander sage (*Salvia chamaedryoides*), moonshine yarrow (*Achillea* 'Moonshine'), bearded iris (*Iris* sp.).

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SEQUOIA: CONTINUATION OF THE SAGA

by Marcel Rejmánek

The redwood—*Sequoia sempervirens* (D. Don) Endl.—is one of the three iconic trees of California, the other two being the giant sequoia (*Sequoiadendron giganteum* (Lindl.) J. Bucholz) and the bristlecone pine (*Pinus longaeva* D.K. Bailey). It is not surprising that so much has been written about this species. One of the last issues of *Fremontia* contained an 11-page article dedicated to this taxon (Lowe 2012). It was rather entertaining, having been written almost like a detective story, but essentially about the origin of the redwood's scientific name.

Lowe's conclusion is plausible

and most likely correct: the name *Sequoia* is not a celebration of the famous Cherokee Indian chief Sequoyah, but originated as a position of this genus in Endlicher's highly artificial suborder Cunninghamameae where *Sequoia* was placed in a *sequence* (therefore *Sequoia*) among genera ordered by numbers of seeds per cone scale. This is an intriguing story. Inevitably, there are many other interesting questions we may ask about our redwoods. Here are just a few of them.

WHO WAS THE BOTANICAL DISCOVERER OF THE REDWOOD?

According to some authors (McClintock 1989, McCarthy 2008), the first botanist to discover the redwood was British surgeon and naturalist Archibald Menzies of the George Vancouver expedition, in 1794. According to others (Lowe 2012), Menzies was the first one who made the proper botanical collection of this species.

However, Willis Linn Jepson in his *The Silva of California* in 1910 (p. 138) writes that the discoverer was Thaddeus Haenke, a botanist of the Malaspina Expedition of 1791. Some specimens of *Sequoia* collected by Haenke may be in Spain, but several of his specimens are in herbaria of the National Museum and Charles University in Prague. This was the material for which Karel (Carl) Borivoj (Boriwog) Presl (1849, p. 237) used the name *Sequoia religiosa*.

Haenke was a blessed botanist. In California, he discovered the tallest tree in the world and 10 years later, in Bolivian Amazonia, he was the first botanist who found the aquatic plant species with the largest leaves, *Victoria amazonica* (giant

waterlily). Haenke's herbarium specimens had quite complicated fates. Haenke died under uncertain circumstances in Cochabamba, Bolivia, in 1816 (Stearn 1973).

What happened to specimens he was sending to Madrid is not clear. However, it was only in 1821 that seven chests with about 15,000 plant specimens, which had lain neglected for many years in Cadiz and the port of Hamburg, were acquired by the recently funded Bohemian National Museum in Prague and thus came into the hands of Haenke's compatriot botanists. Inevitably, many of the taxa that were subsequently described as new had already been named elsewhere. Nevertheless, names of some of the Californian species described on the basis of Haenke's specimens are accepted even in the new Jepson Manual (e.g., *Epilobium brachycarpum* C. Presl, *Juncus falcatus* E. Mey., *Luzula comosa* E. Mey., *Oenanthe sarmentosa* C. Presl ex DC., *Poa secunda* J. Presl, *Scirpus microcarpus* J. & C. Presl).

WHAT ARE THE REDWOOD'S CLOSEST RELATIVES?

Obviously, to follow questions about the first botanist to collect specimens of the *Sequoia* or the origin of its scientific name are interesting and entertaining enquiries. But there are some botanically even more interesting questions as well. *Sequoia* is one of the 32 currently recognized genera in the family Cupressaceae (cypress family, now including the former Taxodiaceae). It is generally acknowledged that the nearest relative of *Sequoia sempervirens* in North America is *Sequoiadendron giganteum* (giant sequoia). In fact, until 1939 these two species



One of the specimens of the redwood collected in California by Thaddeus Haenke in 1791, now in the Charles University Herbarium in Prague. On the labels are three species names: *Sequoia sempervirens* Endl (on the top, obviously added later), *Taxiphyllum sempervirens* Presl, and *Taxodium sempervirens* Lamb. Photograph by Jiri Hadinec.



Simplified phylogenetic (evolutionary) relationships among genera in the family Cupressaceae (after Yang et al. 2012). Genera with asterisks are currently native to California.

were treated by many botanists as members of the same genus, *Sequoia*.

Then, there is the third morphologically similar genus, *Taxodium*. This genus is known mostly as *T. distichum* var. *distichum* (bald cypress, growing in swamps of southeast North America) and *T. mucronatum* (Montezuma cypress or ahuehete, the national tree of Mexico). Besides the fact that this genus is deciduous, there are also several differences in reproductive structures that make *Taxodium* a rather distant relative to the redwood and giant sequoia.

The situation became more interesting when a new deciduous genus—*Metasequoia*, sometimes called dawn redwood—was discovered in China in 1941. Based on fossil records, this genus was historically widespread, including in North America (see Eocene to Pliocene maps of its distribution in western North America on p. 44 in Lowe 2013). Interestingly, it was George Ledyard Stebbins, one of the past presidents of the California Native Plant Society, who immediately asked very fundamental questions about relationships among *Sequoia*, *Sequoiadendron*, and *Metasequoia* (Stebbins 1948).

Stebbins used 27 characters (number of ovules per megasporophyll, shape of cone scales, number of cotyledons, arrangement of leaves, etc.) to assess similarities and differences among *Metasequoia*, *Sequoia*, *Sequoiadendron*, *Taxodium*, and *Glyptostrobus* (shui-sung, Chinese swamp cypress). Based on this analysis, *Metasequoia* resembled *Sequoia* in the largest number of characters (18), differing from it in only nine. The most similar genus to *Sequoiadendron* was *Sequoia*, but the number of differences between these two (10.5) was somewhat larger than that between *Sequoia* and *Metasequoia*

(9). Stebbins therefore concluded that, “if the distinguishing characters are all considered to be of equal importance, *Sequoia* must be regarded as closer to *Metasequoia* than to *Sequoiadendron*.”

Moreover, only weighting certain vegetative characters (arrangement of leaves and deciduous vs. evergreen character) as more important than reproductive characters could lead to the opposite viewpoint. In the same article, Stebbins discussed the type of *Sequoia* hexaployploidy (the configuration of 66 chromosomes in the meiotic metaphase) and suggested that it probably originated via hybridization between two, and perhaps three, distinct ancestral species. His concluding hypothesis was that *Sequoia sempervirens* originated as an allopolyploid from hybrids between an early Tertiary or Mesozoic species of *Metasequoia* and some probably extinct type of taxodiaceous plant.

IS IT A HYBRID?

Since the publication of Stebbins’ seminal paper in 1948, the idea of a hybrid origin of *Sequoia* has been only rarely questioned (Ahuja and Neale 2002). Interestingly, using

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morphological data, Li (1988) inferred that *Sequoia* originated by hybridization between some ancient species of *Metasequoia* and *Sequoiadendron*, rejecting the Stebbins' suggestion that another extinct ancestor was involved. The idea that *Sequoia* originated from a recombination between genera *Metasequoia* and *Sequoiadendron* got some new support in the recent molecular phylogenetic study of Cupressaceae phylogeny by Yang, Ran, and Wang (2012). A simplified picture of Cupressaceae molecular phylogeny illustrates their conclusions.

Nevertheless, this is very likely not the end of the story. In another recent Cupressaceae phylogeny based on nucleotide sequences from plastid, mitochondrial, and nuclear DNA, *Sequoia* and *Sequoiaden-*

dron are always closer to each other than to *Metasequoia* (Mao et al. 2012). This may be in agreement with Lowe's (2013) hypothesis that both *Sequoia* and *Sequoiadendron* are descendants of the Eocene *Sequoia affinis*. The saga of *Sequoia* continues.

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FROM THE EDITOR

Recently I came across an old issue of *National Geographic* (February 1999) that had been given to me by a friend. On the cover are the words, "Biodiversity: The Fragile Web." The lead article's teaser blurb on the table of contents page reads, "Hosting an astonishing array of living things, our hospitable planet is becoming less so for many species."

Biodiversity is critically important to the health of watersheds throughout California and to sustaining life in general, although its importance is not well understood by the general public. The conservation of rare plants has always been at the heart of the CNPS mission, and rare plants and plant communities add greatly to a diverse flora.

For that reason alone, CNPS's new initiative, the Rare Campaign, is a timely idea. We hope it will bring in significant funds to support and expand the invaluable work of the CNPS Rare Plant Program. At the same time, it offers us a fresh opportunity to sponsor a variety of public talks and events that explain why rare plant species are important, and what can be done to conserve them. CNPS chapters can play a significant role in making this happen, and we hope you will involve many of your members in this worthwhile effort.

And here's a sneak preview of what's to come. The next two issues of *Fremontia* will be thematic ones, and will focus on issues related to the richness of California's deserts. The first issue, out in January 2014, will cover the unique plants, diversity, and ecology of the Mojave and Sonoran Deserts. The second issue will discuss threats to desert ecosystems, and what is being done to protect them or minimize those impacts.

—Bob Hass