

VOL. 42, NO. 1 • JANUARY 2014

FREMONTIA

JOURNAL OF THE CALIFORNIA NATIVE PLANT SOCIETY



CALIFORNIA'S DESERTS, PART 1: BIOLOGY AND ECOLOGY

FREMONTIA

VOL. 42, NO. 1, JANUARY 2014

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California Native Plant Society

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Staff and board listings are as of January 2014.

Printed by Lithtex NW: www.lithtexnw.com

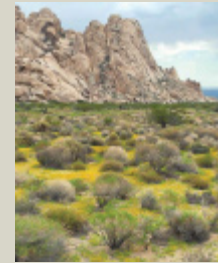
CONTENTS

EDITORIAL *by Kara Moore* 2

FLORISTIC DIVERSITY AND DISCOVERY IN THE CALIFORNIA DESERT

by James M. André 3

The California desert flora is surprisingly diverse and a hotbed for taxonomic discovery. Looming impacts, however, pose a major threat to this unparalleled floristic frontier.



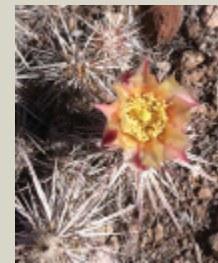
RARE PLANT DIVERSITY IN THE CALIFORNIA DESERTS: PRIORITIES FOR RESEARCH AND CONSERVATION *Kara A. Moore and James M. André* 9

Many of California's rare and unique desert plants are at risk, and research on their biology and distribution is urgently needed to fuel effective conservation strategies in our rapidly changing deserts.

APPLYING SPECIES DISTRIBUTION MODELING TO IDENTIFY RARE SPECIES HOT SPOTS

by Patrick McIntyre 15

How researchers are using predictive mapping tools to understand plant diversity in California's deserts.



THE CASTLE MOUNTAINS: A HOTSPOT OF DESERT PLANT DIVERSITY *by Duncan Bell* 17

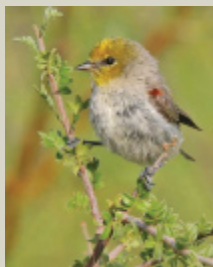
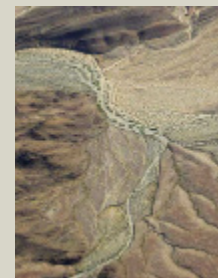
Recent explorations of the Castle Mountains in the Eastern Mojave show that they are rich in botanical diversity.

MICROBIOTIC SOIL CRUST COMMUNITIES: A CRITICAL COMPONENT OF CALIFORNIA'S DESERTS *by Nicole Pietrasiak and Jeffrey R. Johansen* 18

Microbiotic soil crusts are in dire need of conservation because they are essential to desert ecosystems and harbor unexplored biodiversity.

DESERT STREAMS: AN INNOVATIVE NEW APPROACH TO THEIR INVENTORY AND MAPPING *by Carolyn Chainey-Davis* 20

A new science-based method for mapping California's episodic desert streams incorporates an understanding of their unique physical forms and processes where other methods have failed.



THE ECOLOGICAL IMPORTANCE OF WASHES TO DESERT BIRDS *by Andrea Jones and Garry George* 24

Audubon Society staff share a brief summary of the importance of perennial desert streams and microphyll woodlands to migratory songbirds and other bird species in Southern California.

JOHN O. SAWYER, JR.: 1939–2012 *by James P. Smith, Jr.* 25

BOOK REVIEWS 27

THE COVER: Sunrise on the east side of the Granite Mountains in the Mojave National Preserve. In the foreground is a skeleton of buckthorn cholla (*Cylindropuntia acanthocarpa*) and cinchweed (*Pectis papposa* var. *papposa*). September 2013. Photograph courtesy of Stephen Ingram, www.ingramphoto.com.



The first winter storm of the season on Clark Mountain, October 2013. Hidden beyond the mountain lies Ivanpah Solar Electric Generating Facility, covering over 4,000 acres of former desert wilderness. It is expected to power approximately 140,000 homes when it goes on the grid later this year. Photograph by Kara A. Moore.

EDITORIAL

by Kara A. Moore

This is a momentous time to focus the lens of *Fremontia* on the Mojave and Sonoran Deserts. We teeter on the brink of vast changes in the North American deserts as we expand our cities, roads, recreational activities, and energy generation into one of the largest remaining frontiers on the continent. Policymakers and land managers are embroiled in particular on debate over the siting of utility scale solar and wind renewable energy facilities.

Despite the fantastic ability of desert ecosystems to withstand drought, endure floods, and capitalize on favorable conditions when they occur, what they cannot recover from—at least not on the scale of human life times—are disturbances so intense and sizeable that they interrupt entirely the flow of soil, water, and species over the landscape. The next two issues of *Fremontia* focus on the Mojave and Sonoran Deserts and are designed to raise awareness among the public, policymakers, and renewable energy proponents of these threats and make the strong case that deserts are unique and precious ecosystems that warrant vigilant protection.

The common misconception is that deserts are hostile wastelands, that they are useless open spaces that may be carelessly managed. Though they have intense climates, deserts are anything but barren. Even in the most extreme places and times, such as those iconic and seemingly barren landscapes of Death Valley, highly specialized insects and plants persist, soils move, and nu-

trients cycle. Deserts are rich and diverse landscapes in which we can observe the great drama of nature's cycles. They invite adventurous exploration by our city- and computer-trained eyes as they meet the wild horizon.

On my first trip across the Mojave and Sonoran Deserts from forested Michigan, I was struck by the heat and by the expansive landscapes and mesmerized by the seemingly empty yet colorful mountains, dry lake beds, and sweeping plateaus. Later, when I returned as a researcher exploring on foot, I had the gift of time to see closely, to witness change over the course of days and seasons.

During my first desert research project at Ash Meadows National Wildlife Refuge, I saw the desert unfold. I witnessed its dynamic plants and pollinators, lightening quick leopard lizards and charismatically slow desert tortoises, azure pools and pupfish, monarch and sphinx caterpillars, raging flash floods, and moving soils. On each visit, be it to the lava fields around Pissgah Crater or the bajadas descending from Clark Mountain, I continue to find more diversity, more abundant life, and more interesting questions than on the one before. Deserts challenge us—as they do all of their inhabitants—to be patient, to look closely, to build tolerance and resilience.

With this issue of *Fremontia* and the next, we challenge readers to look closely at a region that is undergoing radical physical and landscape level change. In this issue, we first highlight the diversity and ecology of the Cali-

fornia deserts. Then we focus on the incredible taxonomic diversity of plants in general and on the biology of rare plant species. We also emphasize the impact that periodic water has in shaping desert ecosystems.

The second Mojave and Sonoran Deserts issue, slated for distribution in May of 2014, will cover a broad range of management questions. These include a strong focus on the ecological consequences of natural and man-made disturbances. As decisions are rapidly made regarding resource use, we need to challenge each other to cross institutional boundaries and share information including, but not limited to, species occurrences, population dynamics, and management failures and successes. To that effect, the second desert issue will include articles from conservation and restoration practitioners and from participants in policy debates.

There are many additional topics of desert ecology not included in these two issues. Should these issues of *Fremontia* peek your curiosity, *California Deserts: An Ecological Rediscovery*, written by long-time CNPS member and contributor Bruce Pavlik, is an excellent read for scientists and non-scientists alike, and covers topics of history, ecology, and management. But better yet, visit the deserts yourself, and visit more than once. Try to see the deserts in every season. You are likely to gain a new, and deeper appreciation for these rich desert ecosystems, and for the great diversity of life forms that they support.

FLORISTIC DIVERSITY AND DISCOVERY IN THE CALIFORNIA DESERT

by James M. André

No other state in the US can rival California's floristic diversity. The California Floristic Province, which makes up the western two-thirds or cismontane portion of the state, is celebrated widely among biologists for its unparalleled diversity and high degree of endemism, and much of California's extraordinary diversity is attributed to this unique region. This review, however, will focus on the *other* floristic provinces of California that comprise the state's arid transmontane deserts, a region often overshadowed (if not also rain-shadowed) by the California Floristic Province, yet of equal significance and appeal to botanists.

The California desert, as defined by *The Jepson Desert Manual* (Baldwin et al. 2002), comprises the eastern third of the state and includes the Great Basin Province east of the Sierra Nevada crest and the western components of the Mojave and Sonoran Deserts (Figure 1, page 3). This vast region is more than twice the size of the Sierra Nevada, spanning 500 miles from the Sweetwater and White Mountains of Mono County, southward through Death Valley National Park, Mojave National Preserve, and Joshua Tree National Park, to the lower Colorado Desert of San Diego and Imperial Counties. Consisting mostly of federal public lands, largely unpopulated and still unfragmented by development, the California desert is of global significance, as it represents perhaps the largest intact ecosystem in the US outside of Alaska.

EXCEPTIONAL DIVERSITY

Although deserts in general are commonly portrayed in literature and

lore as barren and lifeless places, the flora of the California desert is in fact extraordinarily diverse. At present, approximately 2,450 native vascular plant taxa (henceforth termed "species" in this article) have been documented in the California desert, representing 38% of the native species in the state. If the California desert region was a US state, its flora would rank an impressive 18th among states in total native vascular plant diversity. Even when compared to the renowned species-rich cismontane California, the desert fares quite well. Mid-elevation alluvial fans of the eastern Mojave Desert support perhaps the highest shrub diversity in all of California, and similar overall species diversity (90–120 total species per hectare) to that of the primeval coastal redwood forests of northwest California. The remarkable richness of our desert flora is owed in part to its exceptional geologic and topographic diversity, as well as the rapid speciation and diversification of large genera (e.g., *Phacelia*, *Astragalus*, *Eriogonum*, *Cryptantha*, *Gilia*).

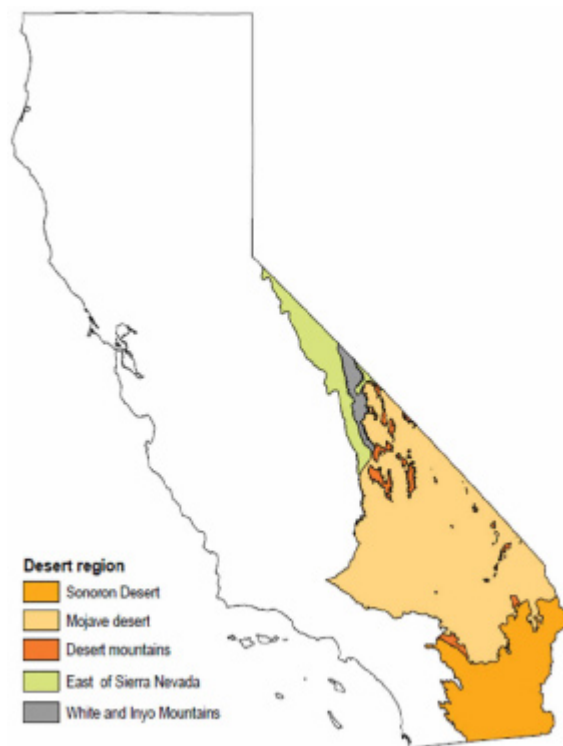
Though often described as homogeneous, the desert region is in fact a place of great variation and extremes. It is where the hottest and coldest temperatures in the state are recorded, and contains the lowest and nearly the highest elevations, and certainly the driest climate. The desert is where we find the oldest vascular plants in California, such as creosote bush (*Larrea tridentata*) and bristlecone pine (*Pinus longaeva*), more ancient than the giant sequoia

and coastal redwood trees. It is also where we find California's shortest-lived vascular plants, such as the ephemeral summer annuals that can germinate and produce viable seed in just three weeks. These same seeds may then lie dormant in the soil for many decades before germinating again. And to underscore the quality of the California desert ecosystem, naturalized alien species make up only 8% of the flora, compared to greater than 20% for the rest of the California flora.

A FLORISTIC FRONTIER

With more than 100 major mountain ranges, myriad canyons,

FIGURE 1. THE CALIFORNIA DESERT REGION AND ITS MAJOR COMPONENTS.



Source: Patrick McIntyre, UC Berkeley, 2013, modified from *The Jepson Manual*, 2nd edition.



TOP: The Castle Peaks region of the Mojave National Preserve, a rich flora only recently documented by botanists. • ABOVE: Early spring bloom of brittlebush (*Encelia farinosa*) on the eastern slopes of the unexplored Dead Mountains near Needles, California. All photographs by the author.

playas, alkali meadows, badlands and sprawling sand dune complexes, the California desert remains relatively unexplored. Yet there is a continuing misconception that we have

completed our floristic inventory of the California desert, and that the remaining hotbeds for taxonomic discovery are limited to places like Indonesia and the Brazilian Ama-



zon. This perspective is not entirely surprising given that in the eastern US, and even much of the west including cismontane California, field exploration and collecting has been fairly comprehensive over the past two centuries.

To gain a better understanding of how well we have documented the desert flora, I conducted an online search of herbarium voucher records, sorted by local physiographic areas (mountain ranges, valley basins, etc.). To date, most desert ranges and basins have fewer than 250 herbarium records in the Consortium of California Herbaria. And some ranges such as the Dead, Hackberry, Resting Spring, Ship, Owlshead, and West Riverside Mountains, have fewer than 100 records. Several major ranges, including the Turtle, Castle, Sacra-

mento, and Chemeheuvi Mountains, remained virtually uncollected until very recently. There are no records from the southern half of the Old Woman Mountains, one of the largest ranges in the eastern Mojave Desert. Although parts of the Klamath Mountains, southern Sierra Nevada, and Modoc Plateau are similarly unexplored botanically, no other region in the state can match the scale of the California desert as a floristic frontier in need of documentation.

Several other important observations stand out when viewing the collections history for the California desert. Efforts to inventory and document desert plants, as measured by the number of vouchers collected per decade, have actually declined since the first two-thirds of the 20th century when famous botanists such

as Marcus E. Jones, Willis Jepson, Phillip Munz, and Robert Thorne explored the region extensively. Though there has been a recent increase in general collecting by several botanists, much of our herbarium collections were made more than 50 years ago.

The vast majority of records in the desert occur along the relatively few paved roads in the region. And while the more inaccessible areas remain major spatial voids for documentation, temporal voids exist as well. Summer annuals and fall-flowering plants are prominent in the California desert, comprising about 40% of the flora, but poorly documented because a disproportionate number of collections have been made in spring and early summer. Major information gaps still exist, and I make the case here that we

Sunrise on the impressive volcanic spires of the northern Turtle Mountains, a region unexplored by botanists until this past decade.





Late summer bloom of cinchweed (*Pectis papposa*) in the Granite Mountains of eastern San Bernardino County, showcasing the often-overlooked floristic diversity of autumn in the desert.

have only scratched the surface in our understanding of the desert flora.

What can we expect to add to the California desert flora with further exploration? Recent floristic studies demonstrate what can be accomplished with robust and focused inventory and assessment. These efforts include, but are not limited to

the San Diego County Plant Atlas Project (desert portion) that began in 2003 (Rebman et al.), a flora of Joshua Tree National Park (La Doux), a flora of Mojave National Preserve and surroundings (André), and flora projects by botanists from Rancho Santa Ana Botanic Garden (e.g., Honer, Fraga, Bell, and De Groot).

Until recently, the Whipple Mountains of southeastern San Bernardino County represented one of the many botanical black holes in the California desert. Sarah De Groot collected the 500-square-mile range extensively in the mid-2000s as part of her graduate research, and documented approximately 400 species,

a four-fold expansion of the flora (De Groot 2007). In the process of adding many common species, she discovered several new species in the state and the California desert flora, and documented numerous significant range extensions.

In 2003 Joshua Tree National Park (JTNP) launched a comprehensive effort to inventory the park's 1,200 square miles. Prior to this effort, many areas in the park such as the Pinto Basin, Long Canyon, and the Coxcomb and Eagle Mountains remained virtually unexplored. Led by park botanist Tasha La Doux, the goal of this project was to build upon previous efforts, with an emphasis on surveying the under-explored spatial and temporal gaps. Over the past 10 years the inventory at JTNP has added 140 species to the park list, expanding the list by 24% to its current 725 species. Roughly 90% of the additions were made via field discoveries, including five new species to science, while 10% were added through herbarium searches and taxonomic revisions.

The final case study presented here is my own work on a flora of the Mojave National Preserve (MNP) and surrounding areas (>3,000 square miles), initiated in 1995. Unlike most of the California desert, the MNP region received considerable attention from early botanists. In particular, the Clark, New York, Providence, and Granite Mountains—the highest ranges in the Preserve—have attracted a number of prominent collectors over the past 150 years. Robert Thorne, Barry Prigge, and James Henrickson explored parts of the MNP extensively about 35–40 years ago, and published a flora that included the Kelso Dunes and the high ranges.

In 1995 I mapped the approximately 15,000 historic vouchers known from the region at the time and noticed that nearly all were clustered in the Kelso Dunes and four high ranges. There were 16 other mountain ranges, such as the Cima

TOP TO BOTTOM: Examples of desert species new to science. A close-up of the unique flower of the rare shrub *Orocopia Mountains spurge* (*Euphorbia jaegeri*). • The showy Clark Mountain monardella (*Monardella eremicola*), one of several new species of this genus that have recently been added to the desert flora. • The showy Clark Mountain green-gentian (*Frasera albomarginata* var. *induta*), only found in California on the limestone substrates of Clark Mountain.

Cinder Cones, Castle Peaks, Piute Range, and Woods Mountains, where few to no historic vouchers existed. Over the course of the project I focused approximately 9,000 field hours upon these voids, and also continued to survey the higher ranges and Kelso Dunes (Thorne et al. 1981). Since that time, 120 native species have been added to the flora (a 14% increase), many of which were found in the “well-studied” areas (e.g., New York and Providence Mountains). Seven of these species are new to science, more than 800 new rare plant occurrences have been added, and noteworthy range extensions continue to be frequently documented.

Assuming the three flora projects outlined above are representative of the undocumented status of the entire California desert, we can take home one clear message: the desert remains a floristic frontier, and these are not the end of days for taxonomic discovery. On the contrary, I would suggest that we are in the midst of a second golden age of discovery.

RECENT DISCOVERIES AND ADDITIONS

To estimate the rate of additions of native plant species to the California desert, I utilized the popular floras that have been published over the past 90 years. The numbers of desert species included in each published flora are as follows:

1925 Jepson CA Flora:	2,149
1973 Munz & Supplement:	2,187



1993 Jepson Manual: 2,267
 2012 Jepson Manual, 2nd ed: 2,430
 2013 (Present): 2,450

While there has been an increase of approximately 300 species over 90 years, representing a 14% increase, more than 60% of these were added in just the last two decades. The lull in the mid-1900s coincided with a national lumping trend in plant taxonomy that occurred during that period. Most of the additions are newly described species, but some represent species previously known only from adjacent states or bioregions of California. In the past two decades the desert flora has expanded by 183 species or 8%. Over the same period, the California flora (including the desert) has grown by only 5%, suggesting that the California desert is indeed a major hotbed for taxonomic discovery. In addition, I am aware of at least 40 proposed new desert species likely to be added to the flora this decade.

This resurgent golden age of discovery is by no means as high as the late 1700s and 1800s when the first wave of exploration occurred, but it's happening now during a time when field collecting (and funding for taxonomy) has seen a general decline. The current taxonomic tendency to split species, combined with the fact that more people are now describing new species than had been the case 50 years ago (and doing so more sensibly I believe) explains some of this recent increase in numbers of species in the California desert. Tools such as Google Earth and the availability of online databases such as that of the Consortium of California Herbaria also greatly improve the efficiency of fieldwork, especially when targeting remote areas that are difficult to access.

WHAT THE FUTURE HOLDS

Based upon fairly conservative assumptions, we can expect another

190–200 native species to be added to the California desert flora by the year 2100. This projection assumes we have reached the peak rate of discovery (33 species per decade), and applies a 10% decline in the number of additions per decade going forward. Another way of looking at this projection is to consider what it means to our present level of understanding. If 200 species are to be added to the California desert by the end of this century, and perhaps another 50–100 more in the next century, then we can safely assume that at least 10% of the flora is presently undescribed. This is quite humbling.

The projection of 200 new additions this century also assumes that the concept of a species remains relatively unchanged and that extinction is not a factor (i.e., that the desert will remain sufficiently protected into the future). As to the latter point, approximately 1,500 square miles of the California desert are currently proposed for industrial-scale solar and wind energy development in the next several years, mostly on undisturbed federal lands. Considering indirect impacts of development (e.g., increased vectors for alien species invasions, losses to biological soil crusts, barriers to dispersal, etc.), the actual degradation of habitat will extend far beyond the footprint of the projects themselves. According to most extinction models, at this unprecedented scale and pace of impact, extinction events will be likely.

My hope is that we continue this push to inventory the California desert, as we still have much work to do, and time is now of the essence. Perhaps more important is that the desert gains the level of appreciation, advocacy, and protection that it deserves. To both grizzled and nascent students of botany, the California desert holds a wealth of research and teaching opportunities. And to those interested in preserving one of our last big wild

places on earth, this is your call to action.

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California bearpoppy (*Arctomecon merriamii*), a rare perennial found in small populations on calcareous gravel deposits of the northeastern Mojave Desert and in western Nevada. Photograph by Erica Smith.

RARE PLANT DIVERSITY IN THE CALIFORNIA DESERTS: PRIORITIES FOR RESEARCH AND CONSERVATION

Kara A. Moore and James M. André

Among people of all cultures there is an inherent appreciation of things that are rare and unique, whether a precious gemstone or green flash on the horizon at sunset. To the conservation scientist, rare organisms are of particular interest because they are genetically distinct aspects of living diversity that may be at risk of extinction, or may signify an impaired ecosystem. As stewards of the planet, most of us believe that we have an ethical obligation to preserve biodiversity and the ecological processes that sustain natural systems. This goal is especially challenging, given that our understanding of how healthy ecosystems

function and the role that each life form plays is incomplete. The unique and diverse array of rare plants in the California deserts presents such a conservation challenge because the distributions and basic life histories of most species remain poorly documented.

While endangered mammals and birds often command more public attention, plants form the basis of all terrestrial life by providing energy, materials, and habitat structure. Globally, 25–40% of native vascular plant taxa (henceforth termed “species” in this article) are at risk (Pitman 2002). Within North America, numbers of imperiled plants may be most underestimated

in our deserts because they have systematically received far less attention from botanists than other bioregions. In the California deserts, native plants are being added to the flora faster than any other region of the state. For more on this exceptional floristic frontier, see the other article by James M. André on page 3 of this issue.

The California Native Plant Society’s (CNPS) Inventory of Rare and Endangered Plants ranks 35% of California’s native vascular flora as being of conservation concern, but only 20% of the California desert flora is similarly ranked. There are at least three reasons for this lower percentage. First, endemism (where



Fantastic bloom in the foreground of the rare Bartow woolly sunflower (*Eriophyllum mohavense*)—a plant that is often less than a centimeter in width and height—in 2011 near Kramer Junction in the northwestern Mojave Desert of California. In infrequent favorable years, these tiny rare sunflowers form an unusually dense carpet under the common annual Bigelow's tickseed (*Coreopsis bigelovii*). Photograph by Kara Moore. Close-up photograph by James André.

a species is only found in a restricted habitat or location) is lower in the California deserts than in the rest of California. Yet even though the California deserts represent only a fraction of the Great Basin, Mojave, and Sonoran Deserts, a striking 25% of the rare species in the California deserts are endemic to the state, highlighting the uniqueness of the California desert flora within the North American deserts. Second, because the deserts are, at present, relatively pristine compared to much of California, most rare desert plants are inherently rare, with only a handful driven to rarity by human activities. Third, we have underestimated the actual number of rare plant species in the California deserts—par-

ticularly given that the region is a hotbed for new species discovery—so most new additions to the flora will be rare.

The California deserts are undergoing rapid change as a result of increasing use by humans, especially on federal public lands targeted for widespread solar and wind energy development. Planning measures for rare plant protection will be based upon limited existing knowledge of the desert flora, and thus lack the necessary level of detail. Even after we document the distributions of rare plants, we are challenged to understand their unique biology.

In this article we focus on key factors that influence rarity in the California desert flora and provide a

basis for establishing strategies for conservation. Our goal is to bring attention to the diversity of rare desert plants and to provide insight on their ecology that will be useful to those planning for their protection. We use case studies to illustrate some of the unique facets of rare desert plants that influence their management, highlighting additional research needs and priorities.

OPPORTUNISTS BY NECESSITY

Desert plants must be adapted to a harsh and variable climate to persist. These adaptations include the climatic responsiveness of an-

nuals, the seasonality of herbaceous and woody perennials, and the enduring architecture of many succulents and shrubs. Desert annuals arise from a long-lived dormant seed bank only when triggered by the right combination of temperature and moisture. Seed dormancy buffers annual populations from climatic fluctuations by permitting emergence only when conditions are likely to lead to high survival (Clausen and Venable 2000). Many desert annuals have a very limited period during which germination and emergence can occur, and it is highly dependent upon precipitation. In some cases, especially in the summer, this window may be only a few weeks. The absence of aboveground plants over multiple years can create the false impression that plant populations are no longer present, although they are merely lying in wait as viable seed in the soil for favorable germination conditions. One plant that demonstrates this dramatic year-to-year variation is the miniscule Barstow woolly sunflower (*Eriophyllum mohavense*), a rare winter annual found only near Kramer Junction and Edwards Air Force Base (photo on page 10).

The long dormancy periods of rare herbaceous desert perennials must be considered in the assessment of population densities and in developing long-term monitoring programs. The flowering phenology of some herbaceous perennials can be highly complex. For example, scarlet four o'clock (*Mirabilis coccinea*) typically flowers in response to localized summer precipitation, but may also respond to late winter rains and then flower in early summer. Some deciduous shrubs such as vera dulce (*Aloysia wrightii*) and desert milkwort (*Polygala acanthoclada*) remain leafless until they receive sufficient precipitation. Many monsoon-responsive summer- and fall-flowering desert species such as desert purslane (*Portulaca halimoides*) apply a different photosyn-

thetic pathway (C4) than the majority of plant species (C3), which allows them to more efficiently grow and reproduce in this warm climate with sparse and/or unpredictable rainfall.

The challenge of limited field documentation and periodic emergence is exemplified by Mojave milkweed (*Asclepias nyctaginifolia*), a tuber-forming perennial limited to the eastern Mojave. Prior to surveys for the construction of the Ivanpah Solar Electric Generating System (ISEGS)—a massive project that has been built on approximately 3,740 acres of federal public land—the milkweed was known in California from only four occurrences, all above 3,000 feet in elevation, and all at some distance from the project site. Mojave milkweed was thus assumed to have low potential to occur in Ivanpah Valley and was overlooked during initial project surveys, which were conducted during fairly dry years. Follow-up surveys in subsequent years of increased rainfall revealed numerous populations in the ISEGS footprint. These plants had been dormant and unaccounted for during the preliminary environmental review process.

RARE PLANT HABITATS

The causes of rarity in the desert are nearly as diverse as the rare flora itself (e.g. Rabinowitz 1981; Fielder 1986, 2001). Many rare desert species are narrow endemics that occur in a single restricted geographic area, and/or may be confined to a unique habitat to which they have adapted. They may have either recently evolved in place (neoendemics), or be ancient species (paleoendemics)



Desert milkwort (*Polygala acanthoclada*) in bloom. Photographs by James André.

that have become restricted and now persist in an isolated location such as a mountaintop. Unique desert habitats rich in endemic rare species include characteristic uplands

such as sand dunes, gypsum clay deposits, and limestone substrates. Deserts also include localized wetland ecosystems that are home to many rare plants, including alkali meadows, non-alkali wetlands, freshwater springs, riparian systems, and infrequently inundated landscape features such as playas and washes (Pavlik 2008).

Another challenge for rare habitat specialists is the limited extent, fragmentation, and disjunction of many of their specialized habitats. For example, species specialized on gypsum clay (gypsophiles) and limestone substrates such as California bearpoppy (*Arctomecon merriamii*) have populations scattered throughout suitable habitat patches that can be separated by many miles. Limestone ranges that extend into California from Nevada, such as Clark Mountain and the Nopah Range, house a suite of limestone specialists that are rare in California, but fairly common in Nevada where limestone substrates are abundant.

Rare species may also be distributed across a range of ubiquitous

habitats, their distribution and rarity being driven by other factors. These include a long list of taxa such as Orocopia Mountains spurge (*Euphorbia jaegeri*), Mojave monkeyflower (*Mimulus mohavensis*), and the crucifixion thorn (*Castela emoryi*). These are fragmented or disjunct populations that are difficult to explain ecologically. Causes of rarity for such species might include geographic isolation due to long-term climate change, altered pollinator guilds, restricted gene flow, or other factors. Additional research is often required to discern whether such widely scattered populations are genetically isolated across the range of the species' distribution.

INFLUENCES OF REPRODUCTIVE BIOLOGY

In developing conservation strategies for rare desert plants it is of critical importance to first understand their diverse reproductive systems.

Of the many factors that can in-

fluence rarity, the production and fates of seeds are often the most critical and least understood, and the complex interaction of flowers and fruits with animals warrants extensive research. Some rare species employ self-incompatibility, meaning that individuals need pollen from another individual to produce viable seed. These species, such as Little San Bernardino Mountains linanthus (*Linanthus maculatus*), need larger population sizes to persist than species that readily self-pollinate.

Idiosyncrasies of rare plants include atypical chromosome numbers, low genetic diversity, and relationships with specialist pollinators or dispersers. And these factors commonly compound to influence rare species. For example, Peirson's milk-vetch (*Astragalus magdalenae* var. *peirsonii*) is restricted to the sands of the Algodones Dunes, is self-incompatible, and requires pollination by a single native bee species (Groom et al. 2007). In addition, its habitat has been severely degraded by off-road-vehicle use. Even when seeds are produced, their ability to survive, disperse, and persist in the seed bank is not assured. Rare plants at Ash Meadows and Pisgah Crater can lose up to 90% of their total seed production due to herbivory by jack-rabbits, sometimes for several consecutive years (Pavlik et al. 2009). Rapid construction of large-scale energy projects in the California desert could exacerbate seed losses due to local distortion of food webs.

NEEDS AND PRIORITIES

We must put our feet to the earth. There is an ongoing need for inventory and mapping of known rare plant species in the California deserts to better inform regional conservation and management. The majority of rare plant records occur within a mile of major roads, in historically popular botanical areas (e.g., New York Mountains, Mecca Hills), or

A PROFILE OF CALIFORNIA'S RARE DESERT FLORA

The 491 listed rare California desert species are an exceptionally diverse group with representatives in 70 vascular plant families. Nearly a quarter of these species (152) are either endemic to the California deserts or rare both here and elsewhere, placing them in the highest rarity class, California Rare Plant Rank (CRPR) 1B. A large proportion (209 species, 43%) are CRPR 2B, meaning they are rare in California but more common in other states. This is a relatively high percentage of 2B species in comparison to the rest of California. Another 118 plants are listed as CRPR 4, a watch list of species with limited distributions.

Of the CNPS-listed desert species, only 13 have federal listing status (are protected) under the Endangered Species Act, with 8 receiving protection as "Endangered" and the other 5 listed as "Threatened." Federal listing of desert plants is often sidelined by other critical research needs or because officials may assume that rare species occurring on federal lands are sufficiently protected. Yet we have identified an additional 20–30 desert species that potentially meet criteria for federal listing status, and listing would greatly improve their prospects for research funding and protection.



White-margined beardtongue (*Penstemon albomarginatus*) in bloom near the Sleeping Beauty Mountains, Central Mojave Desert, California. Despite the numerous flowers in 2011, extremely few fruits and seeds were successfully produced because of strong herbivory and other unknown limits on fruit development. Photograph by Kara Moore.

in areas surveyed prior to development. Geographic models can be used in some cases to estimate species ranges, but have important limitations when applied to rare and under-surveyed species (see article by Patrick McIntyre on page 15). Given that the California deserts remain a floristic frontier (we have added 183 species in the past two decades alone), extensive inventory is still needed to catalog additions to the native flora. Many undiscovered species will also be rare, and not afforded the necessary protections until their taxonomy is confirmed and their distributions mapped. A comprehensive desert-wide inventory will take institutional will, much expertise, and many decades to complete.

In addition, research on the ecology of California's rare desert species is vital for stewarding populations amid rapidly increasing threats,

such as from urbanization, utility-scale energy, mining, recreational activities, invasive species, and climate change. At present, status reports that document basic biology and perceived threats are available for only about a quarter of the 491 known rare desert plants, and fewer than 5% have accompanying conservation management plans. Of equal concern is the fact that established long-term monitoring or research programs exist for less than 1% of all rare plants in the California desert. We need to increase and extend species-specific research to provide a baseline understanding of a representative set of rare desert species.

Basic population studies that follow the fates of individual plants and their progeny are especially needed to make predictions about the effects of landscape fragmentation, population reduction, and climate change on the long-term per-

sistence of species. A comprehensive life history approach that includes monitoring of all life stages, including seed banks, is necessary in order to make realistic predictions on population viability. Each stage of growth and reproduction can be greatly affected by other species in the community, some negatively (competition and herbivory) and some positively (pollination, seed dispersal). Therefore it is necessary to implement research that includes interacting species and is conducted over several decades. Such a time frame can better capture population responses to fluctuations in climate and variations in species interactions. Unfortunately, such long-term studies are extremely rare.

Currently, we are assembling 13 years of field data and observations on white-margined beardtongue (*Penstemon albomarginatus*), an herbaceous perennial known in Cali-

fornia from a single population near Pisgah Crater. We are assessing how different life stages, precipitation, and species interactions affect its ability to persist. We found that caging plants from black-tailed jackrabbit herbivory increases survival and seed production, but perhaps not enough to protect the species from other factors that threaten local extinction. Increased drought frequency, as predicted by global climate change models, radically increases the probability of extinction. Additional demographic monitoring is needed to determine if this population will rebound or rapidly advance to California Rare Plant Rank 1A status (plants presumed extinct in the state).

For many desert rare plants, including the white-margined beard-tongue, perhaps the most curious and important life stage is the most challenging to study: the soil seed bank. Unknown factors include the longevity of seeds under field conditions, mechanisms and rates of dispersal, local density, and conditions that trigger germination. Seedling emergence, determined by environmental factors controlling germination and mortality in the soil, is often the most critical driver of population growth. When mathematical models are used to simulate populations of white-margined beard-tongue, small variations in the measured rates of seedling emergence can result in very different probabilities of population growth and persistence.

We also must improve our understanding of rare species' interactions with other plants, pollinators, mutualists, and herbivores. Many plants endure strong herbivory, at least periodically, when populations of insects, jackrabbits, pocket gophers, wood rats, or other species reach high densities (often cyclic or due to a lack of predators), or during drought when food resources are limited. For example, in some years, alkali mariposa lily (*Calo-*

chortus striatus) and crowned muilla (*Muilla coronata*) can be nearly impossible to observe before herbivores consume aboveground leaves and stems. However, for the majority of rare species, by far the most critical interactions are those they have directly and indirectly with humans.

A CALL FOR RESEARCH

Ongoing research is needed to determine the diversity, abundance, and distributions of rare desert plants and to understand the fundamentals of their ecology. We emphasize that the most critical facet of inventory and mapping for rare species is to remember that absence cannot be assumed from a single survey (or even a few) for species that have a dormant life phase. And with rapid and extensive changes in arid land use, we need to advance taxonomic research on both known species and those that are not yet described in order to forward their protection.

There is a pressing need for population biology research on rare plant species. Focal points must include research on the detection and function of dormant life stages and the positive and negative effects of species interactions. We must deepen our understanding of how both dormant life stages and interactions with other species vary with fluctuations in climate that are characteristic of these ecosystems. Furthermore, research to explore the effects of proximity to development, landscape fragmentation, soil erosion, altered hydrology, and other anthropogenic disturbances on rare plants is critical to their persistence.

Regional and global processes such as atmospheric nitrogen deposition and global climate change have far-reaching effects on local populations and must be included in the scope of studies. Although species-specific management is required by the biological uniqueness of rare species, clearly all forms of life are best served by protecting functioning

ecosystem and landscape units. Preservation of large contiguous and diverse wildlands throughout the California deserts is the only way to ensure protection of its many rare species.

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APPLYING SPECIES DISTRIBUTION MODELING TO IDENTIFY RARE SPECIES HOT SPOTS

by Patrick McIntyre

In the last 15 years, ecologists have developed mapping tools to predict new areas where rare species may occur, based on their known localities. These tools are broadly referred to as *species distribution* or *ecological niche* models. (Ecologists debate whether the method predicts the ecological niche of a species or merely where the species occurs on the landscape.) Species distribution modeling identifies aspects of the environment, such as elevation, temperature, and rainfall associated with where a species is known to occur.

Using mathematical models and Geographic Information System (GIS) technology, ecologists can

then make a map of predicted habitat for a species beyond areas where it is currently known by identifying places with similar habitat. Combining these tools with predicted changes in temperature and rainfall, ecologists can also make predictions about where species have the potential to occur in the future, given different scenarios of climate change.

A MAP OF RARE PLANT HOTSPOTS

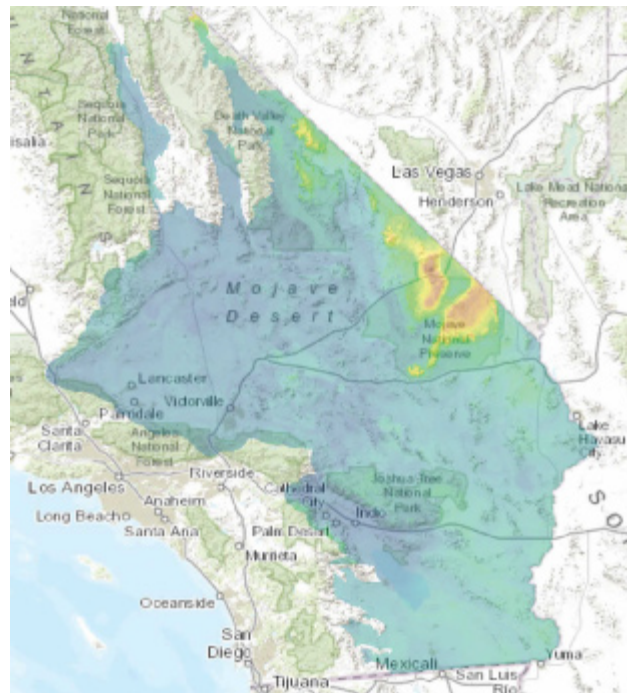
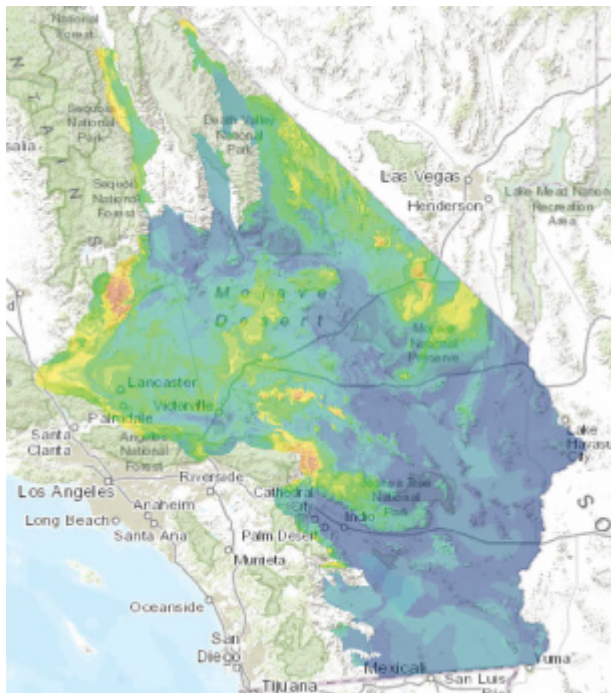
To illustrate how these tools can inform plant conservation, I built species distribution models for 151



Two California endemics known from the Ord Mountains southeast of Barstow, a predicted hotspot of rare plant diversity. LEFT: Mohave monkeyflower (*Mimulus mohavensis*). • RIGHT: Creamy blazing star (*Mentzelia tridentata*). Both photographs by the author.

rare plant species whose documented occurrences allowed us to identify at least 5 populations. Using

PREDICTIVE MAPS OF RARE PLANT DIVERSITY IN THE CALIFORNIA DESERTS.



LEFT: MAP OF CRPR 1 PLANTS (PRIMARILY CALIFORNIA ENDEMICS). • RIGHT: MAP OF RARE OR THREATENED PLANTS IN CALIFORNIA AND WHICH OCCUR MORE COMMONLY OUTSIDE OF THE STATE.

Note: Areas in warmer colors (yellows and browns) are areas of higher predicted rare plant diversity. The predicted region corresponds to the proposed boundaries of the Desert Regional Energy Conservation Plan.

Source: Patrick McIntyre, UC Berkeley. Predictive mapping of rare desert plants, 2013.



Four rare plants known from the Clark and Kingston ranges in the eastern Mojave desert of California, a known and modeled hotspot of rare plant diversity in California. CLOCKWISE FROM TOP LEFT: Stephen's beardtongue (*Penstemon stephensii*). Photograph by Jim André. • Mohave milkweed (*Asclepias nyctaginifolia*). Photograph by Drew Maraglia. • Parish's club cholla (*Grusonia parishii*). Photograph by Kara Moore. • Mojave desert plum (*Prunus eremophila*). Photograph by Jim André.

a standard set of climate data for the 20th century (worldclim.org), I made maps of where these plants were predicted to occur across the Desert Renewable Energy Conservation Plan (DRECP) area. This area is the recent focus of rapid development and conservation planning. I then overlaid predictions for California Rare Plant Rank (CRPR) 1 species (those primarily endemic to California) and CRPR 2 species (those rare in California but more common elsewhere) in order to identify predicted regions of rare plant diversity in the California deserts (see maps on page 15).

Several patterns emerge from examination of the maps of predicted diversity. First, western areas of the desert abutting mountain ranges are identified as areas of high diversity. This highlights how these areas support both true desert species and

species from other habitats that extend to the edge of California's Mojave and Sonoran Deserts. Secondly, the Clark and Kingston mountain ranges in eastern California, much of which are included in the Mojave National Preserve, are identified as centers of diversity both for endemic and non-endemic taxa. The Preserve's ranges host many species that normally occur outside of California, but also occur in these mountains.

Another intriguing area of predicted high diversity is the Ord and Lavabed mountain ranges southeast of Barstow. This area falls outside of National Park/National Preserve areas and currently is known to support a number of rare California endemics, such as the creamy blazing star (*Mentzelia tridentata*), Mohave monkey flower (*Mimulus mohavensis*), and Mojave menodora

(*Menodora spinescens* var. *mohavensis*), and is predicted to have suitable conditions for several other rare species. Based on the simple maps presented here, this area might support additional rare species not currently documented in those locations, or might be a region that could act as a refuge for plants from other areas forced to shift their ranges as a result of climate change.

Predictive maps such as the ones accompanying this article represent valuable tools that can help guide field-based efforts to document plant diversity. They can identify unanticipated locations where rare species might be found. They can also be used to help predict where appropriate habitat for rare plants could occur over large areas that are infeasible to survey by foot. In addition, they provide a means for predicting where species might occur in the future under scenarios of climate change, something that cannot be accomplished through field surveys.

However, predictive maps are based on imperfect data—known localities that represent only a subset of each species' real distribution. They are not substitutes for on-the-ground exploration by experienced botanists. It's one thing to use a species distribution model to identify likely areas to hunt for new rare plant occurrences, and another thing entirely to use the predictions of a model to decide which parcels of land to preserve and which to develop. Finally, models can't predict the distribution of a species that has never been described, and new species are described every year in the California desert. These models are useful tools that we can use to guide research and focus field exploration based on what we know today, and what might likely occur in the future.

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Joshua tree woodlands amidst a unique assemblage of grasses at sunset in a valley surrounding the Castle Mountains. Photograph by the author.

THE CASTLE MOUNTAINS: A HOTSPOT OF DESERT PLANT DIVERSITY

by Duncan Bell

The Castle Mountains are a fantastic example of the great diversity of relatively small mountain ranges in the California deserts. In San Bernardino County, the Castle Mountains are only approximately 30 square miles, yet they are home to over 30 rare plant species and hundreds of common species. Enter any canyon of the Castle Mountains, scramble onto any ridgeline, or walk any wash and you will find unique and interesting plant species, some of which are found only in this rugged corner of the Mojave, such as canyon bird's foot (*Lotus argyraeus* var. *multicaulis*) and the showy pinto beard-tongue (*Penstemon bicolor*).

The Castle Mountains, publicly owned by the Bureau of Land Management, are best accessed by Hart Mine Road from the Mojave National Preserve. Access requires a high clearance vehicle, and four-wheel drive is seasonally necessary. The

center of the Castle Mountains is rugged and rocky, with hidden canyons containing a diversity of rare desert annuals, including nine-awned pappus grass (*Enneapogon desvauxii*) and Clark Mountain spurge (*Euphorbia exstipulata*).

Steep canyons spill out into wide valleys that surround the range. They are home to dense and extraordinarily healthy stands of Joshua trees that are part of a desert savannah containing a diversity of native annual and perennial grasses. Around two dozen grass species are found here, of which half a dozen are rare grasses. Some species, such as burro grass (*Scleropogon brevifolius*) and false buffalo grass (*Munroa squarrosa*), are part of unique desert grasslands found nowhere else in California. Also present are many other rare plant populations such as matted cholla (*Grusonia parishii*), Abert's sanvitalia aster (*Sanvitalia abertii*), and red four o'clock (*Mirabilis coccinea*).

The botanical frontier of the Castle Mountains has only recently been breached by botanists such as James André, Andy Sanders, and myself. Every year we are finding new and previously unknown rare plant populations, and certainly more discoveries remain. For example, in 2012 both James André and I found Mexican panicgrass (*Panicum hirticaule*) in the Castle Mountains area, the first collections of this species for San Bernardino County and an 88-mile northern range extension.

Every field press that is filled with care in the Castle Mountains is likely to hold important discoveries that will allow us to further understand our rare plant populations and their distribution in the rugged but fragile California deserts.

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MICROBIOTIC SOIL CRUST COMMUNITIES: A CRITICAL COMPONENT OF CALIFORNIA'S DESERTS

by Nicole Pietrasiak and Jeffrey R. Johansen

Now more than ever, pristine and fragile desert ecosystems are facing major threats from human development, and efforts are being made to protect sensitive, special-status plant and animal species. In contrast, microbial communities of desert soils have been neglected in conservation efforts, although they are often considered as critical to ecosystem health. It is well documented that the microbial communities within biological soil crusts

are especially crucial to the ecological functioning of desert ecosystems. The crusts harbor diverse taxa including mosses, lichens, fungi, green algae, diatoms, and cyanobacteria that bind together mineral soil particles into water- and wind-stable aggregates at the soil surface. This crust is vital because it prevents erosion in sparsely vegetated landscapes.

In addition to their important role in stabilizing soil surfaces, their contribution to soil fertility is essential. Some crust microbes are capable

of converting atmospheric nitrogen to ammonium, an essential but limited nutrient in desert systems. Thus, crusts represent an important nitrogen source for associated vascular plant communities or soil food webs. Biological soil crusts also can sequester substantial amounts of carbon. The carbon can accumulate in the microbial biomass, ultimately adding soil organic matter to the system. This organic matter is then available in the soil food web. In fact, biological soil crusts are rightfully

Biological soil crusts of Californian Deserts. • BELOW: The darkened soil surface indicates the presence of lichen and algal crusts. The measuring tape gives an idea of scale. • FACING PAGE, TOP: An algal crust is all that holds together soil particles on this desert slope, which contains little vegetation. • FACING PAGE, BOTTOM: A picture taken with a microscope of a potential new cyanobacterial genus and species found in a wilderness area of Joshua Tree National Park. All photographs by Nicole Pietrasiak.





considered to be the fertile mantle of desert landscapes.

The physiological performance of crust communities and the resulting ecological impact in the landscape varies with community composition. Depending on climatic, geomorphic, and soil properties, crust communities differ in the structural components of microbiotic crusts (lichens, mosses, fungi, cyanobacteria). Where this happens, crust communities have distinct forms and structures. The Great Basin, Mojave, and Sonoran Deserts are especially rich in crust types,

which vary with regards to the dominance of mosses, lichens, algae, and fungi. In the Mojave Desert, significant differences in soil aggregate stability, nitrogen fixation, and carbon fixation can be detected among crust types. For example, lichen and moss crust communities contribute most to these ecosystem functions, whereas some weakly-developed algal crusts perform poorly. Hence, the effect crusts have on an area depends both on the community types present and how much of the ground is covered.

In addition to the important ecological role of these communities, they harbor a multitude of undiscovered species and genera. A research team led by Valerie Fletchner investigated over 100 strains of eukaryotic algae and discovered 15 clades (a clade is a group of organisms whose members share features from a common ancestor), of which only 6 could be identified to established genera. Recently, Radka

Muehlsteinova, together with the authors, investigated over 150 cyanobacterial strains and found at least 23 clades, with most of these lineages being potential new genera and species to science. These findings are just an initial indication of how little we know about the biodiversity of these amazing microscopic communities.

In summary, one of the greatest anthropogenic threats to desert systems is the loss of biological soil crust communities, and the concomitant loss of biodiversity, erosion control, and soil fertility.

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Although smaller streams may not always support classic desert wash plants, the denser and more robust vegetation along even smaller streams provides shade, escape cover, breeding and nesting sites, seed, and other food sources. Unnamed distributary channel on desert pavement near El Centro, CA. Photograph by Kris Vyverberg, California Department of Fish and Wildlife.

DESERT STREAMS: AN INNOVATIVE NEW APPROACH TO THEIR INVENTORY AND MAPPING

by Carolyn Chainey-Davis

One of the most startling paradoxes of the world's drylands is that although they are lands of little rain, the details of their surfaces are mostly the products of the action of rivers. To understand the natural environments of drylands is to understand the process and forms of their rivers.

—W.L. Graf (1988)

A PARADOX AND A PARADIGM SHIFT

The physical processes that shape streams in the desert are very different from those in other parts of California. The hydrology of desert streams has been likened to an early description of life in the trenches of World War I: "long periods of boredom, brief moments of terror." Desert

streams—driven by wildly unpredictable rain patterns, heavy flood flows, and sparsely vegetated and erodible soils—have a form and hydrology that are remarkably different from streams elsewhere in the state.

Concepts and methods used to delineate streams that were developed for streams in areas of greater rainfall, and an historical bias for perennial streams, has led to an underestimation of the extent and importance of desert streams. With the increasing pressure to develop renewable energy projects in the desert, there is an urgent need for an entirely new approach to the way we perceive, map, inventory, and evaluate desert streams, one that recognizes and incorporates their unique physical, hydrological, and ecological processes. A new science-based geomorphic and ecological

method for delineating episodic streams in the California desert successfully meets that challenge where other methods have failed.

Surprisingly, one of the most prominent features of desert landscapes is their system of stream channels (Schwinning et al. 2011). Indeed, sometimes entire alluvial fans—those vast triangular aprons of sand, gravel, and arid soils that are built from arid mountain canyons and comprise 30–40% of the desert landscape—are characterized by complex networks of actively shifting stream channels. These water-driven landscape features breathe life into otherwise harsh environments, but are routinely ignored or undervalued in development planning and environmental impact assessments.

Until recently, change came slowly to the California desert. Habi-

tats were generally intact or minimally impacted, with disturbance generally limited to highways, railroad and utility corridors, scattered mining operations, and sheep grazing. Populations of many of the desert's rare plants and animals were considered relatively stable. But in the last decade the political and economic push for renewable energy development has placed many desert species and ecosystems at risk, ecosystems inextricably linked to the functional integrity of streams and their floodplains.

ECOSYSTEM BENEFITS

All streams are life giving, but perhaps nowhere more so than in deserts. Streams occur in a variety of channel forms in the Mojave and Sonoran Deserts, but there are very few *perennial streams* (those that flow year-round). The most common are the episodic streams, which include *ephemeral streams* (flowing briefly during and after a rain event) and *intermittent streams* (those that flow seasonally). Although they look

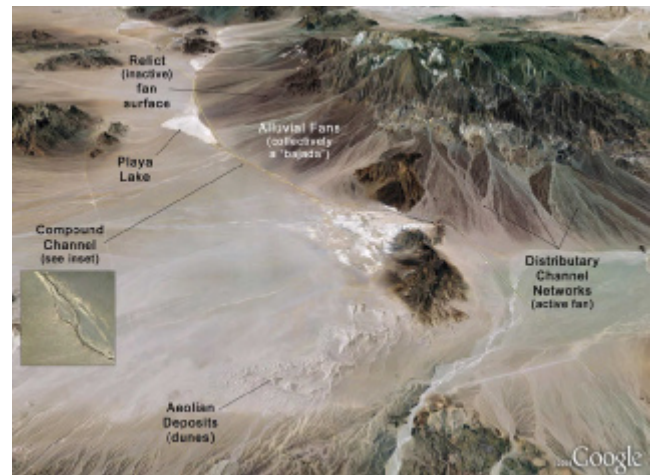


Pooled water at the terminus of a small channel where it dissipates near the toe of an alluvial fan, three days after a quarter-inch summer storm event. Two weeks later, the channel was filled with native summer annuals. Pahrump Valley, CA. Photograph by Carolyn Chainey-Davis.

and behave differently than perennial streams, episodic streams provide all of the same ecosystem services—ecological, hydrological, and physical (Levick et al. 2008). However, our cultural bias for perennial streams has led to a dismissal of the desert's episodic streams and the unique habitats they support as having little or no habitat value.

The fundamental importance of ephemeral and intermittent streams to wildlife in the desert is undisputed. Streams and their floodplains provide not only critical wildlife habitat, but provide a foundation for much of the desert's biotic diversity. Higher soil moisture content and topographic relief of desert streams provide shade and cooler temperatures, which are used extensively by wildlife, and especially by less mobile creatures that cannot avoid the harsh environment outside the stream ecosystem. The higher moisture content, gravel, sand, and soils delivered by stream flows, and the rapid drainage properties of these loose, stream-deposited sediments support plant communities that are distinct from those on upland soils. This contrast is particularly stark on desert pavements where in some areas nearly all the wildlife habitat is found along streams, even in the smallest of channels.

The streamside vegetation of larger ephemeral streams can be quite distinct: the floriferous woodlands of palo verde (*Parkinsonia floridum*), ironwood (*Olneya tesota*), and smoketree (*Psoralea argemonea*) that characterize the large compound channels of the Sonoran Desert region of California; or the oases of lush Fremont cottonwood (*Populus fremontii*) and sandbar willow (*Salix exigua*) on wide reaches



Distributary channel networks on alluvial fans running off the Avawatz Mountains near Death Valley, CA. They provide groundwater recharge and storm runoff to playa lakes and replenish the sand source critical for the maintenance of dunes. Oblique view of Google Earth imagery provided by Jeremy Lancaster, California Geological Survey.

of the Mojave River; or the distinctive shrubby thickets of catclaw (*Senegalia greggii*) or desert almond (*Prunus fasciculata*) on the single-thread channels of desert mountain canyons.

In comparison to larger streams, the smaller channels of alluvial fans and their broad active floodplains may not be as floristically distinct from adjacent plant communities. Yet they are nearly always measurably denser, more robust, and have greater vegetative cover than the adjacent drier uplands. The smaller channels play an equally important role in seed dispersal and germination, including the seeds of some rare species. The hard seed coats of some species, especially the leguminous plants like ironwood, palo verde, catclaw, and smoketree, are abraded by the flows, promoting more efficient germination in seeds that may otherwise require years of weathering to germinate.

Where small streams dissipate on the valley floor, water sometimes pools at the terminus of the channel, and provides valuable temporary access to water for wildlife. Pooled water and fine sediments can germinate abundant annuals follow-



Unnamed stream east of Twentynine Palms, San Bernardino County, California. The smaller swales that dissect the upper fan surfaces collect runoff and initiate stream flow from the surrounding, less permeable dark desert pavement surfaces. These are important sources of water, sediment, nutrients, and other materials during runoff, and are considered integral parts of a desert stream system. Photograph by Jeremy Lancaster, California Geological Survey.

ing summer storms, like Bigelow's monkeyflower (*Mimulus bigelovii*), scarlet lupine (*Lupinus concinnus*), and shaggyfruit pepperweed (*Lepidium lasiocarpum*). These provide fresh young greens for habitat and forage in a dry summer landscape.

Reptiles and amphibians are present in higher diversity in desert streams than uplands, and many species preferentially use streams and their floodplains because of denser plant cover (Baxter 1988). Desert streams provide important

food sources for desert tortoise and other species because they support more diverse plant communities with greater cover and higher diversity of summer and fall annuals. They also host greater bird abundance and diversity, in fact up to 1.5 times more breeding species and twice as many wintering species than the drier adjacent desert scrub (Kubick and Remsen 1977; Tomoff 1974; Daniels and Boyd 1979a, 1979b).

The ecosystem benefits provided by desert streams extend well beyond watercourse boundaries. Downstream and downwind dune ecosystems are wholly dependent on the replenishment of sands delivered by episodic streams to the "Aeolian" (wind-based) sand transport systems that maintain dunes and the many rare animals and plants they support, such as Coachella Valley milk-vetch (*Astragalus lentiginosus* var. *coachellae*). Episodic streams provide storm water runoff to playa lakes and recharge the groundwater sources, which in turn support the unique and often rare habitats that occur at the playa margins: marshes, saltgrass meadows, alkali sink scrubs, and dune thickets. Where the playas and wetlands occur along migratory pathways, they seasonally provide critical

invertebrate resources and resting opportunities for migrating shorebirds on their journey across the desert (Robinson and Oring 1996).

NEW METHODS TO MAP DESERT STREAMS

As pressure to develop the desert increases, it has quickly become apparent that 1) the old concepts and methods used to delineate streams in wetter regions—which assume regular and reliable flows, well-defined channels, or the presence of classic riparian zones—don't work in the desert; and 2) there is an urgent need to develop a reliable and consistent method for mapping and evaluating streams that incorporates an understanding of the distinctive physical, hydrologic, and ecological processes of desert streams.

In response, the California Department of Fish and Wildlife (CDFW), with additional funding from the California Energy Commission (CEC), is preparing a science-based methodology for the delineation of desert streams to assist agency staff and energy project developers, and to help interested parties in their review of project im-



Dense stringers of galleta grass (*Hilaria rigida*) line the small channels of an alluvial fan on the Palo Verde Mesa near Blythe, California, providing predator protection and a cooler microclimate for wildlife. Photograph by Roland Brady, Brady and Associates Geological Services.

pacts to streams. Though still in its infancy, *MESA: Mapping Episodic Stream Activity* (Vyverberg and Brady 2013) provides a photographic atlas of the geomorphic indicators of episodic stream activity, mapping guidance, guidance in the interpretation of aerial photos, and six stream mapping case studies. Even to the non-professional this field guide, which is filled with interesting photos and diagrams, provides a riveting crash course in desert fluvial geomorphology (the shaping of rivers and streams). This document will be available on the CEC and CDFW websites by spring 2014.

STREAM INFLUENCE FAR BEYOND THE CHANNEL

Stream channels are among the most conspicuous features on the desert landscape and contribute to the ecological health of desert plant communities (Schwinning et al. 2011). Thus, when we modify or eliminate desert streams we essentially halt life-giving flow to an entire watershed. For example, multiple studies that compare the vegetation of unaltered alluvial fans to the dewatered portions downstream of a diversion have found compelling results. No matter how small the channels nor the frequency or duration of flows, the health and integrity of alluvial fan ecosystems depends on the integrity of their stream channel networks (Schwinning et al. 2011).

Ecological impacts and the impacts on stream-forming processes are suffered far beyond the original disturbance sites (Schwinning et al. 2011; Schlesinger and Jones 1984; Ludwig 1986; Johnson et al. 1975). In one study near Joshua Tree National Park (Schlesinger and Jones 1984) that compared vegetation on transects of 4,350–4,750 feet above and below a railroad that bisects an alluvial fan, creosote bush suffered a 50% reduction in biomass on the

dewatered portions of the fan, and shrub density was reduced over 30%. Such studies provide an important new perspective on the function, complex structure, and intrinsic value of distributary channel networks, regardless of their size or the frequency of their flows. The desert is an enchanting place, home to many remarkable plants and animals that are wonders of adaptation. The enduring health of these species and their living habitats are undeniably linked to the functional integrity of the desert's complex drainage systems. The challenge for the conservation, management, and restoration of the desert's unique episodic stream ecosystems begins with our perception of them. They are highly dynamic systems in time and space and their influence, particularly on alluvial fans, spans the entire watershed.

Regardless of the duration of their flows, episodic streams provide all the same ecosystem benefits of perennial streams, and their ecological importance is particularly significant given their vast extent. *MESA: Mapping Episodic Stream Activity* by Vyverberg and Brady (2013) is an important starting point in the development of a new science-based method for mapping, inventorying, and evaluating desert streams that incorporates an understanding of their unique forms and processes.

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Desert riparian areas are relatively rare, yet provide critical breeding and migratory habitat for many endangered bird species. Photograph by Andrea Jones.

INSETS: (TOP) An endangered desert bird, the Least Bell's Vireo, depends on desert washes and riparian habitats to breed. Photograph by Steve Mlodinow. • (MIDDLE) The Verdin, distinguished by its yellow facial pattern, is often found in desert areas containing desert washes. Photograph by Greg Smith. • (BOTTOM) Le Conte's Thrasher is a bird that breeds in desert scrub and desert wash habitat in Southern California, including the Carrizo Plain. Photograph by Alan Schmierer.

THE ECOLOGICAL IMPORTANCE OF WASHES TO DESERT BIRDS

by Andrea Jones and Garry George

Desert riparian habitats in Southern California are rare and of additional conservation concern because they represent critical habitat for endangered breeding bird species such as Southwestern Willow Flycatchers, Western Yellow-Billed Cuckoos, and Least Bell's Vireos. In addition, in vast desert regions, these green patches with fresh water support thousands of songbird migrants while they are en route from their wintering grounds in Central and South America to breeding grounds further north.

Of particular note to avian communities are desert washes—dry streambeds subject to rapid flow during flash flooding—in the Colorado and Mojave Deserts, which occur in both upland and riparian habitat, and may include trees, shrubs, or a combination of both. In *A Natural History of the Sonoran Desert*

(2000), Mark Dimmitt says that “dry washes occupy less than 5% of this subsection of the Sonoran Desert, but support 90% of its bird life.” The structural diversity in desert washes can include trees such as palo verde (*Parkinsonia aculeata*) and ironwood (*Olneya tesota*) that provide breeding and feeding habitat for a variety of songbirds, particularly Phainopeplas, Ash-Throated Flycatchers, Verdin, Crissal, LeConte's and Bendire's Thrashers, Long-Eared and Western Screech Owls, Black-Tailed Gnatcatchers, Gila and Ladder-Backed Woodpeckers, Lucy's Warblers, Northern Mockingbirds, and Loggerhead Shrikes, some of which are California bird species of special concern.

The National Audubon Society has recognized the significance of these habitats by naming the “Colorado Desert Microphyll Woodland” an Important Bird Area. This area

includes significant stands of microphyll woodland associated with desert washes that flow east into the Colorado River, including the Chemehuevi Wash, Vidal Wash, and Miltiptas Wash. Another major occurrence of microphyll woodland habitat lies at the base of the Algodones Dunes, halfway between the Colorado River and the southern end of the Salton Sea. In spring, these areas attract large concentrations of migratory songbirds and provide nesting areas for breeding species such as the Elf Owl, Gila Woodpecker, Long-Eared Owls, and Bendire's Thrashers. Additional information is available at: <http://www.prbo.org/calpif/html/docs/desert.htm>.

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JOHN O. SAWYER, JR.: 1939–2012

by James P. Smith, Jr.



CHRIST NAVARO

John Sawyer passed away at his home in Arcata on August 19, 2012. His loss is deeply felt by his wife, Jane Cole, his family, and his many colleagues and friends with whom he had close professional and personal relationships. We will miss his comradeship, infectious laugh and smile, support, boundless energy, and wealth of knowledge. With his passing, our state has lost one of its most respected and influential plant ecologists. The California Native Plant Society has lost a former president, an effective advocate for the preservation of our native flora, and an individual who continued to make significant contributions to the society for over 40 years.

John earned his bachelor's degree at California State University, Chico, and his MS and PhD in plant ecology from Purdue University. While pursuing his graduate degrees, he was an instructor at CSU, Chico, a graduate assistant at Purdue, and a field ecologist for a consulting firm with projects in Costa Rica and Thailand.

Sawyer joined the faculty of Humboldt State University in 1966 where he remained until his retirement in 2001. He taught general ecology, plant ecology, arctic and alpine ecology, California natural history, and plant taxonomy lab sections. Early on, he was the prime mover in a very popular spring break offering—the desert field trip—an intensive excursion in a state bus from Arcata to Southern California. In all of these classes John demonstrated critical thinking, and he insisted on it in his students as well. He was especially proud of his cadre of about 50 graduate students, many of whom remained close friends and who now occupy professorships and responsible positions around the country.

John's favorite instructional arena was the field, where he ex-

celled. It was there that students or participants in CNPS or Jepson Herbarium field trips experienced his passion and detailed knowledge of plants. He was not known for leading casual strolls across the countryside. The lack of a well-defined trail was only a slight impediment if there was a manzanita or a gooseberry to be examined.

John's mobility became increasingly limited by the effects of the cancer that would take his life. So on our private sojourns together, we just changed our mode of operation to day trips in the car. John would spot a plant, usually of the woody persuasion, we would screech to a stop, and Jane and I would gather specimens for him to look at.

His countless hours in the field, extending well beyond his formal retirement, resulted in more than 40 books and papers! There were excursions into such diverse topics as the biological formations of the eastern United States, the vegetation life zones of Costa Rica, and even a flora of a region in northern Thailand. But John's first passion was the vegetation of California, particularly that of the northwestern part of the state. Having gone into the field with him for 43 years, I can attest to both his boundless enthusiasm and incredible knowledge.

In particular, as his students would say, John had this thing for woody plants, especially conifers. You can see this so clearly in his book, *Northwest California: A Natural History*. He was also a coauthor, along with his close colleague

Todd Keeler-Wolf, and Julie Evens, of the second edition of *A Manual of California Vegetation*. It is recognized as the standard reference on the subject.

John wrote sections for *Terrestrial Vegetation of California* on the montane and subalpine vegetation of the Klamath Mountains, the forests of northwestern California, and alpine vegetation. His *Trees and Shrubs of California*, coauthored with John Stuart, a Humboldt State colleague, has become a favorite field guide. He also produced a book with Andrea Pickart, a former graduate student, on the ecology and restoration of coastal dunes in Northern California.

Some plant ecologists have little knowledge of the flora itself. Not so with John. He was involved with Dale Thornburgh in documenting a range extension of subalpine fir into California; authored a paper on the serpentine flora of the Lassics; co-authored the description of a new subspecies of *Frangula*; and authored or coauthored four family treatments



John out on the Bridge of Heaven trail in Colorado's San Juan Mountains, July 2001. Photograph by Todd Keeler-Wolf.



LEFT TO RIGHT: John Sawyer, Virginia Keeler-Wolf, and his wife Jane Cole, enjoying a ride in an outboard up the Yacumama River of the Amazon Basin, Peru, summer 2002. Photograph by Todd Keeler-Wolf.

in *The Jepson Manual* and the treatment of Rhamnaceae that will appear in the *Flora of North America North of Mexico*.

John and I wrote 5 editions of our *Keys to the Families and Genera and Vascular Plants in Northwestern California*, and 22 editions of our checklist of the plants of that same region have appeared. We were working on a specimen-based checklist of the vascular plants of the Klamath Region, and Sawyer exacted a promise that I would see it completed.

John became the fourth president of CNPS in 1973, the first “outsider” to occupy the position, in the sense of not being one of the group that founded the society. He began the process of making CNPS a statewide organization. Board meetings that had been held on Thursday evenings, typically in the home of a Bay Area member, were moved to Saturday. An unfinished set of bylaws that had not permitted chapter presidents to vote at board meetings was rewritten. He would later serve as a member of five state-level committees: Conservation, Educational Grants, Publications, Rare Plants, and Vegetation. I doubt that anyone else can match that record of such diverse committee service.

He was an editor of the second edition of the *CNPS Inventory of Rare and Endangered Vascular Plants of*

California. John was a frequent contributor to the *CNPS Bulletin* and *Fremontia*. His first article, appearing in the *CNPS Newsletter* in 1973 (later to become *Fremontia*), was on the Klamath Region. A bibliography of John’s publications will soon be available at the Humboldt State University Herbarium website (www.humboldt.edu/herbarium/).

John was a founding member of the North Coast Chapter of CNPS in 1970 and served as its first president. He was especially interested in the vegetation and flora of the Klamath region of northwestern California and southwestern Oregon. His field trips to the Lanphere Dunes, Russian Peak, The Trinity Alps, Scott Mountain, Stony Creek Bog, Walker Ridge, and serpentine areas were legendary.

His local conservation efforts were exceptional. John was a critical player in the establishment of the Lanphere Dunes near Arcata and in maintaining its natural state by organizing “lupine bashes” to eradicate the invasive yellow bush lupine (*Lupinus arboreus*). The coastal dunes were also the home of one his major research efforts on the status of the Menzies’ wallflower (*Erysimum menziesii*).

He was also intimately involved in the work that led to the designation of the Russian Wilderness in Siskiyou County. There he and Dale Thornburgh would document the occurrence of 17 conifers in a one-square-mile area around Little Duck Lake, which must make it one of the richest conifer forests in the world. John and Jane assisted our friend and colleague, Dave Imper, in protecting serpentine barrens in The Lassics (Humboldt and Trinity counties), the home of the endemic Lassics lupine (*Lupinus constancei*).

Among his many honors, John was recognized by Humboldt State University as its 1997 Scholar of the Year, by the California Botanical Society in the 2008 dedication of its journal, *Madroño*, and by CNPS in making him a Fellow in 1994. In

2011 he received the J.C. Pritzlaff Conservation Award from the Santa Barbara Botanical Garden. He was active in several organizations, including as a Councillor of the Save the Redwoods League and in the Ecological Society of America, where he served as a technical advisor.

In addition to this impressive list of accomplishments, John was also an avid hiker, serious photographer, world traveler, follower of Purdue University football, habitué of art museums, student of the opera, and an admirer of the music of Bach, Villa Lobos, Piazzolla, Ives, Loreena McKennitt, Cecilia Bartoli, Bob Dylan, and Judy Collins.

John would not have wanted a traditional memorial service. In its place, Jane, her sister Susan, Michael Kauffmann (a fellow “conehead”), and I organized a celebration of John’s life and accomplishments at Patrick’s Point State Park, just north of Arcata. About a hundred people attended. As you would expect, there was a time for recollections. I thought that I knew John pretty well, but I was amazed at stories that were new to me, at the depth of emotion expressed, and at how important he had been in the lives of so many who were there and others who sent remembrances to be read.

If I might end on another personal note, someone once observed that you are lucky in life if you have one really good friend. If so, I was very lucky indeed.

Memorial contributions may be made to any of the organizations mentioned above, to a memorial bench that will be dedicated to John at the Lanphere Dunes (Friends of the Dunes, P.O. Box 186, Arcata 95518), or to the John O. Sawyer, Jr. Endowment to support field studies in botany (Advancement Foundation, Gift Processing Center, Humboldt State University, 1 Harpst Street, Arcata 95521-8299).

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BOOK REVIEWS

I Am the World's Oldest-Known Living Tree by Dr. Gilbert G. Thibault. 2012. Winmark Communications, Glendale, AZ. 56 pp, \$21.56 hardcover. ISBN# 978-1-89222-515-3.

This book is dedicated “to the children of the world and their parents . . . and to the wise people who had the foresight to preserve and protect this unique habitat. . . .” This fine 2012 children’s book about bristlecone pines will delight all readers and deepen their appreciation of this remote native.

From the first leaf, author/photographer Gil Thibault’s graphic expertise is evident. Soft greyed illustrations point out detail the reader might miss in the striking photos, giving the reader the ability to see the forest *and* the trees. A tone of respect for these trees is set in the beautifully detailed introductory map. Section themes pique curiosity, particularly the bristlecone as a weather indicator, historian, or survivor. Stunning photos of bristlecone pines against the night sky are accompanied by an invitation to visit them, and an assurance that “. . . we will leave the lights of the Milky Way on for you.”

A master storyteller, Thibault engages the reader in devising names for creatures and trees and speculating about phenomena. He informs with fascinating facts: scientists have found downed deadwood that’s 11,000 years old, and the trees do not die of old age! Humor threads through nearly every page: “I have heard some people say my foliage is very green for my age.” Children will love the extremes he describes, from stormy winter weather to drought.

Told from the perspective of The Methuselah, a 5,000-year-old bristlecone pine, the book is unabashedly anthropomorphic. And in an interesting variant of personification, Methuselah suggests humans can learn adaptability and resilience from bristlecone pines. A fascinating four-page timeline places these trees amid human habitation, discovery, and invention.

Children of all ages will be drawn to the rich imagery the scientific language elicits, from *dendrochronology*, *contiguity*, and *fortitude*, to *dolomite*.

Thibault takes the opportunity to teach good science rather than avoid topics contentious to a few. There are several references to the potential impact of climate change on the bristlecones. The author notes that they are threatened in summer by bark beetles, which die off in cold weather. A rise in global temperatures may endanger them and benefit the bark beetle, since warmer temperatures encourage the development of softer wood, which bark beetles prefer. On the other hand, there is a missed opportunity to explore balanced ecological relationships: pine bark beetles are eaten by Clark’s Nutcrackers, which disperse bristlecone seeds. In nearby yellow pine forests, bark beetles are a normal part of fire ecology.

In an adaptation that improves on Joyce Kilmer’s sing-song cadence, Thibault adapts his well-known poem “Trees” to celebrate the bristlecone. Also included is a folksong, “Bristlecone Pine,” by Hugh Prestwood, along with an online video link. The lyrics evoke the forest, but mentions of Jesus and heaven and hell may put off non-Christian readers. Along the same trail, the timeline would benefit from more non-Western entries. Small criticisms in a stunning book.

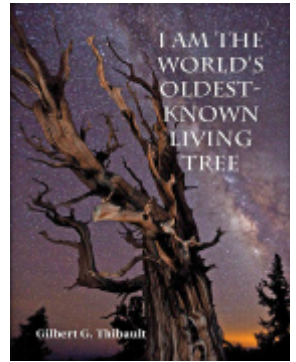
While a broad audience will be captivated by *I Am the Oldest Known*

Living Tree, teachers and parents can use the text to meet the goals of the state’s curriculum standards in science literacy, particularly in grades 3–6.

They expect students will “actively seek the wide, deep, and thoughtful engagement with high-quality literary and informational texts that build knowledge, enlarge experience, and broaden worldviews.” This book certainly qualifies as such a text.

Author Gil Thibault has written a volume that’s full of wonder, visual and verbal treasures, accurate science, humor, and reverence for bristlecones and their habitat. *I Am the Oldest Known Living Tree* makes one want to ensure that these venerable trees survive for generations to come.

—Barbara Roemer and
Merry Byles-Daly



CORRECTION

The photo caption on p. 2 of *Fremontia*, Vol. 41, No. 3 (September 2013) identified Fremont Canyon as located in Irvine County. It is actually located near the city of Irvine, but in Orange County.

A Special Offer for CNPS Members



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Wildflowers of Orange County and the Santa Ana Mountains by Robert L. Allen and Fred M. Roberts, Jr. 2013. Laguna Wilderness Press, Laguna Beach, CA. 498 pages, \$35.00, soft-cover. ISBN 978-0-9840007-1-5.



Southern California plant enthusiasts—especially those in Orange County—have reason to celebrate the publication of a new book. *Wildflowers of Orange County and the Santa Ana Mountains*, by Robert (Bob) Allen and Fred Roberts, is a glorious nearly 500-page guide to the showy flora of Orange County and adjacent areas.

Nearly ten years have passed since rumors of this ambitious project first surfaced, and the end product will thrill readers. The authors are two childhood classmates from Orange County who evolved along parallel paths as botanists and natural historians. Bob Allen, known to his followers as “Bug Bob,” is well known for his extensive local knowledge of plants and insects, as well as his entertaining public presentations and classes. *Wildflowers* began as his brain child. Fred Roberts is the leading authority on status and distribution of plants in Orange County and has enriched the county as botanical guru and artist for years. Together, they are the perfect team to have created this work.

The authors first introduce the region, habitat types, and terminology needed to identify flowering plants.

The plant guide that follows is organized alphabetically by family and, within family, more loosely by genus and taxonomic relatedness. A tremendous amount of information has been packed into the book; literally no inch of space is wasted and nearly every species is not only succinctly described, but also represented by multiple photographs.

Even local variations within a species such as occur in California buckwheat (*Eriogonum fasciculatum*), coast goldenbush (*Isocoma menziesii*), and gum plant (*Grindelia camporum*) are diagrammed or described with photographs. Key anatomical and morphological traits such as floret structure in sunflowers or flower keel shape and distribution of hairs in lupines are also clearly diagrammed to allow for easier identification.

Allen and Roberts’ book has several other unique and refreshing features that place it in the top tier of local natural history references. Pollinators and animal guilds are described for key species and habitats. For example,

nine insect species associated with milkweed and dogbane are described (with photographs!) for the reader. The etymology of all genus and species names is provided. Symbols are added for sensitive species that have federal or state protected status, as well as for those of current local concern.

While the guide is extremely thorough, readers should note that it is not all-inclusive. A scattering of less showy species such as walnut, oak, alder, members of the goosefoot family, and all grasses and their relatives are excluded to save space. Several non-native plants occurring in wildland habitats are also missing. Keeping both would have moved the book out of the realm of a field guide and into that of a desk reference.

Most refreshing to me is that the authors take a holistic view of plants in our fragile landscapes. What they have produced will not only serve as a field guide to specialists and lay people, but also as an encyclopedia of local plants and their ecology.

—Jutta Burger

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CNPS members and others are invited to submit articles for publication in *Fremontia*. If interested, please first send a short summary or outline of what you'd like to cover in your article to *Fremontia* editor, Bob Hass, at bhass@cnps.org. Instructions for contributors can be found on the CNPS website, www.cnps.org, under Publications/*Fremontia*.

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California Native Plant Society
2707 K Street, Suite 1
Sacramento, CA 95816-5130

Nonprofit Org.
U.S. Postage
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Printed on sustainably harvested paper containing 50% recycled and 10% post-consumer content, processed chlorine-free.

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FROM THE EDITOR

This issue and the next of *Fremontia*, two issues focused on California's deserts, exemplify what CNPS does best. As the leading organization concerned with the health of the state's native plants and vegetation types, we bring together in one place science-based information gleaned from the work of our own staff and a cadre of CNPS citizen-scientists, along with that of other prominent scientists from academia, government agencies, and independent consultants. This information is then available to guide those who are entrusted to make decisions about how best to manage and conserve our environment.

For those who know little about California's deserts, these two issues will be eye-openers, and are likely to dispel the myth that a desert area is a wasteland devoid of ecological value. One of the reasons some may hold that view is because the richness of deserts is not readily apparent to the untrained eye. Much is hidden by nature to protect it from the comparative harshness of the desert ecosystem. But after reading the articles in this issue, you may be amazed at all you discover should you decide to take a hike in any of California's deserts.

We owe a debt of gratitude to those researchers who are willing to endure the challenges presented by deserts in order to inform us of what is happening there. Researchers are a unique, unheralded lot, and their work demands considerable patience, precision, dedication, and a systematic approach. Each adds their own piece to the jigsaw of scientific knowledge. While it is exciting to discover new species and occurrences and to work in beautiful surroundings, most botanists I know are more concerned with protecting our native plants and ensuring that their vitality and beauty endures.

—Bob Hass