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CALIFORNIA'S DESERTS, PART 2: THREATS AND CONSERVATION STRATEGIES

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California Native Plant Society

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CNPS carries out its mission through science, conservation advocacy, education, and horticulture at the local, state, and federal levels. It monitors rare and endangered plants and habitats; acts to save endangered areas through publicity, persuasion, and on occasion, legal action; provides expert testimony to government bodies; supports the establishment of native plant preserves; sponsors workdays to remove invasive plants; and offers a range of educational activities including speaker programs, field trips, native plant sales, horticultural workshops, and demonstration gardens.

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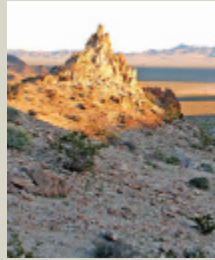
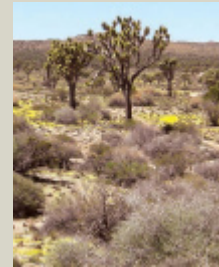
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THE COVER: The Ivanpah Valley in 2010 (top) and in 2013 (bottom) highlighting rapid and radical land conversion of intact desert habitat to the largest solar thermal energy project in the world, which now covers 3,500 acres of leased public land. Ivanpah Valley is a biodiversity hot spot in the Central Mojave Desert and is home to several threatened and endangered plant and animal species. Such desert landscapes are easily damaged by the direct and indirect effects of human activities, and are under mounting pressure from large-scale development. Photographs by Amber Swanson (top) and Kim Clark (bottom).

EDITORIAL

by Greg Suba

The two most recent desert-focused issues of *Fremontia* describe incremental advances in our understanding of the desert and our ability to plan for its long-term conservation. At the same time, these issues highlight the high stakes at this moment of extraordinary decision making in the California desert.

In the first *Fremontia* desert issue (January 2014), James André summarized the paradox facing desert plant conservation: across the desert there is still much to discover, and very much to lose. Conservation and development decisions today will influence the functionality of desert ecological systems for centuries to come. Yet our current lack of information about desert species biology, distributions, and the changing climate creates troubling uncertainty when weighing where human activities will have least impact to Great Basin, Mojave, and Sonoran ecosystems. Design of an effective conservation reserve system is challenging due to the current gaps in our knowledge of desert ecology.

In this second desert issue we present examples of natural and manufactured disturbances occurring across California's desert landscape. Extreme temperatures and low, unpredictable precipitation are among the primary elements of a natural disturbance regime to which desert life has adapted, evolved, and persisted over millennia. More recent man-made disturbances add further stress to desert ecosystems. Increased nitrogen deposition alters soil chemistry. Introduced invasive weeds outcompete native species and fuel uncharacteristic fires. Off-highway vehicle recreation, powerlines, and roads create linear vectors for encroachment by invasive species and fragment intact landscapes. Extensive mining operations remove not only some of the rarest desert plants, but take the mountainsides on which they grow along with them. Today these challenges are overshadowed by impending, widespread impacts of massive desert solar and wind energy facilities.

Political, financial, and climate forces have created a situation that pairs our incomplete understanding of desert ecology with a resolute insistence to develop desert lands. In this issue we present examples of how scientists are working to address data gaps (Evens and Keeler-Wolf; DeFalco and Esque), test planning assumptions (Tanner, Moore, and Pavlik), improve predictability of species habitat, and reduce uncertainty by providing transparency for stakeholders engaged in desert development and conservation planning (Degagne).

While many of the scientific advances discussed in these two desert *Fremontia* issues might well have happened by their own merits, the expediency and funding that produced them are in response to America's ongoing effort to move away from carbon-based fuels by relying on energy generated by sunlight and wind. This culturally transformative endeavor has proven cumbersome to say the least, and many fundamental questions remain unresolved and controversial. For instance, why do financial and political incentives for distributed generation (such as rooftop solar) continue to lag far behind those that benefit proponents of utility-scale facilities?

Part of the answer lies in our country's deeply entrenched energy generation model, where private electric utility companies are granted a regulated monopoly over a service area in exchange for government (public utility commission) control of their pricing and profits. Distributed power, microgrids, and energy storage create dissonance within this model, and resolution will require more sociopolitical change than technological fixes.

Meanwhile, the push to develop our wild deserts goes on and desert science attempts to keep pace. As we assemble the last details of this issue of *Fremontia*, state and federal dignitaries gather at a bend in the highway along the California-Nevada border to cut ribbon on the world's largest solar thermal energy facility. Just to the

north, field crews work to complete vegetation mapping surveys for another 100,000 acres of previously unmapped desert, while botanists (such as many of the authors in these two issues of *Fremontia*) continue searching for new and long-lost species, and collect seeds to ensure the survival of desert species long into the future.

Perhaps humans in the 22nd century will see the wind and solar projects we build in the desert today as the early steps in a global transition to a renewable energy future, one ultimately based on a much different technology than remote, city-sized desert power plants. Indeed, we may be seeing the beginning of the next phase of renewable energy unfolding today, as investment financing for energy projects has shifted toward much smaller-scale facilities, and as public awareness of and demand for the benefits of rooftop energy continue to grow.

I hope history will tell of an equally transformative philosophy that took place during our time, when disparate groups communicated through differences and found ways to thoughtfully balance our use of the land with our will to protect it. It will take more than we are doing now to demonstrate that our society is capable of finding that balance. We will need to place greater value on protecting entire ecosystems in the desert—those we understand well, those we know little about, and still others we have yet to discover.

I hope you enjoy reading and looking through these desert *Fremontia* issues. If you find something particularly remarkable, I encourage you to share it with family and friends, and better still copy and send it to those with a stake in making energy decisions affecting our use of desert lands.

California's desert remains a botanical frontier, where its mysteries provide both opportunities for botanical exploration and challenges to conservation planning. We must not expect those unfamiliar with its beauty to value the desert without knowing about it first. Speak up for the desert. Pass it on.



Joshua tree (*Yucca brevifolia*) woodland, lower Covington Flat, Joshua Tree National Park. The Joshua tree is an important indicator species of species shifts under climate change. Photograph by Edith Allen.

THREATS TO CALIFORNIA'S DESERT ECOSYSTEMS

by Michael F. Allen, Cameron W. Barrows, Michael D. Bell,
G. Darrel Jenerette, Robert F. Johnson, and Edith B. Allen

Not since the late 1800s, when European grazing animals were introduced, have California's deserts faced such ecosystem-altering threats. Chronic impacts including climate change, atmospheric pollution, and both urban and industrial development are affecting desert wildlands in ways that are initially subtle and difficult to detect, but have long-term devastating effects on the functioning of these ecosystems. Understanding how human impacts to our deserts will promote new monitoring and adaptive management approaches may help policymakers address increasing threats. This is a timely pursuit as the Desert Renewable Energy Conservation Plan (DRECP) is generated, critiqued, and debated for adoption by California counties.

The desert is threatened by many widespread and local disturbances

caused by humans that influence ecological processes across the region. These include both immediate impacts from development and longer-term impacts from climate change. This article discusses impacts from climate warming driven by elevated atmospheric carbon dioxide (CO₂), nitrogen deposition from atmospheric pollution, and changes in carbon cycling and sequestration due to soil disturbance and water depletion. Invasive species, wildfire, habitat fragmentation, and soil disturbance are additional compounding threats. Some impacts indirectly affect plant and animal species, while others directly alter the physiology and reproductive capacity of individual organisms. Beyond the measureable effects of each of these disturbances is the unpredictability that comes from the complex interactions among them. Our deserts are rapidly becoming a test

case for studying these interactions, and present us with the challenge of better managing our desert wildlands.

CLIMATE CHANGE IN THE DESERT

It is clearly getting hotter. What does that mean for landscapes that are already among the hottest in North America? Are plants and animals that are adapted to deserts genetically programmed to deal with climate change, or are they already at their physiological limits? In many cases temperature may not be the limiting variable. Rather, unpredictable changes in the timing and abundance of precipitation drive species out of their current distributions. Arid lands will likely get even drier with more severe and longer droughts (Cayan et al. 2007,



Air pollution in the western Coachella Valley, with a view to the Little San Bernardino Mountains that border Joshua Tree National Park. The gray haze consists in part of nitrogen oxides from the Los Angeles air basin. Nitrogen is deposited in the form of nitric acid and ammonia, fertilizing the landscape. Invasive grasses are especially productive with high nitrogen deposition, more so than native species. Photograph by Edith Allen.

IPCC 2007). Will species have time to adapt or move to track suitable climate and conditions on their own, or have humans created barriers that block such movement? Can and should we assist those migrations when possible?

We know species distributions have already changed (Kelly and Goulden 2008). Plants and animals are moving upslope along the University of California's Deep Canyon Desert Research Station just south of Palm Desert. We do not know how far species will be able to migrate in response to climate change, nor can we predict for individual species and communities how their ability to migrate will be affected by human barriers, by other habitat characteristics such as soil substrate, or by their interactions with other species such as predators, pollinators, or symbionts (organisms that depend on one another for survival). And what happens when they reach mountain peaks? These are the questions facing scientists and resource managers dealing with climate change. There are no easy answers, but coming up with objective predictions is critical to reduce losses in biodiversity that are predicted worldwide.

Often we hear that because

deserts are already hot, climate change will not be an important issue, but that is simply not the case. In humid regions, water vapor is the dominant greenhouse gas, and reduces the impact of increasing atmospheric CO₂. But in deserts where humidity is low, CO₂ influences climate significantly. Climate models suggest that in our Southern California deserts, the average annual temperatures will increase from 5.4° to 9° F (3° to 5° C). What are the impacts of this degree of change?

To illustrate this point, we compared two sites in the California desert—Indio, east of Palm Springs, and Death Valley, approximately 200 miles to the north with the hottest climate in North America. Death Valley has an average *annual* temperature of 2° F higher than Indio, which is less than half of the increase projected by climatologists. Indio already has a warmer winter than Death Valley. If we increase the *summer* temperature of Indio to match the summer temperature of Death Valley, then the average *annual* temperature of Indio would still increase by only 3° F overall. In contrast, to reach the projected annual average temperature change of climate models for Indio, we must increase the average Indio tempera-

tures by an additional 5° F throughout the year! This example demonstrates the dramatic everyday increases that are being projected, which will be stressful for all organisms. Since heat is not evenly distributed in time, projected temperature increases will happen through more frequent and longer heating events, in addition to a likely increase in minimum temperatures.

Another way to assess the effect of temperature changes is to relate them to the physiological tolerances of plants and animals. For example, 114° F is considered an extreme temperature for plant leaves that results in greater water use, reduced enzymatic activity, and even mortality. With our projected change in Indio (equivalent to summers at the Death Valley average temperature *and* a 5° F increase throughout the year), three months of the year are predicted to have average highs at or exceeding 114° F. Lizards, such as the desert iguana, have a maximum temperature tolerance of about 112° F, below the projected increase to 114° F. While some animals will be able to shift their activity times or stay underground to avoid lethal temperatures, obviously plants cannot move and are likely to be affected more by temperature increases.

USE OF SPECIES DISTRIBUTION MODELING

One analytical tool that scientists have developed to predict how species may respond to climate change is called “species distribution modeling.” A reasonable approximation of a species’ current distribution can be developed by creating a spatially-explicit model of soils, topography, and climate at each site where a species is known to occur, and then comparing these values to the rest of the region. A model can then be extrapolated by shifting temperature and precipitation values in directions that we expect as climate change increases. From these models, we can then estimate where a species needs to move if it is going to stay within its current preferences for climate, soils, topography, and ecosystem type.

We have constructed such models for many desert species including the Joshua tree (*Yucca brevifolia*) within Joshua Tree National Park (Figure 1). Our model shows that local adaptations to conditions at the southern edge of this species’ distribution in and near the park could impact how it responds to climate change (Barrows and Murphy-Mariscal 2012). While 90% of the current distribution of Joshua trees in the park would be lost, 10% or more of the species at the park’s higher elevations would still be able to survive through the end of the century and beyond.

In order to test if our model was a valid projection of how Joshua trees will respond to a hotter, drier climate, we examined the natural distribution of seedlings. We found that Joshua tree seedlings measured in 2011 were distributed only within the modeled area for adult trees with a 1.8° F (= 1° C) increase in summer temperatures (Barrows and Murphy-Mariscal 2012). This indicates that when Joshua trees die in these areas they will not be replaced, since seedlings cannot establish in areas where the temperature increases more than 1.8° F.

THREATS FROM INVASIVE SPECIES

Many species would struggle to compete for resources in their current locations based on changing climate conditions alone, but their habitat is also being changed by spreading invasive plant species. In comparison to many other ecosystems, the extreme aridity of deserts can be a barrier to the establishment of invasive plants. Unlike warm, mesic climates like Florida or Hawaii where thousands of invasive species exist and are increasing every year, the number of invasive species that threaten California’s deserts do not exceed a few dozen. However, despite their relatively low numbers, several of these invasive species are highly productive. They

outcompete and replace native species, thereby reducing native biodiversity.

Many of our desert invaders also cause changes in ecosystem processes, with impacts spanning whole communities. Examples include salt cedar (*Tamarix ramosissima*), a tree that depletes water from seeps and increases soil salinity in desert wetlands (Shafroth et al. 2008). Invasive annual forbs like Russian thistle (*Salsola* spp.) and Sahara mustard (*Brassica tournefortii*) stabilize active desert sand dunes, habitats that are otherwise centers of speciation and endemism for plants, arthropods, and lizards. Endangered dune plants such as the Coachella Valley milkvetch (*Astragalus lentiginos* var. *coachellae*) depend on sand movement to scarify its seeds (Barrows et al. 2009). Milkvetch is in dramatic decline in these invaded sand dunes. Mediterranean grasses such as *Bromus rubens*, *B. tectorum*, and *Schismus barbatus* are largely responsible for causing shifts to increased fire frequencies across landscapes. This has greatly reduced the abundance of local native species that lack fire response adaptations (Steers and Allen 2011).

EFFECTS OF AIR POLLUTION

Air pollution from automobile emissions and agriculture are increasing levels of nitrogen oxides (NO_x) and ammonium (NH₄) in the California deserts. These are the forms of nitrogen that plants use, and they are deposited across the landscape at high levels near urban and agricultural areas where they are emitted, to low levels downwind, forming gradients of high to low nitrogen deposition. For instance, nitrogen deposition is high in the western Coachella Valley, declining to low levels toward the eastern side of Joshua Tree National Park (Allen et al. 2009). Most of the deposition occurs in dry form, and accumulates on plant and soil surfaces until

Joshua tree woodland burned in the May 1999 Covington Flat fire, and in April 2005 dominated by red brome. Photograph by Edith Allen.





The fringe-toed lizard responds to hot temperatures by burrowing under the sand. Plants, of course, do not have that flexibility. Photograph by Cameron Barrows.

the next rainy season when it moves deeper into the soil. Where nitrogen deposition is high, productivity of invasive grasses increases and diversity of native wildflowers declines (Allen et al. 2009).

Concomitantly, the frequency of fires in the deserts is increasing, since higher nitrogen availability leads to increased grass productivity, which in turn results in higher fine fuel loads (Figure 2). Historically, fires were extremely rare in California deserts (Brooks and Matchett 2006). Desert vegetation

recovers poorly from fires, and increased fire frequency can reduce plant diversity (Steers and Allen 2011). Based on vegetation responses in areas of varying levels of nitrogen deposition and in fertilized test plots, we determined that the probability of fire increases above 3.2 kilograms of nitrogen per hectare/year (Rao et al. 2010). This value may be useful for setting air quality regulations to protect areas with sensitive desert vegetation.

Atmospheric CO₂ is also rapidly increasing (IPCC 2007). In spring of 2013, the concentration of CO₂ in the atmosphere exceeded 400 parts per million, a 40% increase from pre-industrial revolution levels of 280 ppm (~1750). Photosynthesis is the fixation of CO₂ into organic carbon, the basis of most life on earth. How does increased CO₂ affect desert plants? Desert shrubs and cacti may have increased growth rates because CO₂ becomes less limiting to growth as its concentration increases in the atmosphere. However, studies show that the plants that respond most to increased CO₂

are fast-growing invasive annuals, particularly brome grasses (Smith et al. 2014). Increased productivity of annual brome grasses is another cause of increased desert fires, thus elevated CO₂ and nitrogen deposition may interact to increase burn frequency.

SOIL AND VEGETATION DISTURBANCE

Plants are the only known organisms that collect and store atmospheric carbon (a process called carbon sequestration). As atmospheric CO₂ increases, plant fixation of the increasing CO₂ increases proportionally. Indeed, recent estimates show that if plants were not absorbing the increased levels of CO₂, atmospheric CO₂ would be well above 450 ppm and temperatures as much as 2°–5° F higher than currently exists (IPCC 2007). Rain forests are often where scientists find clear evidence of carbon sequestration because they have high levels of easily observed production (wood) and high leaf area. However, a little

known fact is that during wet periods, desert plants can fix as much CO₂ per leaf area as tropical rain forests!

Desert plants also provide an added CO₂ fixation benefit. They grow roots deep into the soil to access water, depositing carbon in places where it can not easily make its way back into the atmosphere. This process slows the release of carbon, thereby reducing atmospheric CO₂. Alternatively, tropical rain forests fix a lot of carbon, but the CO₂ is respired rapidly back out. Deserts currently sequester a large proportion of global carbon, but cannot continue to do so if the vegetation is disturbed by development.

Another fascinating



Brittlebush (*Encelia farinosa*) in foreground (near Mount San Jacinto) has responded to climate warming by moving upslope 100 meters since 1977. Photograph by Edith Allen.



CaCO_3 crystals associated with the roots of desert plants. Shown are (above) a microscope taking high-resolution images of soil, root, and microbial dynamics at Deep Canyon Natural Reserve System, and an image magnified 100 times its original size showing CaCO_3 crystals forming along a single hypha radiating from a fine root. Deposition of CaCO_3 on the surface of soil microorganisms is one important mechanism by which CO_2 is sequestered in the soil. Photographs by Mike Allen.

means of carbon sequestration in deserts is how deep respiration by deep-rooted plants promotes the formation of desert caliche, a soil profile in which a substantial amount of carbon is bound. The amount of carbon bound in caliche worldwide is equivalent to the amount in the atmosphere, so it is a substantial sink for CO_2 .

Caliche is comprised of calcium carbonate (CaCO_3) dissolved in soil water and is deposited deep in the soil profile. This causes CO_2 to be locked in calcium carbonate globally in the form of caliches and desert sediments. While CaCO_3 deposition is generally considered only a geologic process, our results show that it is also biological and dynamic (Allen et al., in preparation). CaCO_3 crystals repeatedly form on the sur-

face of microorganisms in the rooting zone (see photos at left). We measured surprisingly high levels of CO_2 respired by deep roots and microbes, up to 10,000 ppm CO_2 , following precipitation. This is much higher than atmospheric CO_2 of 400 ppm, and has not previously been recognized as the reason why so much CO_2 can be sequestered in desert soils. When surface soil layers are disturbed and vegetation, particularly deep-rooted trees and shrubs, are destroyed and removed due to large off-road vehicle development or utility scale renewable energy construction, the carbon losses may be measureable at a global scale.

Water extraction for urban and energy development will have negative impacts on deep and shallow-rooted plants of washes and wetlands by lowering water tables. Deep-rooted plants, particularly legume trees in desert washes, use groundwater that has recharged over decades or centuries. Other plants in washes and sloughs, such as the endangered Amargosa niterwort (*Nitrophila mohavensis*) or the federally listed Ash Meadows gumplant (*Grindelia fraxino-pratensis*), require periodic surface waters to survive (Hasselquist and Allen 2009). Overuse of ground and surface water, whether locally for agriculture, golf courses, suburban development, or utility scale steam-based, wind, or solar energy development, will inevitably impact plant and animal communities.

INTERACTIONS BETWEEN IMPACTS

Probably the most critical research area in ecology today is the complexity resulting from the interactions of multiple factors on an ecosystem. Our deserts represent a critical test case for both the theory and application of how different threats

converge to further impact desert species and ecosystems.

Many plant and animal species, such as the Joshua tree, have persisted through climate change for millennia by migrating in response to environmental change. But fragmentation of California's deserts by urban expansion and energy development reduces the migration potential of all species by altering species movement, dispersal, gene flow, and interactions. Simultaneously nitrogen and CO_2 levels are rapidly increasing, which creates a novel environment in which weedy species readily proliferate.

As the productivity, fire, climate, and competitive environments within desert plant communities change simultaneously, it will become increasingly difficult to manage and protect this sensitive habitat. Conceptual approaches, such as single-species conservation or a single factor focus upon invasives or fire or climate change, are clearly inadequate to protect California's deserts. Monitoring, measuring, and understanding the simultaneous host of impacts is critical to managing and protecting desert resources.

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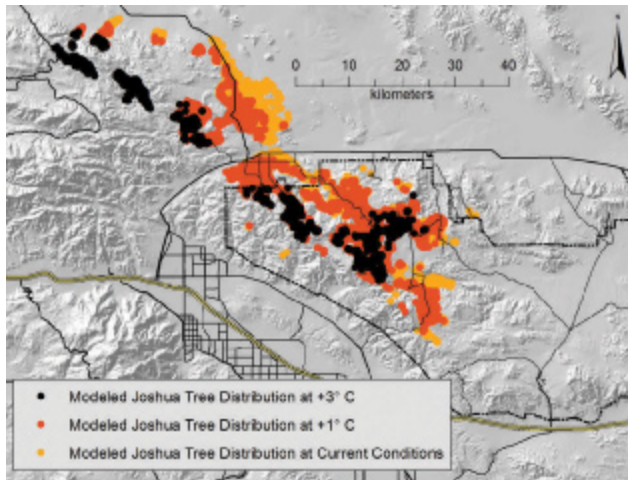


FIGURE 1. CLIMATE-SHIFTED DISTRIBUTION MODELS FOR JOSHUA TREE WITHIN AND SURROUNDING JOSHUA TREE NATIONAL PARK.

The western park boundary is indicated by the black dashed border. These models suggest that Joshua trees (*Yucca brevifolia*) will move up in elevation in the Little San Bernardino and San Bernardino Mountains as a result of climate change, with a reduced presence in Joshua Tree National Park.

Source: Barrows and Murphy-Mariscal, 2012.

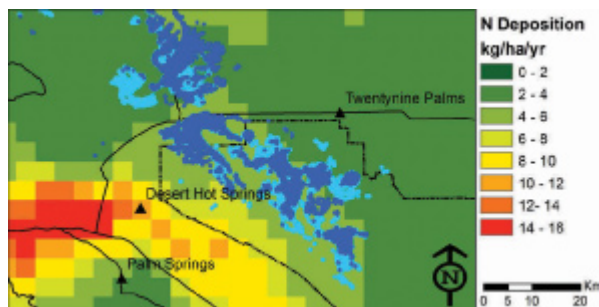


FIGURE 3. MODEL OF PROJECTED MOVEMENT OF JOSHUA TREES SHOWING COMPLEX NATURE OF MULTIPLE STRESSORS IN A DESERT LANDSCAPE.

The projected model of Joshua Tree movement across the western region of Joshua Tree National Park, outlined by the dashed line. The current distribution model is in dark blue. The model with a +1°C temperature shift is in light blue, showing an upslope and a westerly shift. But this is into the area of increasing nitrogen deposition, shown in the color banding of low (green) to red zones. The critical load for desert ecosystems is three kilograms per hectare per year. The added nitrogen stimulates the growth of invasive grasses that, in turn, promote fire during the dry season.

Source: Cameron Barrows, unpublished.

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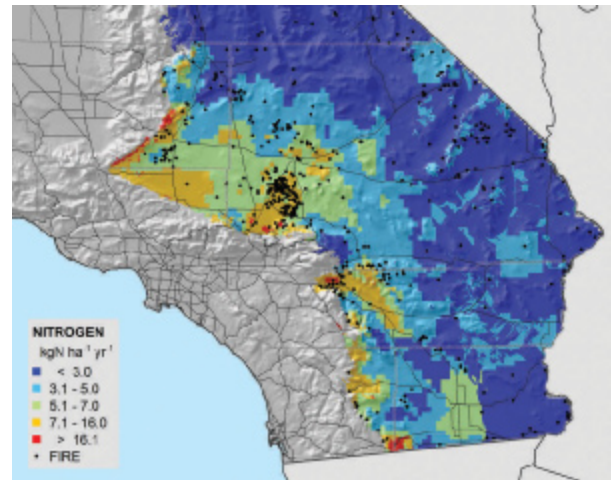


FIGURE 2. NITROGEN GRADIENTS AND FIRE OCCURRENCES WITHIN THE CALIFORNIA DESERT.

Most desert fires can be found in regions of higher nitrogen deposition. Invasive grass grows profusely in such areas, and is largely responsible for carrying fire into shrubs and trees.

Source: Nitrogen deposition data are from Fenn et al. 2010, and fire data from the Department of Interior, 2009.

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CONSERVATION AND ENERGY DEVELOPMENT IN THE DESERT

by Greg Suba

Global climate change, the need to reduce human-made greenhouse gas emissions, and myriad political and economic forces are driving a global effort to transform how society generates, distributes, and uses energy. In the US, construction of utility-scale renewable energy projects across the West has been the centerpiece of these efforts. Today a major conservation challenge, especially for native plants, is to identify appropriate locations to build utility-scale solar and wind energy facilities, while mitigating the impacts associated with their construction. In California this challenge is greatest in Mojave and Sonoran desert regions where native habitats remain undisturbed and the flora is largely under-surveyed, relative to other less remote and more inhabitable parts of the state.

By early 2014, federal, state, and county agencies had received over 150 applications for energy generation and transmission projects in the California desert. The environmental review and approval process

for such applications varies depending on the location, size, and type of energy project. Each new construction site can disrupt the integrity of existing habitat and create a vector for further degradation over time.

Inadequacies in the current energy project review process threaten conversion of intact desert into fragmented landscapes while insufficiently considering cumulative effects to the desert ecoregion as a whole. The north end of Ivanpah Valley has become an unfortunate example of how an intact, highly biodiverse area of critical desert habitat, which has persisted over millennia, can be undone over the course of a few months. Silurian Valley, Rice Valley, the McCoy Wash, Chuckwalla Valley, Indian Pass, and other areas of California's Mojave and Sonoran deserts face similar threats.

Two desert energy-related regional conservation plans, the US Bureau of Land Management's (BLM's) Western Solar Program, and the multi-agency-led Desert Renewable Energy Conservation Plan

(DRECP), aim to lessen the environmental costs associated with the current project-by-project approach. In general the plans would reduce regulatory and financial uncertainty for energy developers, direct energy projects and their impacts to predetermined areas, and use mitigation funds to build a comprehensive network of conservation lands that can be adequately monitored and adaptively managed. If well executed, these plans could offer a better future to desert wildlife than the status quo by proactively guiding projects to desert areas where they would cause less ecological disruption.

BLM's Western Solar Program provides expedited federal environmental review for projects built on public lands in specified Solar Energy Zones (SEZs). Approved in 2012, the Program has established three California SEZs totaling approximately 200,000 acres located in areas east of El Centro, west of the Chocolate Mountains, and across the Chuckwalla Valley. The location and extent of California's SEZs reflect the politics more than the

The view across Broadwell Dry Lake, California. This is one of many vast, intact desert landscapes where solar and wind companies have proposed building projects, and where vistas and habitat would be forever altered by industrialization. Photograph by James M. André.



science associated with the planning process. BLM is currently developing pilot mitigation, long-term monitoring, and adaptive management plans for SEZs in California and Nevada.

The DRECP will develop a comprehensive conservation strategy across 22 million acres of California desert habitat, while expediting the permitting of desert renewable energy projects. The DRECP must meet the conservation standards required by California's Natural Communities Conservation Plan (NCCP) Act, and will need the

support of stakeholder groups and local governments to be successful. The draft plan is scheduled for public review by summer 2014. As this process will continue into late 2014 and perhaps beyond, its outcome remains uncertain.

To date, construction of several large-scale wind and solar energy projects have permanently impacted habitat of rare and ancient native plant species, and have fragmented sensitive plant communities in Chuckwalla, Ivanpah, and western Antelope Valleys. During this time, there have been some beneficial plant conservation outcomes as a consequence of desert energy project planning and certification processes. For example, one huge benefit of the DRECP process thus far is a recently completed vegetation map, whose detailed data greatly improves our ability to identify and avoid rare vegetation types, and differentiate between more and less degraded locations (see Evens and Keeler-Wolf in this issue).

Additional conservation advancements from the energy development process include



Fatalities to avian species, especially Golden Eagle and California Condor, are among the greatest negative impacts of desert wind turbines. Though wind projects require fewer acres cleared during construction, their linear disturbances provide inroads for invasive weeds and can significantly fragment terrestrial habitat like this Joshua tree woodland in northwest Antelope Valley. Pausing the blades for approaching birds, and micro-siting turbines to avoid sensitive terrestrial species can lessen wind project impacts. Photograph by Michael Fortuna.

- a requirement that both spring and fall rare plant surveys are conducted in areas that experience rains in late summer, as well as in winter;
- mitigation measures for California Rare Plant Rank (CRPR) 4 plants if they are found to be locally important, i.e., those exhibiting unusual morphologies or occurring in atypical habitats for the species;
- a more sophisticated and transparent process for developing species habitat models for desert rare plants than originally employed (see Degagne in this issue);
- new protocols for more accurately delineating ephemeral desert streams (desert washes) and their associated vegetation (see Chainey-Davis in previous issue);
- specific conservation targets and conservation management actions that have been developed for rare and at-risk plant communities including microphyll woodland, Joshua tree, desert dune, and alkali soil plant alliances;
- research to test methods of predicting rare plant habitat (see McIntyre in previous issue); and

- research to document how plants respond to life under solar panels (see Tanner et al. in this issue).

These are byproducts of stakeholder and scientific input by groups, including CNPS, related to the planning and building of desert renewable energy projects. All represent useful plant conservation tools that could be applied elsewhere in California.

As noted, establishing a botanical baseline to facilitate desert conservation planning is an ongoing effort. To help achieve this,

CNPS has recently received grant funding from the Giles W. and Elise G. Mead Foundation to compile on-the-ground knowledge from professional and amateur botanists with desert expertise, and include this information into comments advocating for the conservation of desert botanical priority protection areas.

Together, accurate up-to-date field data, the new vegetation map, and progressive plant conservation requirements will help advance CNPS's efforts to ensure that the needs of California's native flora are appropriately addressed during desert energy planning. At the same time, CNPS will continue to advocate a greater emphasis on alternative approaches to energy generation, such as "distributed energy"—small power generating sources located near where the energy will be consumed, such as rooftop solar panels—that do not carry the impacts associated with utility-scale footprints.

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VEGETATION MAPPING IS ESSENTIAL IN CONSERVING RARE DESERT SPECIES AND PLANT COMMUNITIES

by Julie Evens and Todd Keeler-Wolf

Detailed mapping of vegetation is one way to assess the biological values of an area. A vegetation map depicts the natural patterns of plant life including forests, woodlands, scrub, grasslands, and sparsely vegetated cliffs, dunes, and flats. Today's vegetation maps are created using a combination of botanical field surveys, high-resolution aerial imagery, and geographic information system technology. Based on analysis of field survey data, vegetation types are defined using a nationally prescribed set of rules. For example, if an area has at least 2% cover of Joshua trees, it would be classified as a type of Joshua Tree Wooded Shrubland. These rules are then used to interpret aerial imagery and map vegetation over larger areas, and again used to determine the accuracy and value of the end product.

A CONSERVATION PLAN FOR CALIFORNIA'S WARM DESERTS

The Desert Renewable Energy Conservation Plan (DRECP) is the largest and most complex of any Natural Community Conservation Plan (NCCP) ever undertaken in California. Identification and mapping of distinct natural vegetation types, or "Natural Communities," are foundations of regional planning because these communities sustain species and habitats of conservation concern. Examples in California's deserts include the federally endangered Lane Mountain milk-vetch (*Astragalus jaegerianus*) occurring in Mojave mixed desert scrub with rocky soils in the western Mojave Desert, and rare habitats such as fan



The Joshua Tree (*Yucca brevifolia*) Wooded Shrubland Alliance in the Mojave National Preserve is a diagnostic natural community of mid-elevations in the Mojave Desert. Photograph by Julie Evens.

palm oases at spring sites, and blue palo verde–ironwood woodlands along washes of the Colorado Desert.

Natural communities define species' habitats, provide tools for assessing landscape quality within the plan area, and serve as units of conservation based on their distinctive assemblages of species. By preserving intact communities we ensure habitat is preserved for individual species and promote the persistence of functioning desert ecosystems.

SELECTING A CLASSIFICATION SYSTEM

Conservation planners in this vast and diverse area can't employ a simple "one-size-fits-all" approach because decisions are based on multiple variables including species, communities, ecosystems, and natural processes. Within the vast DRECP area (Figure 1) two main issues arose in developing a classifi-

cation system for mapping natural communities. The first challenge was how to adopt a single standard for describing vegetation in distinct categories. Second, and more difficult, was how to craft a plan-wide geographic approach to classify all natural communities embodied in the NCCP. For a map to be useful for conservation, great consideration must be given to accurately represent the many patterns of vegetation, some of which are visually subtle or small in size. This consideration is particularly important for a map of desert vegetation, which, by definition depicts a landscape with sparse plant cover.

The key to developing an NCCP is to have sound definitions for natural communities and to appropriately depict the ecological relationships that capture the conservation requirements of the plan at the species, community, and ecosystem scales. The US National Vegetation Classification (NVC) system was



California Fan Palm (*Washingtonia filifera*) Oasis in the Orocopia Mountains Wilderness. This iconic desert riparian community is isolated in fewer than 100 locations in the Sonoran Desert and adjacent southern Mojave Desert. Photograph by Bob Wick.

chosen as the best standard for defining vegetation types because of its quantitative, defensible, and hierarchical design, and its adherence to rigorous mapping standards. The NVC was updated in 2008 by researchers from federal and state agencies, conservation organizations, and universities to standardize vegetation mapping across the US. It recognizes natural vegetation, as well as semi-natural (introduced self-perpetuating), cultural (agricultural and horticultural), and sparsely vegetated (e.g., dunes, playas, badlands, and rock outcrop) natural communities. For more information, go to <http://usnvc.org/overview/>.

By using this standard, the Cali-

fornia Native Plant Society, California Department of Fish and Wildlife, and other agencies and organizations have mapped and classified vegetation in detail across more than one-third of the state during the past 15 years. These efforts have collectively identified many natural vegetation communities, some rare, some common, providing an unprecedented understanding of California's vegetation.

WHAT WAS MAPPED

These vegetation mapping methods were applied to the DRECP region largely because the plan's 2010 Independent Science Advisory (ISA)

report identified better vegetation data as a fundamental data gap to be addressed. The resultant new DRECP Vegetation Map uses fine-scale classification and mapping, and covers approximately six million acres or 30% of the planning area. This revised fine-scale map focused on areas where no detailed vegetation maps had been available, including the western Mojave, to evaluate impacts of renewable energy projects and to help decide where future renewable energy sites might be placed.

Unfortunately, constraints of time and funding restricted detailed mapping across the entire DRECP area. Therefore, in addition to the



fine-scale DRECP Vegetation Map for focal areas, a coarser-scale map, the DRECP Land Cover Map, was produced for the entire plan area. To generate this map, a related “ecological systems” classification and coarser, mid-scale maps from earlier vegetation mapping efforts (such as the 2008 California GAP analysis and Landfire maps) filled in the gaps where recent, finer-scale mapping was incomplete. Both old and new maps were joined using the broader units of the NVC to produce a seamless land cover map for the entire 22.5 million-acre DRECP area.

The final DRECP Land Cover Map integrates the DRECP Vegetation Map with the best available mapping data for the entire planning area, including data from California



TOP: A mixture of ironwood (*Olneya tesota*), blue paloverde (*Parkinsonia florida*), smoketree (*Psoralea arguta*), sweetbush (*Bebbia juncea*), wolfberry (*Lycium spp.*) and other shrubs make up the microphyll woodland (*Parkinsonia florida*–*Olneya tesota* Alliance) washes in the southeastern DRECP. This vegetation is considered important wildlife habitat for the rare burro deer and other wildlife species. Photograph by Julie Evens. • BOTTOM: One of the largest and least disturbed stands of the Big Galleta Grass (*Pleuraphis rigida*) Alliance occurs adjacent to Rice Valley Dunes (Riverside County), part of the new mapping area in the Colorado Desert to be completed in April 2014. Photograph by Edward Reyes.

GAP 2008, California Department of Fish and Wildlife for Anza-Borrego (Keeler-Wolf et al. 1998), the Mojave Desert Ecosystem Program (Thomas et al. 2004), and updates for agricultural and urban areas from the California Department of Conservation Farmland Mapping and Monitoring Program. (See Figure 1 for details.)

ACCURACY OF THE MAPS

The classifications used in the coarser-scale DRECP Land Cover Map were also used during DRECP environmental review and conservation planning. They differ, as described, from those used in the finer scale DRECP Vegetation Map and can be viewed on the CDFW BIOS



Experimental panels at a study site near Daggett, California. Panels shade Wallace's woolly daisy and alter the amount of sunlight and rainfall delivered to plants. Control plots at the site (not shown) expose plants to natural sunlight and rainfall patterns. All photographs by Karen E. Tanner.

MEASURING IMPACTS OF SOLAR DEVELOPMENT ON DESERT PLANTS

by Karen Tanner, Kara Moore, and Bruce Pavlik

The state of California has set a goal for electric companies to generate 33% of their power from renewable sources by 2020. This requirement has spurred large-scale solar development in California's desert regions, home to unique natural communities and many rare plant species. We need to understand how changes imposed by solar installations may

directly or indirectly affect desert plant communities, particularly those supporting numerous rare species that require state or federal protection.

Desert plants are adapted to intense solar radiation, high temperatures, and low rainfall. Plants shaded by solar arrays experience less sunlight, lower temperatures, and less rainfall than those growing near the edge of arrays, where extra water is

delivered via storm runoff and washing of solar panels. With funding from the Barrett Foundation, the California Energy Commission, and CNPS, we designed and installed an ongoing study using experimental panels to mimic conditions created by photovoltaic solar arrays.

Its purpose was to measure the effects of shading and water runoff from these panels on annual plants



LEFT: Wallace's woolly daisy (*Eriophyllum wallacei*) in flower, exhibiting both ray and disc flowers. When rain is plentiful these daisies unfurl a bright yellow carpet across the landscape. • RIGHT: Two Barstow woolly sunflowers (*Eriophyllum mohavense*) nestle together. In a good rainfall year, individual plants may reach 2 cm in diameter and have dozens of disc florets. In drier years plants have few florets and diameter may only reach half a centimeter.



In each year thus far, density of Wallace's woolly daisy was lower in shaded plots, suggesting that shade suppressed emergence from the seed bank. In 2013, significantly more plants died before flowering under shade panels, which means that average seed production per plot was reduced in shaded plots. We also found that species richness (the number of different species present) and community abundance (the number of individual plants present) was reduced by panel shade. We await more favorable climatic conditions to ascertain the effects of panels on Barstow woolly sunflower and its community. The important thing is to keep the experiment going for many years in order to capture the full range of biological responses to our intervention.

We will be collecting additional data in 2014 to extend our findings, and are excited to see what the next field season will bring. By taking a rare experimental approach to exploring the effects of solar panels, this work will provide insight that can be used by public land agencies as they consider impacts of solar development on rare desert plants and their communities.

in the Mojave Desert. Our monitoring focused on two tiny, closely related species: the common Wallace's woolly daisy (*Eriophyllum wallacei*) and Barstow woolly sunflower (*Eriophyllum mohavense*), a CRPR 1B.2 species (rare, threatened, or endangered in California and elsewhere). Our goal was to compare the performance of individuals of each of these two species and their annual plant communities under the experimental panels, where they were shaded and received limited rainfall, and in control plots where they received natural light and rain. We measured performance by tallying the number of individuals of each species, their size, and their seed production.

Collecting data in the Mojave Desert can be physically demanding, and finding young plants of the *Eriophyllum* species is made all the more difficult when adult plants are only the size of a thumbnail. However, in our study the greatest challenge is that these two annual species are not present in every year. Rainfall in the Mojave is highly variable, and annual plants only emerge from the soil seed bank in some years under a narrow range of appropriate moisture and temperature conditions.

We began our study in 2011, a year when a thick carpet of desert annuals covered many areas due to heavy winter rains. In that year, we observed average densities of 850 Barstow woolly sunflowers and 454 Wallace's woolly daisies per square meter. In contrast, not a single Barstow woolly sunflower emerged from the seed bank in the extremely dry conditions that followed in 2012. Wallace's woolly daisy did emerge, but average density was less than one plant per square meter. Sufficient rain fell in 2013 to trigger emergence of both species, but in far lower numbers than observed the first season. These fluctuations obviously affect sample size and statistical power in our experiment, so analyses of data must take that into account.

Despite this enormous variability in annual plant density, we've found clear effects of experimental shading on Wallace's woolly daisy and its community. Under panels, photosynthetically active radiation is reduced by about 85%, and afternoon soil temperatures are on average 11° C cooler. These conditions represent a strong departure from the natural regime which is reflected in species and community response.

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TOOLS FOR BALANCE: CONSERVATION AND RENEWABLE ENERGY PLANNING IN CALIFORNIA DESERTS

by Rebecca Degagne

California's deserts sustain unique ecosystems that have been shaped by fierce physical constraints of climate, soils, and topography. These vast expanses of land, much of which is managed by public agencies, support numerous rare and endemic species. Ironically, these very landscapes forged from extremes are some of the most sensitive to human impacts (Pavlik 2008). Consequently, the growing interest in developing these lands for renewable energy (primarily solar and wind) presents exceptional conservation challenges.

THE DESERT RENEWABLE ENERGY CONSERVATION PLAN

The Desert Renewable Energy Conservation Plan (DRECP) was created to balance renewable energy development with conservation over the coming decades using a science-based management strategy. This planning effort, which covers 22.5 million acres of Southern California, arose from an unprecedented collaboration between federal and state agencies. The plan's goal is to preserve, restore, and enhance native vegetation while providing renewable energy developers with streamlined permitting under the Federal and California Endangered Species Acts.

There are approximately 50 species (19 plants and 33 animals) and 30 native plant communities proposed for coverage under the plan's regulatory considerations, including special protections, monitoring and

management guidelines, and/or "take" permits (<http://www.drecp.org>). Understanding where these flora and fauna occur across the DRECP landscape is crucial to determining the best locations for new protected areas and energy infrastructure. However, this information is not readily available, even in today's data-driven world.

FILLING GAPS IN OUR KNOWLEDGE

To help fill gaps in the data record for the California deserts, scientists

from UC Berkeley, UC Davis, UC Santa Barbara, US Geological Survey, Dudek (an environmental consulting firm), and the Conservation Biology Institute used digital modeling techniques to predict where plants and animals likely occur across the DRECP area. During this process, species location information was combined with mapped environmental conditions (temperature, precipitation, topography, vegetation) to create species distribution maps for many rare plant and animal species being considered in the regional planning effort. Such maps approximate where the environment



The Desert Renewable Energy Conservation Plan area spans seven California counties and covers an area approximately the size of the state of Indiana (35,300 square miles). Photograph by Bob Turitz.



Scientists use digital modeling techniques to predict where animals and plants, such as Bakersfield cactus (*Opuntia basilaris*), likely occur across the landscape. This information can then be used to guide the creation of new conservation areas. Photograph by Steve Prorak.

high biodiversity and help guide decisions about which areas should be designated as high priority for conservation.

AN INFORMATION GATEWAY

Given the size of the DRECP area and the plan's scope and complexity, full engagement of participants and timely communication of goals, objectives, and progress is essential for this endeavor to succeed. Plan information must also be managed in a manner that promotes accessibility, transparency, and functionality over time. To that end, the Conservation Biology Institute is working with agencies and other stakeholders to create the DRECP Gateway, a Web-based interface



Alkali mariposa lily (*Calochortus striatus*) is one of approximately 50 species (19 plants and 33 animals) proposed for coverage under the DRECP's regulatory considerations, including special protections, monitoring and management guidelines, and/or "take" permits. Photograph by James M. André.

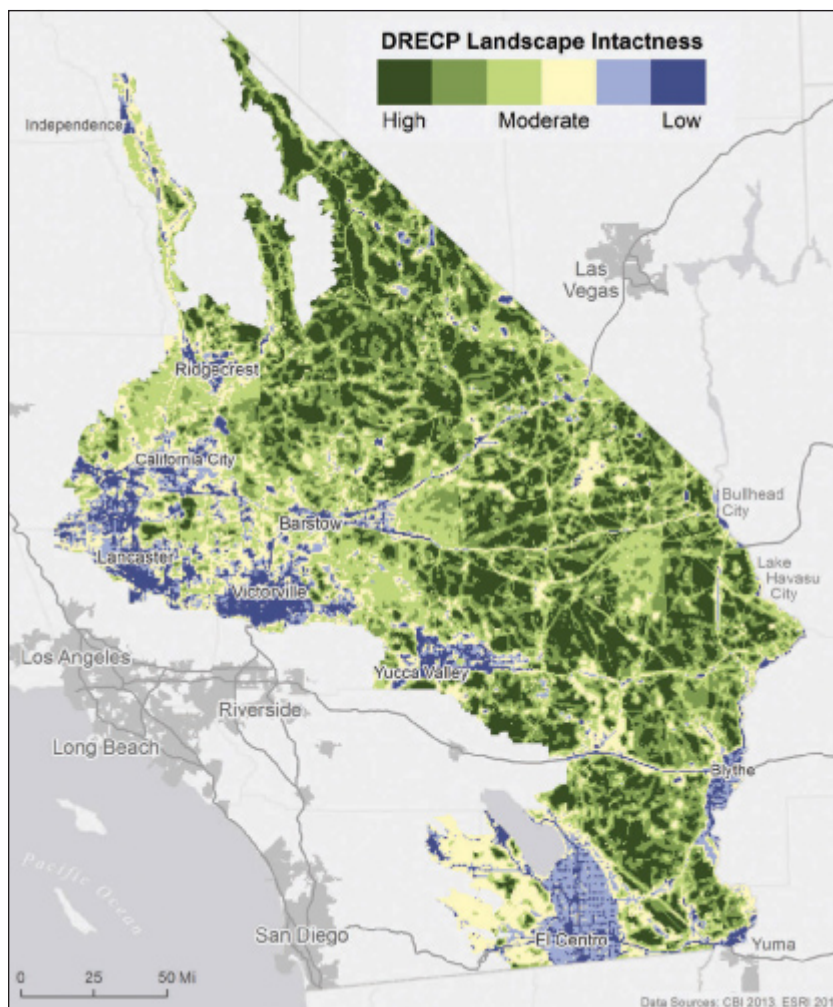
is suitable to sustain a species, thus giving insight into its geographic distribution (Guisan and Thuiller, 2000; Wintle 2013).

While such maps are not a substitute for extensive survey data, they can provide a useful planning foundation. Biologists and managers can

use them to estimate where rare and/or sensitive species might occur and can refine these predictions based on future field surveys. Furthermore, overlaying multiple species' distribution maps can reveal places with



The DRECP digital gateway was created to provide information and geospatial data to all project stakeholders, including the public. Please come explore the site and see how you might participate at <http://drecp.databasin.org>.



A decision-support map showing the degree of human impacts (from agriculture, grazing, development, invasive species, and non-natural fire regimes) across the DRECP landscape. Areas that are more “intact” (less impacted by humans) generally contain higher biodiversity and therefore warrant greater protection from development.

where participants can access interactive planning tools and share important geospatial information. This online portal was developed using Data Basin (drecp.databasin.org), a science-based mapping and analysis interface that supports learning, research, and sustainable environmental stewardship. Data Basin is currently used by thousands of people, including interested citizens, students, educators, natural resource practitioners, and scientists. In this virtual space, participants collaborate on conservation projects, create custom maps to display features of interest, and explore geographic information. Such increased access to information is likely to

increase the openness of decision-making and make greater use of public input to strengthen conservation plans.

DIGITAL DATA FOR DECISION-MAKING

The DRECP Gateway website houses a wide range of data, including products that compile multiple layers of complex information into easily digestible formats to facilitate objective decision-making. Among the unique datasets created by the Conservation Biology Institute are interactive layers that allow stakeholders to examine factors affect-

ing landscape condition and value across the DRECP area. One such layer represents human changes to the natural landscape, such as agriculture, grazing, urban development, invasive species, and non-natural fire regimes. Judicious use of this information during infrastructure planning can focus development toward disturbed areas, and preserve intact areas with higher conservation value.

The DRECP Gateway’s numerous offerings are designed to give stakeholders the means to empirically weigh evidence before choosing a path for renewable energy development. Ideally, this approach engages all people vested in the land, thus ensuring that the conservation of California’s deserts is thoughtfully coupled with development of a clean energy future. As renewable energy implementation pushes further into our local areas and onto our public lands, planning efforts like the DRECP offer opportunities to plan for the long-term protection of unique species and habitats while allowing energy development, and extend to citizens the chance to participate in the planning process.

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SOIL SEED BANKS: PRESERVING NATIVE BIODIVERSITY AND REPAIRING DAMAGED DESERT SHRUBLANDS

by Lesley A. DeFalco and Todd C. Esque

Vascular plants in California's Mojave and Sonoran deserts produce seeds that withstand inhospitable conditions in the soil for months or years. Viable seeds that accumulate in the top inch of soil comprise the "seed bank." Often underappreciated, seed banks represent future plant populations and comprise the species that may persist in a changing climate.

In 1949 botanist and ecologist Fritz Went (1949) gathered surface soils at then-named Joshua Tree National Monument that revealed distinct annual floras hidden below ground. He discovered a flora that germinates in summer when soil temperatures are warm and a different flora in winter when soil temperatures

are cold. In the Coachella Valley, Lloyd Tevis (1958) snatched seeds from harvester ants as they foraged near their nests and observed how granivores could change the species composition of desert vegetation. Since these early efforts, awareness has grown about the importance of seed banks as well as their role in revegetating disturbances throughout the deserts.

THE EXPOSED SEED AND STRATEGIES FOR PERSISTENCE

Ripened seeds are vulnerable from the time they fall to the ground and settle into the seed bank until the right weather conditions trigger germination. Precipitation is unpredictable in California's deserts, and seasonal rains that promote germination are often followed by dry periods that stress or kill developing seedlings before they reproduce and replenish the seed bank. Many species cope with the possibility of mass seedling mortality by maintaining a portion of their seed bank in a dormant state for successive years, a strategy known as "bet hedging."

Seeds need specific environmental conditions to overcome dormancy. For example, heavy rains wash away chemical inhibitors in the seed coat, and hot or cold

soil temperatures initiate physiological changes for germination (Baskin and Baskin 1998). Various strategies of seed dormancy promote species coexistence and high biodiversity in desert shrublands. This biodiversity is important at a time when extreme and fluctuating climate patterns present strong selective pressures for adaptation.

Birds, small mammals, and ants distribute seeds to locations that are favorable for seedling establishment (Tevis 1958, Nelson and Chew 1977), but they also consume copious amounts of seeds. Perennials known as "masting" species produce extraordinarily large seed crops in some years. These large crops during "mast years" overwhelm seed harvesters by producing more seeds than can be consumed or stored. For example, Joshua tree (*Yucca brevifolia*) produces large seed crops only once or twice a decade. Because seeds rapidly lose viability in the soil, the opportunity for seed germination and seedling establishment is urgently timed to coincide with summer rains that closely follow seed dispersal (Reynolds et al. 2012).

THREATS TO NATIVE SEED BANKS

Seed banks are vulnerable to human-caused disturbances that impact desert soils. Concentrated vehicle use has cascading impacts on seed banks: vehicles crush and kill seed-bearing shrubs, and they compact soils or destabilize soil aggregates so that soil, litter, and seeds are exposed to wind and water erosion. In a study at Fort Irwin, California's National Training Cen-

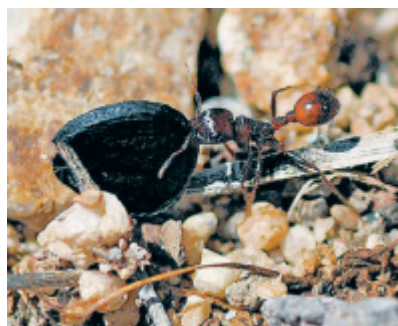


ABOVE: Understanding seed banks commonly starts in the greenhouse by subjecting field-collected soils to alternating wetting-drying cycles until all seeds germinate and seedlings are identified and counted. This process takes up to nine months. TOP: Native seeds of perennial shrubs such as white bursage (*Ambrosia dumosa*) are rare in the seed bank compared to annual species. All photographs by Lesley A. DeFalco unless otherwise noted.

ter near Barstow, military training reduced the number of species in the seed bank by half and the number of seeds to one-sixth those of undisturbed areas (DeFalco et al. 2009). Excavation of trenches for tank exercises diminished the abundance of perennial seeds, burying them too deep for seedlings to emerge when the trenches were refilled. These disturbances resemble those common throughout the desert associated with recreation, construction of aqueducts, power lines, and pipelines. Comparable impacts to seed banks are expected as urban areas expand and alternative energy projects increase.

Fire and invasive species also threaten desert seed banks. The increasing incidence and size of wildfires in recent decades is paralleled by the invasion and dominance of exotic annual grasses at middle (cheatgrass, *Bromus tectorum*) and low elevations (red brome, *B. madriensis* ssp. *rubens*; Mediterranean grass, *Schismus* spp.). In contrast to California coastal scrub, many Mojave and Sonoran shrubland species do not readily resprout after injury by fire. Whereas new seedlings typically arise from the seed bank following natural disturbances, a recent study found that fire killed 55%–80% of seeds in a Mojave Desert seed bank of northern Arizona (Esque et al. 2010). Two exotic species, one with small seeds that filtered into soil cracks (Mediterranean grass) and another with a self-drilling appendage (stork's bill, *Erodium cicutarium*) helped them escape lethal temperatures.

Comparing seed banks in recovering burned and unburned shrublands, we found seed densities of the dominant native annual grass (six-weeks fescue, *Festuca octoflora*) declined by more than 70% and native forbs by more than 50% due to wildfire. In contrast, exotic annual grass and forb seed densities



Small mammals such as kangaroo rats (*Dipodomys* sp.) and harvester ants (*Pogonomyrmex rugosus*) collect seeds of most shrub species. Rodents gather seeds and store them in shallow caches, and seedlings emerge when seeds are forgotten. Also pictured is a Joshua tree seedling (*Yucca brevifolia*). Harvester ant and Joshua tree seedling photographs by Todd C. Esque.

were two- and six-times higher, respectively, than their native counterparts. Furthermore, burned sites had one-third the number of native species than adjacent unburned areas, signaling a significant loss of plant diversity.

Air pollution associated with urban development, particularly from the Los Angeles basin, is making its way into desert wildlands. Nitrogen emissions are blown inland and enrich the ordinarily infertile desert soils. Exotic annual grasses are well-

sued to nitrogen pulses for growth and reproduction compared with native species. A study at Joshua Tree National Park showed that sites with the lowest nitrogen deposition had the highest seed bank species richness (Schneider and Allen 2012). Continued nitrogen exposure is expected to reinforce exotic dominance in the seed bank, thereby reducing native species diversity.

A PRESCRIPTION FOR REPAIR

Rehabilitating degraded shrublands depends in part on minimizing further disturbances, developing methods for suppressing aggressive exotics, and replenishing native seed banks. We have found across multiple sites that pre-emergent herbicides (applied before the arrival of fall and winter rains) are effective at not only suppressing exotic annuals by 50–95% up to three years after application, but also at reducing their seed bank in as many years. Furthermore, native annual species—six weeks-fescue in particular—increased in shoot mass and seed bank density following herbicide treatments. Seed dormancy may play a role in protecting native seed populations from herbicide impacts, whereas exotic species such as red brome that lack dormancy can be gradually reduced in infested areas.

In a related study, herbicide application in combination with native seeding increased the density of early-colonizing species six-fold, including desert marigold (*Baileya multiradiata*) and desert globe-mallow (*Sphaeralcea ambigua*). Larger areas of treatment may exclude exotic annuals for longer periods of time and restore native species' ability to accumulate in the seed bank. Limited herbicide use is intended to accelerate native species establishment so that the plant



Landscape-scale disturbances such as concentrated vehicle areas (above) and areas burned by desert wildfires (below) kill seed-bearing shrubs and disrupt vulnerable surface soils where seeds reside, making vegetation recovery difficult.

community can resist reinvasion and rebound from future disturbances. However, the impacts of herbicides to soil microbes and to the animal populations in larger treatment areas are unknown.

Based on supplemental seed studies, ants and rodents can collect more than 80% of the seeds broadcast during revegetation (DeFalco et al. 2012). We are exploring methods to encapsulate seeds and shield them from granivores until suitable conditions promote establishment. One method has been to use “seed balls,” a mixture of seeds, clay, and organics. When dried, the marble-sized pellets are durable when scattered across large disturbances.

However, initial evaluation of seed balls using native desert species proved less successful than expected, so we are adjusting the recipe to improve seedling emergence and assessing plant establishment at a variety of sites.

Despite our progress using restoration methods on small experimental plots, seed availability for restoration projects is limited because desert species do not reliably produce enough seed from one year to the next. Seeds purchased from commercial collectors are expensive and not always representative of local ecotypes, or may even have been collected outside the desert ecoregion. Since 2010, federal and state agencies, universities, arboreta, and botanic gardens have cooperated to acquire local populations of native species (see the Seeds of Success Program, nps.gov/plants/sos).

Spring 2013 was a unique mast year for a variety of species including Joshua tree, Nevada joint-fir (*Ephedra nevadensis*), and blackbrush (*Coleogyne ramosissima*). In fact, blackbrush reproduced across its entire range in the Mojave Desert and the Colorado Plateau. These mast events are opportunities to collect the seeds of multiple populations across species’ ranges for use in restoration, and when properly stored, the seeds remain viable for up to 20 years (Kay et al. 1988). However, collecting seeds cannot, alone, keep pace with the growing need caused by increasing disturbances. Seed production of native species by farmers distributed across the desert ecoregion may eventually provide a reliable and abundant source for wildland seedings and at reasonable prices.

Even when seed production is sufficient,

preserving and restoring vulnerable topsoil layers is essential for revegetating degraded desert lands. Surface soil not only holds the seed bank but also holds organic litter and microbes important for plant mineral nutrition. Topsoil collection and replacement (using heavy equipment) has potential application for severe disturbances (for example, bladed sites for solar arrays, wind farms, and geothermal facilities). Large-scale seed bank conservation is difficult, however, because conventional equipment collects soil below a 1–2 inch depth, often mixing deeper seedless soil fractions with seed-rich topsoil. This mixing dilutes seed numbers in the stored soil and upon redistribution, buries seeds too deeply for seedling emergence (Scoles-Sciulla and DeFalco 2009).

Traditional approaches to rehabilitate degraded shrublands, in addition to seed bank conservation, aim to replace ecosystem components destroyed by disturbances and include transplanting seedlings, providing structure through vertical mulch, and improving soils before reseeding, to name a few. Although restoration ecologists are working on solutions to reverse the degradation of disturbed shrublands, minimizing disturbances and promot-



Experimental application of herbicide in late fall (blue dye) has been effective at diminishing exotic annuals in the seed bank of repeatedly-burned areas.



Reseeding with natives in combination with herbicide applications promotes native establishment, as pictured here for desert marigold (*Baileya multiradiata*) on small experimental plots in the eastern Mojave Desert.

ing shrubland function is the first priority.

Importantly, our progress in developing rehabilitation solutions does not justify the continuing degradation of California's desert lands, because plant community composition does not readily recover for many decades to centuries. Limiting human activities to areas already disturbed and protecting areas with minimal disturbance is the best strategy for preserving our unique desert shrublands and the plants and animals that depend upon them.

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Laboratory trials with “seed wafers,” an improvement over seed balls, have shown that encapsulating seeds in a soil matrix improves water status and increases seedling emergence over unprotected seeds. Field trials are ongoing to determine if wafers reduce the need for high seeding densities, thereby reducing costs.

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NEW CNPS FELLOW: DOREEN SMITH

by Amelia Ryan

After more than 30 years as a member of CNPS and more than 20 years of service on the Marin Chapter Board, Doreen Smith joined the august ranks of CNPS Fellows in June 2013. Today Doreen is generally regarded as the chapter member with the deepest and most comprehensive knowledge of the flora of Marin.

Her introduction to the Society came through interactions with another CNPS Fellow and pioneering member of the Marin Chapter, Wilma Follette. For many years Wilma had taught a course on plant communities at the College of Marin, but when a young transplant from Britain joined her course sometime in the late 1970s, the newcomer immediately stood out.

"She was by far the most knowledgeable person in the class," says Wilma of Doreen. Through Wilma's encouragement, Doreen soon joined the California Native Plant Society and began accompanying Wilma on her weekly wildflower walks. Thus began a long and fruitful relation-



ship with the Marin Chapter and CNPS.

Doreen's interest in the plant kingdom predates her arrival in the US in 1967. The daughter of a gardener and a housemaid, Doreen Lina Wood was born outside Luton, England in a country in the midst of a war, and spent her childhood in the austere years that followed. Nevertheless, growing up as she did, part of the "downstairs" of a large country estate did afford some advantages. The formal gardens her father oversaw and the pastures and remnants of wild woods were wonderful places to learn plants and explore wildflowers when the estate's owners were not in residence and the head gardener's daughter could wander about.

A good student, Doreen won a scholarship to Bristol University where she acquired a bachelor of science in botany and importantly met Vernon Smith, then a young physics student from the North of England, now her husband of more than 50 years. She also achieved a cer-

tificate in secondary science education, but ended up working on the flora of Tropical East Africa at the herbarium of the Royal Botanic Gardens, Kew, noting that "this was a much quieter job than managing a classroom of adolescent girls." She'd even begun work on a master's degree when Vernon was offered a position at UC San Francisco, and the couple set sail for the Bay Area.

Although Doreen began her activities with the Society when she was a young mother in the seventies and continued them when she went back to work as a science teacher in the Marin Public Schools, they were necessarily more limited until her retirement in 1991. At that time she then became the education chair for the Marin Chapter, a post she served in for five years. From 1995 to 2013—a period of 18 years—she served as the chapter's rare plant chair. She also served briefly as co-vice president in 2009–2010. In total, she served on the chapter's board for nearly 25 years.

Doreen's passion for, and knowledge of, the flora of California are legendary. Her knowledge of the Marin flora, and in particular its rare plant species, is encyclopedic. She knows the locations, lineages, ecology, and nomenclature of all the recognized and unrecognized variations of the plants that grow there. She has been responsible for finding uncountable new populations of rare species, for rediscovering several species thought extirpated, for expanding the list of known Marin natives, and for being the first to spot and sound the alert on many a new invader. In fact, by all accounts she drove the authors of the Second Edition of the Marin Flora quite crazy because, as co-author Wilma Follette recalls, "she kept adding new species and occurrences."



Doreen Smith botanizing at Bodega Bay in 1970. All photographs by Vernon Smith.

The Marin Chapter is not the only group that has relied on her detailed and precise knowledge of the county's flora. Many public agencies call on her to identify tricky new species, locate cryptic rarities, and double check lists for accuracy and completeness. In addition, she is often found at public meetings providing testimony on behalf of rare plants.

No matter how versed you are in the California flora, you are sure to learn something new if you accompany Doreen on an excursion. Says fellow board member Carolyn Longstreth, "I went on a field trip with Doreen along a trail I often hike. I thought I knew all the plants that grew along that trail, but she must have pointed out a dozen plants I hadn't even noticed before." In fact, a great way to test your plant

knowledge is to take along on a hike one of the dozens of Marin plant lists that Doreen maintains, adds to, and continually updates. It can be a humbling experience!

CNPS, land managers, and the public have all benefitted from Doreen's formidable knowledge and willingness to share it. But even more, in Doreen Smith, the rare and special plants of California have an unwavering champion.

Amelia Ryan, P.O. Box 162, Inverness, CA 94937, amelia_byrd_ryan@yahoo.com



TOP: Doreen and fellow Marin CNPS member Vivian Mazur on a rare plant monitoring excursion led by Doreen in March 2013 at Kehoe Beach. Vivian is the Marin Chapter historian. • BOTTOM: Doreen leading another rare plant outing at Abbott's Lagoon, Point Reyes National Seashore, in April 2013.

BOOK REVIEW

Seed of the Future: Yosemite and the Evolution of the National Park Idea by Dayton Duncan. 2013. Yosemite Conservancy, San Francisco, CA. 224 pp., \$27.00 softcover. ISBN# 978-1-93023-842-8.

To start, this is my kind of book! It is packed full of interesting facts and history about Yosemite and how it became a park. Included are over 100 archival images and beautiful landscape photographs of Yosemite and

those visionary people who were instrumental in protecting this sublime part of California for future generations, including Galen Clark, John Muir, Frederick Law Olmsted, Theodore Roosevelt, and others. The

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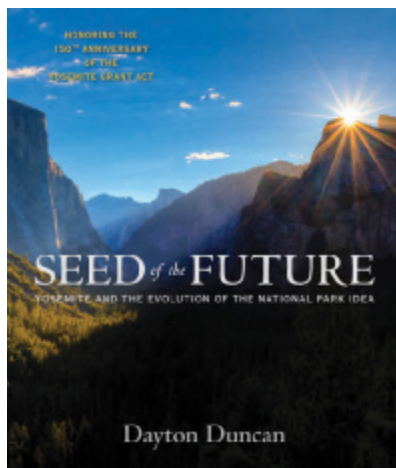
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book also familiarizes us with those people who wanted to exploit Yosemite for their own financial gain without considering the environmental importance of such outstanding natural places. Dayton also explains how the idea of preserving natural areas like Yosemite turned into our current National Parks program, which inspired similar programs throughout the world.

The book includes copies of important documents that are integral to the protection and formation of Yosemite National Park. Its publica-



tion is in honor of the 150th anniversary of the founding of the Yosemite Grant, a bill signed by President Abraham Lincoln.

In his compelling narrative, Dayton describes the struggles that visionaries like Muir and Olmsted had with the powers that be on how to save and protect Yosemite. John Muir struggled to his dying day to protect the Hetch Hetchy Valley from having a dam installed, and Frederick Law Olmsted knew way before his time how best to develop Yosemite while protecting it for future generations. Dayton reminds us that Muir knew the only way to get people to protect this beautiful area, especially those in a position of power, was to have them experience the place for themselves. Olmsted had written a very detailed management plan for Yosemite, which

was squashed and buried for political reasons. It took Congress and the National Park Service many decades to actually figure out that his plan was spot-on. The report wasn't rediscovered until 1952 when a descendent found it in Olmsted's papers.

My only complaint about the book is that it is relatively heavy because it is printed on high-quality paper, making it hard to hold in your hands. However, this could be seen as an opportunity for armchair enthusiasts to get some exercise (if only for their arms and wrists).

Seed of the Future could easily serve as an authoritative historical reference on our National Parks due to its thoroughness in covering the history of the formation of this jewel of a national park, and in tracing how the idea of setting aside natural areas for preservation and enjoyment grew into our national park system. It belongs in every library, and is also attractive enough to display on a coffee table.

Dayton's book has inspired me to get back to Yosemite, which I have not visited now for several years, and it will likely inspire many other people to visit and fall in love with Yosemite and our other national parks. It is certainly a great book to read, as I did, in front of a fire on a cold winter evening, although it will hold your interest just as much on a balmy summer day.

—David L. Magney



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WHAT SHAPED YOUR LOVE OF NATURE?

[Editor's Note: Fremontia readers were invited to send in their stories of what shaped their love of nature. These are the first two responses we've received. If you are motivated to send us yours, it can be about 250 words, and should be emailed to bhass@cnps.org. Be sure to include a high-quality headshot, or a photograph of yourself in a natural place you love, and the name of the photographer who took it.]

SUZANNE SCHETTLER Santa Cruz County Chapter

I grew up in a middle-class suburb. On weekends the family took care of the yard. The neighbors across the street always had a perfectly manicured yard, and we tried to keep up with the Mullinses.

I must have taken to gardening more than my two sisters, because I adopted a little planting bed by the front door of our house. I grew portulaca and zinnias and other mundane things appropriate for a child gardener.

Later, when I was eight, I asked for a garden of my own. There was a strip of land, maybe 18–20 feet wide, on the east side of the house (ideal!) under my bedroom window that my parents let

me have. I had to climb over a fence to get to it, and I grew vegetables and flowers all mixed together long before that was fashionable. The fence would be a challenge now.

In fall when we raked leaves in the back yard, my sisters and I would play in the leaf piles. A neighborhood friend had parents who let us build a tree house and dig a fort at the back of their yard. We were at home in nature, and it's sad that children are now so isolated from their natural home.

On the question of which is more formative in a person's life, nature or

nurture, I apparently had both because I was lucky that my parents supported my budding interest. Today I am a licensed landscape contractor specializing in native plant restoration.

♦ ♦ ♦

Suzanne Schettler's varied career has included, among other things, working as a native plant nursery manager and on a UC natural history reserve. She also served as state CNPS president from 1989 through 1991.



SAXON HOLT

KATHERINE GREENBERG East Bay Chapter

My impressions of the natural world were formed by childhood walks in the wildflower fields of the Jolon Valley, hikes in the rugged canyons of Big Sur and mountain meadows in the High Sierra, and summers at Camp Cawatre in Arroyo Seco. I grew up hearing stories about the homestead where my great grandparents lived near Mission San Antonio, my grandfather's adventures with his childhood friend John Steinbeck, and my father's native plant scrapbooks that he filled with pressed leaves and flowers.

I also remember my first encounter with poison oak, when I was warned

not to touch it just as I was about to pick some of the most beautiful, glossy red leaves that I had ever seen. In my garden in the East Bay hills I have tried to recreate the landscapes of my childhood with plants from California's grasslands, chaparral, oak woodlands, riparian woodlands, and redwood forests.

♦ ♦ ♦

Katherine Greenberg is a garden designer and co-author of *Growing California Native Plants* (2nd edition, UC Press, 2012). She was the founding president of the Friends of the Regional Parks Botanic Garden in Berkeley, California.



TERRY BROWN



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(continued from back cover)

Julie Evens is director of the CNPS Vegetation Program and oversees surveying, classification, and mapping of vegetation in California.

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David Magney is a botanist and environmental consultant with over 30 years of experience, and since the mid-1980s has served CNPS in leadership roles at the state and chapter levels.

Bruce M. Pavlik founded BMP Ecosciences, an Oakland-based environmental consulting firm, and is the head of restoration ecology at the Royal Botanic Gardens, Kew, England.

Amelia Ryan is an ecologist and a member of the CNPS Marin Chapter Board since 2010.

Greg Suba is the CNPS Conservation Program Director.

Karen Tanner is a biological researcher at BMP Ecosciences, and is currently assessing solar development impacts on rare plants in the Mojave Desert.

SUBMISSION INSTRUCTIONS

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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Michael D. Bell was a postdoctoral fellow at UC Riverside where he did research on modeling for habitat conservation plans, and is currently a postdoc at the Center for Environmental Biology, UC Irvine.

Lesley DeFalco is a research plant ecologist with US Geological Survey. She studies endangered plants, impacts of invasive annual species, and restoration of desert habitats.

Rebecca Degagne is a biologist and GIS analyst for the Conservation Biology Institute, a nonprofit providing scientific expertise to support conservation and recovery of biodiversity locally, regionally, and globally.

Todd Esque is a research ecologist with USGS. His recent work focuses on habitat modeling, climate change, landscape genetics, and conservation in desert lands.

FROM THE EDITOR

In the last issue I extolled the hard work of researchers who spend countless hours “in the field”—an expression widely used by those who trek out into nature to conduct surveys, gather data, or restore habitat. Maybe because I spend so much time working with words and enjoy all their nuances, I’ve always found that expression mildly entertaining, because being told someone will be “in the field” conveys an implicit message that they may be unavailable for a while. And the “field” being referred to is not the one described in the dictionary, but instead a wild or undeveloped area that we hope still contains an intact ecosystem with a diversity of plant and animal life.

This second *Fremontia* issue on California’s deserts contains additional valuable information on these “fields” of biological observation, with an emphasis on current threats and promising conservation strategies.

As these two issues have materialized, I’ve come to appreciate more than ever the central, essential role that photographs play in telling the story of our deserts. When a natural area is under threat, the old saying that “a picture is worth a thousand words” rings true. Photojournalists have known this for decades, but so have naturalist photographers, which is why the photographs of Ansel Adams and others move us. They convey so much information without the use of a single word.

Before and after photographs taken in the same spot over time are the most effective way for people to really grasp the scale of the changes taking place in our deserts and other natural areas. It was a challenge for us to find the perfect photos for these two desert issues of *Fremontia*. Naturalist photographers reading this note, pay heed to this great challenge!

—Bob Hass

(continued on inside back cover)