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FREMONTIA

RESTORATION

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CALIFORNIA
NATIVE PLANT
SOCIETY

Protecting California's native flora since
1965

Our mission is to conserve California's native
plants and their natural habitats, and increase
understanding, appreciation, and horticultural
use of native plants.

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FREMONTIA

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FROM THE EDITORS

What kind of world do we want, and how do we get there? These are the questions that drive restoration, the central theme of this issue. They are also the questions that have led the California Native Plant Society leadership to initiate an important change to this publication, which will take effect in the spring 2021 issue.

The name of this publication, *Fremontia*, has been a point of concern and discussion since last winter, when members of the CNPS leadership learned some disturbing facts about John C. Frémont, from whom dozens of North American plants, including the flannelbush plant *Fremontodendron californicum*, derive their names. According to multiple sources, including the State of California Native American Heritage Commission, Frémont was responsible for brutal massacres of Native Americans in the Sacramento Valley and Klamath Lake. As a consequence, the CNPS board of directors voted unanimously to rename *Fremontia*, a process slated for completion by the end of 2020.

The decision to rename *Fremontia*, a name that dates back to the origins of the publication in 1973, is about the people who have been—and continue to be—systematically excluded from the conservation community. It reflects the recognition that conservation science cannot achieve its full potential until all barriers to participation for Black, Brown, and Indigenous people; women; and other marginalized groups are eliminated. Many concrete steps are needed to reach that goal, and CNPS is committed to identifying and taking the actions required to be truly inclusive and representative of the incredible diversity of our state. Though more symbolic than many of the other necessary actions, finding a new name for CNPS's flagship scientific journal is an important part of that process.

Like ecological restoration, the goal of making conservation science fully inclusive is not one that can be accomplished quickly, over the course of a single season or even decades. It must begin by understanding the harm that's been done and recognizing the damage that's ongoing, including the history of how things came to be as they are now. Renaming *Fremontia* is not an attempt to rewrite that history, but to learn from it, acknowledge it, and chart a new path forward—one that not only continues this journal's tradition of native plant science but enriches it. Stay tuned for the announcement of our new name in 2021, and many great issues to come.

—Emily Underwood, CNPS publications editor, and

Liv O'Keeffe, CNPS senior director of communications and engagement

Cover: A flannelbush (*Fremontodendron californicum*) in bloom at the Devil's Punchbowl in the Angeles National Forest. (Photograph by Sean Hueber)



Wetlands in Manchester State Park, CA. [Photograph by Alexis LaFever-Jackson]

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INTRODUCTION

Andrea Williams

As 2020 draws to a close, we will enter what the United Nations is calling the Decade on Ecosystem Restoration, a “rallying call for the protection and revival of ecosystems” across the globe. CNPS has a long history with restoration, and this journal first published an issue detailing best practices and state-of-the-science information four decades ago. *Fremontia* has presented articles on restoration throughout its history, but this issue revisits the topic in the context of a new century.

What does it mean to restore a place to a natural state? Ecologists tend to think of ecosystems as existing along a continuum of functionality and diversity, with “functionality” representing an ecosystem’s capacity to carry out important processes such as water and nutrient cycling, and “diversity” referring to the number and proportion of species present and amount of genetic variation a system can support.

Broadly speaking, restoration is an attempt to return an ecosystem to a desired state or range of conditions on this continuum. But as you’ll read in the following pages, this work is challenging, filled with hard choices, philosophical questions, and humbling lessons. With contributions from an outstanding panel of authors,

we explore this important discipline through case studies, instructional articles, and essays on the ethical, cultural, and practical considerations of the work.

In practice, the term restoration encompasses actions as diverse as removing invasive species, creating rare plant populations, altering landforms and hydrology, and introducing or removing major disturbances such as fire or grazing. Restoration can be undertaken for the love of place and native plants, as we read in a conversation between David Loeb and Lech Naumovich on page 32. It can be a process of ecological and cultural revitalization that provides sustenance to Indigenous communities, as Jonathan Long, Ron Goode, and Frank Lake detail on page 14. Frequently, however, restoration projects stem from the legal obligation to mitigate the impacts of development. In these cases, external factors such as time, budget constraints, or political expediency can impose limitations on the work that hinder its long-term success, and even affect how “success” is defined.

Underpinning restoration must be an understanding of the system in a natural state, the drivers of its depar-

Above: Restoration team planting native California cordgrass (*Spartina foliosa*) to prevent erosion at Sears Point in Sonoma, CA.

[Photograph by Michael Vasey]

ture from that state, and an identification of the path to a desired future state. Where do we place these desired states? Do we have a reference location for our natural state, or is that reference location itself impacted by stressors such as climate change and surrounding land use changes, such that the reference location has shifted from an ideal baseline? Can we reach that desired state? Can we know it? Do we work to assemble an ecosystem that will be functional and diverse in a theoretical climate future by incorporating non-local species or genetics, or do we collect seed from native species in a hotter, drier site nearby that are already thriving under the current pressures of invasive plants? CNPS's recent symposium, "Genetic Considerations in Planting and Restoration," explored both the diversity hidden in local variation, and the implications for restoration, including prospective "climate future" plantings and special considerations for rare plant populations.

Restoration is expanding and evolving rapidly, and we need to meet it with practical considerations grounded in science. Patrick Reynolds describes such considerations in his article on seed-based restoration on page 24, and Matthew Garrambone and Sunny Saroa lay out the challenges of scaling seed-based restoration up to the landscape scale on page 20. Restoring populations of even a single rare plant species can take decades of trial and error, as Stuart Weiss, Lewis Stringer, and Michael Chassé chronicle through seven California case studies on page 4. Once a population or ecosystem recovers, the question remains of how to maintain it in the face of increased pressures from invasive species, land use, and climate change.

In addition to practical concerns, restoration professionals must grapple with ethical quandaries such as those Naomi Fraga describes on page 38. In her essay on a mining company's efforts to mitigate its impacts on the endangered Tiehm's buckwheat (*Erigeron tiehmi*) in Nevada, Fraga asks restoration professionals to carefully consider the ethics of approving rare plant reintroduction for mitigation purposes, and to uphold the duty to conserve and preserve species in their native habitats. The article by Weiss, Stringer, and Chassé underscores the importance of preserving plants in their original locations, even as we attempt to restore and create new populations of rare plants. Most of the species they describe grow exclusively in a specific soil type or place, raising the question of whether plants taken from their original context are being preserved merely as specimens in a "plant museum."

At times we balance the risk of inaction against the risk of uncertain or imperfect actions, and restoration often weighs these risks. We can minimize restoration risks or failures by incorporating an adaptive management framework. The first step is creating a conceptual model: outlining the expectations for how the natural system is currently (mal)functioning, and what actions are needed to reach a desired state for that system. The type, duration, and frequency of monitoring should follow logically from a project's stated goals, and the results from monitoring should inform additional or corrective actions, as well as any adjustments to the conceptual model of the system. If restoration is to succeed at any scale, we must allow adequate time to gather sufficient information for planning, seed sourcing and pre-project monitoring, and support for longer-term, post-project monitoring and adaptive management.

If the belief that we can recreate ecosystems is the hubris behind mitigation, what then is restoration? At its core, it is a human response to fix one or more human-caused problems, and must therefore be guided by our core values, from impetus to long-term maintenance and stewardship. In its 2020 resolution, the United Nations emphasizes that restoration "needs to be carried out in ways that balance social, economic and environmental objectives, and with the engagement of relevant stakeholders, including Indigenous peoples and local communities." Long, Goode, and Lake detail examples of how such engagement can work, and how Indigenous knowledge can strengthen the science of restoration projects.

The success of restoration hinges on the involvement of stakeholders and their future interactions with restored sites. Public lands in particular may depend on local volunteers for restoration and stewardship, as John Hunter describes in his overview of CNPS chapter-based restoration work on page 28. In 2020, Governor Newsom issued an executive order to protect 30 percent of California's land and water and involve working lands in climate and biodiversity solutions. To achieve that mission, the conservation community must include diverse groups in creating solutions that preserve biodiversity, and build reciprocal relationships with land and people. Ultimately, the goal should be to restore nature not as something separate from us, but as the living connection between each of us.

—Andrea Williams is the director of plant science at the California Native Plant Society.
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RESTORING IMPERILED PLANT POPULATIONS

Stuart B. Weiss, Lewis Stringer, and Michael Chassé

In the deepening shadows of the global extinction crisis (IPBES 2019), Californians must tend their own biodiversity hotspot, a responsibility expressed in the 2018 California Biodiversity Initiative and Governor Gavin Newsom's 2020 executive order on biodiversity. Conservation of biodiversity spans ecosystems, landscapes, communities, species, and populations, extending to the molecules of DNA entangled in chromosomes. Even the most diminutive rare annual plants are irreplaceable, and carry aesthetic, moral, and scientific value.

The combination of narrow endemism and intense human pressures has resulted in more than 270 California plant taxa listed as threatened or endangered. The *CNPS Inventory of Rare and Endangered Plants* considers hundreds more as rare. These taxa often require exacting soil and climatic conditions and intensive habitat management to counteract rapid environmental changes such as climate chaos, invasive species, nitrogen deposition, and disease, and to overcome the genetic and demographic perils inherent to small populations.

We fully embrace the need to conserve large, diverse, connected landscapes where feasible (Beier et al. 2015). For example, the Bay Area Conservation Lands Network (BAOSC 2019) developed a regional conservation strategy to formally conserve 50 percent of the land in 10 counties surrounding San Francisco Bay, protecting biodiversity at all scales. Nevertheless, we also embrace species as fundamental units of biodiversity, that present integrated genetic solutions to the challenges of survival through evolutionary time (Wilson 2016).

The importance of species is eloquently enshrined in the powerful US and California Endangered Species Acts, and in Aldo Leopold's 1947 assertion that "to keep every cog and wheel is the first precaution of intelligent tinkering." Small remnant populations, often located in tiny, isolated habitat fragments, demand customized combinations of weed management, propagation, and population augmentation and reintroduction to achieve recovery. Funding, permitting, institutional alignment, and scientific knowledge

Above: Andrew "Drew" Schuyler planting Franciscan manzanita clones on the Presidio serpentine bluffs on April 11, 2013.

[Photograph by Michael Chassé]

gaps pose additional obstacles as we make rapid decisions in the absence of certainty.

Here, we draw on collective decades of experience to illustrate what we consider the key elements of successful species restoration, through seven case studies of imperiled California taxa. These elements include, but are not limited to: immediate intervention to prevent extinction of small populations; use of copious seeds; sustained restoration efforts and funding; and rigorous experimentation to document what does and doesn't work. Because population biology is a numbers game, we report population trends in some detail. By sharing our experiences, even briefly, we hope to further the calling of conserving our rich, vulnerable, and irreplaceable California flora.

SAN MATEO THORNMINT: RESCUED FROM THE BRINK



Acanthomintha duttonii
Federal and California
Endangered Species
CNPS Inventory Rank 1B.1

[All photographs by Stuart Weiss unless otherwise noted]

The San Mateo thornmint (*Acanthomintha duttonii*) is a diminutive annual forb restricted to rare serpentine vertisols (deep clay soils). Historically the plant occurred in six locations on the San Francisco Peninsula, but by the mid-1990s only one population remained, consisting of roughly 50,000 plants within a few hundred square meters at

Edgewood Park and Natural Preserve. Biologists Bruce Pavlik and Erin Espeland (1998) spent five years attempting to start a new population on similar vertisols on the San Francisco Peninsula Watershed, putting out more than 10,000 seeds collected from the native population, but that effort failed.

By 2008, the Edgewood population had declined to 250 plants in 27 m², due in large part to the encroachment of Italian ryegrass and accumulating thatch. Two US Fish and Wildlife Service (USFWS) programs, “Preventing Extinction,” and “Partners for Fish and Wildlife” funded three years of restoration. Seed amplification (the process of collecting wild seeds and growing them specifically for seed production) was jump-started when Holly Forbes, of the University of California Botanical Garden at Berkeley, found out from Pavlik that he had retained some seeds in his office. Efforts to amplify these seeds met with consid-

erable success, aided by the plants’ tendency to produce additional flowers as they grow larger under ideal conditions, known as indeterminate flowering, and self-pollination.

In November 2009, volunteers from Creekside Science and Friends of Edgewood spread 12,500 seeds in 25 unoccupied 1 m² plots among the extant population at Edgewood Preserve. That initial seeding resulted in 2,885 mature plants, a 23 percent yield. Scraping away newly germinating grasses and forbs just prior to seeding significantly reduced annual grass cover and increased thornmint survival. In spring 2010, Creekside Science and San Mateo County Parks Department mowed upslope areas to reduce annual grasses and then scraped and seeded in fall 2010. By spring 2011, 3,450 plants occupied 102 m². Unfortunately, from 2012 to 2014 funding dropped to maintenance level, which did not support new seeding. Friends of Edgewood, San Mateo County Parks Foundation, San Mateo County Parks Department, and even a Kickstarter plea, funded project monitoring over those years.

The original site was not conducive to long-term success. The population fell to 608 plants in spring 2014 as annual grasses rebounded, and an alarming increase in parasitic dodder (*Cuscuta californica*) sucked the life from many of the remaining individuals. In 2015, a new phase began with funding from the San Francisco Public Utilities Commission (SFPUC) through an ecosystem restoration fund. Seed amplification moved to the Creekside Science Conservation Nursery, and the annual output increased to 50,000-100,000+ seeds. Creekside Science staff and CNPS volunteers applied the seeds to additional serpentine vertisol patches at Edgewood and Pulgas Ridge (SFPUC lands), concentrating on naturally bare areas to reduce risks of grass overgrowth and thatch accumulation. Some seeding expanded to larger (16 m² or greater) macroplots starting in 2018. As of June 2020, more than a decade into the project, 43,000 thornmint plants occupied over 500 m² in six occurrences, while the original population fell to only 29 individuals in 9 m². Based on the success and experience of this project, USFWS revised recovery goals upward from the original 1998 recovery plan.

Creekside Science, with support from numerous volunteers from Friends of Edgewood and CNPS, has censused all of the seeded 1 m² plots each year since 2008. Detailed demographic analyses at this scale documented wide variation in germination, survival, and reproduction, and made it clear that spreading risks

and opportunities across sites, microsites, and years was the key to positive population growth. For example, sites and microsites that became waterlogged in a wet year had low survival rates, but produced many plants in a drier year.

As with all annual plants, San Mateo thornmint must establish a soil seed bank in order to bridge bad years (Pavlik and Espeland 1998). Plants are now spreading just outside seeded areas, indicating some natural dispersal through hydrochory (by water) during an intense storm in December 2014. Creekside Science is mowing additional areas in preparation for new macroplots, and scaling back intensive monitoring. Maintaining adequate funding moving forward is a challenge, but the San Mateo thornmint is back from the brink and advancing toward the revised USFWS goals (USFWS 2019).

TIBURON PAINTBRUSH: FINDING THE RIGHT HOST PLANTS



Castilleja affinis subsp. *neglecta*
Federal and California
Endangered Species
CNPS Inventory Rank 1B.2

The Santa Clara Valley Habitat Conservation Plan/Natural Community Conservation Plan (HCP/NCCP) and other mitigation projects have protected thousands of acres of serpentine grasslands at the fringe of Silicon Valley, driven by the imperative to conserve habitat for the federally threatened Bay

checkerspot butterfly (*Euphydryas editha bayensis*) as an umbrella species. Despite the progress of this landscape-scale conservation, some of the covered plant taxa still require explicit attention to meet recovery goals.

The Tiburon paintbrush (*Castilleja affinis* subsp. *neglecta*) is a perennial hemiparasite, which absorbs some of the water and minerals it requires from the roots of host plants such as common yarrow (*Achillea millefolium*). The plant is known from six occurrences, four in the North Bay and two in Santa Clara County, on unusual serpentine soil variants. At the Santa Clara County occurrences, Creekside Science estimated population sizes at roughly 1,000 (Paintbrush Canyon) and 100 plants (Paintbrush Hill). The small Paintbrush Hill population, on a rocky hilltop, suffers from browsing by deer and cattle and uprooting by wild pigs. The larger population in Paintbrush Canyon occupies less

than one hectare on a steep (25-35°) northerly slope.

With funding from the Central Valley Project Conservation Program, in 2013 Creekside Science began restoration experiments at Paintbrush Canyon. Because of emerging problems with the pathogen *Phytophthora*, outplanting (transplanting from a nursery, greenhouse, or other location) with host plants was not possible. The Creekside Science Conservation Nursery started production beds with seeds collected from both local populations, with common yarrow as a host, and produced tens of thousands of seeds after two years. Randomized block design experiments carried out in Paintbrush Canyon in 2015-2016 and 2016-2017 tested the effects of stratification, irrigation, and seed numbers in plant establishment. Seeding rates of 750-2,000 seeds/m² were similar to seed rain around established plants. The cover of golden yarrow (*Eriophyllum confertiflorum*) was a good predictor of establishment of mature flowering plants, indicating that it is a good host plant. Establishment rates were higher on the steepest, most shaded north-facing slopes and in irrigated plots, indicating that moisture could be a limiting factor in seedling establishment.

Funding for the project from the Central Valley Project Conservation program ran out in 2017, discontinuing the experiments except for monitoring. A disagreement with the new landowner of Paintbrush Hill, Santa Clara Valley Water District, arose over whether it was appropriate to mix the seeds of the two local populations despite only 1800 m of separation, high genetic similarity, and moderate inbreeding in each population (Widener and Fant 2018). To quell the conflict, the nursery ripped out the established seed production beds and restarted with seeds from Paintbrush Canyon only, but the experiment had already introduced genetic material from Paintbrush Hill into Paintbrush Canyon, which can counteract the moderate inbreeding.

In 2018, the Paintbrush Canyon population approached the USFWS recovery goal of 2,000 plants. The next phase targeted seeding adjacent to host plants, especially *Eriophyllum*. Seeding in fall 2019 preceded a near-record dry spell in January-February 2020. Few seedlings survived, but as of May 2020, seeded plots from all years have added more than 200 mature plants to the Paintbrush Canyon occurrence. Creekside Science plans to increase seeding in fall 2020 and beyond: The next major milestone is to document unambiguous natural recruitment from the new plants.

METCALF CANYON JEWELFLOWER: SEND IN THE COWS AT THE RIGHT TIMES



Streptanthus albidus subsp. *albidus*
Federal Endangered Species
CNPS Inventory Rank 1B.1

[Photograph by Justen Whittall]

The Metcalf Canyon jewelflower (*Streptanthus albidus* subsp. *albidus*) is a narrowly distributed annual forb with six mapped occurrences on rocky serpentine grasslands in the northern reaches of Coyote Ridge in San Jose. White sepals distinguish it from the pink “most beautiful” jewelflower (*S. albidus* Greene subsp. *peramoenus*) located further south, separated by a several kilometer-wide zone of mixed phenotypes.

The published taxonomy is uncertain: *The Jepson Manual* designated the Metcalf Canyon jewelflower as a subspecies of *Streptanthus glandulosus* and eliminated the most beautiful jewelflower as a recognized taxon. However, the *CNPS Inventory of Rare and Endangered Plants* retains both taxa, and both are covered in the Santa Clara Valley Habitat Plan. Ongoing research aims to discern the phenotypic patterns and underlying genetics of the two taxa, and to designate occurrences under the Valley habitat plan.

On Tulare Hill, a 150-ha serpentine outcrop west of Coyote Ridge, intense overgrazing and development eliminated Metcalf Canyon jewelflower in the 1990s. Reintroducing the plant at that location could establish a large population on now-protected land. Toward that end, in 2012 the Central Valley Project Conservation Program funded experiments conducted by Justen Whittall of Santa Clara University and Creekside Science.

Whittall and Creekside Science staff collected seeds from several pure white Metcalf Canyon jewelflower occurrences. Growing the seeds in optimal greenhouse conditions produced large plants and copious seeds. The team built grazing exclosures in December 2013, and planned to seed Tulare Hill after the first 50 mm of rain. December, January, and most of February passed with no significant rainfall, until a soaking storm finally materialized in early March. At that point, with the help of CNPS volunteers, the team seeded 160 plots with 100 seeds/m². The results were disappointing: Out of 16,000 seeds, only 17 seedlings and no reproductive plants appeared in the spring of 2014.

The failure of the seeding effort contrasted greatly with the success of natural populations. Despite the

extreme drought, 2014 was one of the best jewelflower years on record. Supposedly unoccupied control plots on Coyote Ridge, which contained no jewelflower skeletons and received no seeding, sprouted numerous vigorous jewelflowers.

In early November 2014, the team sowed 64,000 seeds in a different set of subplots on Tulare Hill and left them to the whims of the weather. December 2014 brought heavy rains and >4,700 seedlings emerged. Seeds from the March 2014 plantings had survived over summer 2014 as a seed bank, and germinated in December, along with the newly seeded plots. The 1,160 mature plants that survived produced 4,050 siliques (seed pods) by September 2015. These replaced roughly 96 percent of the 80,000 seeds planted over the two preceding years.

In December 2015, the team planted the remaining seeds in 30 x 1 m strips outside the original plots, but these produced few germinants and no mature plants. Cattle breached the exclosures meant to keep them out, resulting in only 45 fruiting plants by June 2016. Demographic data showed that cattle grazed the vegetative plants in mid-spring, when annual grasses had cured and even small amounts of green foliage were attractive. However, grazing is absolutely necessary on Tulare Hill to control the intense annual grass growth stimulated by atmospheric nitrogen deposition from Silicon Valley smog (Weiss 1999). Fortunately, the rancher can remove cattle in early May, before the herbivory becomes too intense, averting conflicting conservation needs.

Jewelflower populations on Coyote Ridge undergo large fluctuations from year to year, a fundamental characteristic of annual plants. Accepting these natural fluctuations is necessary when judging conservation outcomes. Even in extreme drought conditions, the production of copious seeds is possible if the timing of rainfall is favorable, and seed banks are key to survival for annual plants. Also, exposing seeds to the natural sequence of the heat and drought of summer, and the cold and wet of fall and winter may beat trying to second-guess Mother Nature with regard to the timing of seeding.

By 2020, the population of Metcalf Canyon jewelflower had expanded to more than 6,000 plants in six distinct areas of Tulare Hill, including two sites located well away from the experimental plots. Additional mass seeding, carried out at a modest cost, can rapidly expand this nascent occurrence under the revised grazing regime and meet an important goal of the Santa Clara Valley Habitat Plan.

PRESIDIO CLARKIA: CONTROL ANNUAL GRASSES



Clarkia franciscana
Federal and California
Endangered Species
CNPS Inventory Rank 1B.1

Presidio clarkia (*Clarkia franciscana*) is an annual forb restricted to two serpentine grassland sites in San Francisco and Oakland. Once thought to be endemic to San Francisco's Presidio, in 1980 Katherine Culligan discovered a distinct population in Oakland at Serpentine Prairie, on

land owned by the East Bay Regional Park District. Disturbance from off-road vehicles and competition from invasive species pushed the Presidio population to the brink of extinction in the late 1960s.

In the early 1970s, the founding director of the Regional Parks Botanic Garden, James Roof, likely saved Presidio clarkia from extirpation through seed rescue, amplification, and reseedling. However, in the ensuing time between Roof's work and the transfer of the former Army base to the National Park Service in 1994, the population dropped once again to perilously low numbers due to competition and shading from invasive trees and annual grasses.

Prior to the USFWS listing of Presidio clarkia as an endangered species in 1998, the National Park Service (NPS)—under the leadership of Sharon Farrell and Marc Albert—removed Monterey pines that had invaded Presidio clarkia's serpentine grassland habitat at Inspiration Point in the Presidio in the mid-1990s. Subsequent stewardship of the grassland by NPS resulted in moderate upticks in the population, but the plant's inherent interannual variability and competition from annual grasses still posed a threat. The USFWS *Recovery Plan for Serpentine Soil Species of the San Francisco Bay Area*, authored by Diana Elam, set an annual target threshold of at least 2,000 individuals for the core Presidio population, but by 1997 a census found only 800 individuals. Mowing and string-cutting annual grasses helped to increase the population tenfold in the following years, but it was unclear how efficient and effective the control methods were, because they had not been rigorously tested.

In 2008, the Presidio Trust contracted with Creekside Science to test eight management treatments in a randomized block design experiment with 243 plots, with the goal of identifying efficient and practical methods

to increase Presidio clarkia abundance (Niederer et al. 2014). The results clearly indicated that the previous mowing and string-cutting were ineffective compared to three treatments applied in the fall after grass germination. These treatments included tarping (laying down 6 mm polyethylene sheets over fall germinated annual grasses for six weeks), soil scraping (using a McLeod rake hoe to scrape two inches of soil off the surface), and flame-torch burning (using a propane flame torch to heat vegetation beyond the typical wilting point). Direct seeding followed the treatments, using seed collected from the wild and stored over summer (no amplification).

The post-germination treatments increased Presidio clarkia numbers five to tenfold, increased native plant cover and species richness, and reduced annual grass cover for at least two years. The plant also emerged in unseeded areas, indicating that earlier generations had established a seed bank. Today, the Trust is effectively managing grasses in small 10 x 10 m patches of this 8-ha site by conducting these post-germination treatments every few years. Since implementing this patchwork strategy in 2009, the annual sampled population of Presidio clarkia within a 100 x 100 m macroplot has ranged between 25,000-350,000, hitting its peak in 2019. Several locally rare and significant forbs, as well as overall native cover, have also benefited from the periodic reduction in annual grasses.

The other Presidio clarkia occurrence, at Serpentine Prairie, has expanded following tree removal that opened up grasslands and stimulated seed bank germination. In 2010, new fencing discouraged the area's use as an off-leash dog park. Mowing and timed grazing by goats and sheep has also effectively reduced annual grasses over this larger site.

Although the two sites have different management, shared knowledge benefits both projects. As in the Presidio, Golden Hour Restoration Institute and the East Bay Regional Park District collect seeds from wild plants and redistribute them into newly treated areas. The two populations are well on their way to meeting recovery goals—a minimum of 28,000 plants and a rolling average of 140,000 plants over a 20-year period (Service 2019)—and the lessons learned will inform actions to increase numbers in other populations targeted in the recovery plan.

MARIN DWARF FLAX: SELECT THE RIGHT SITES AND SEED STOCK



Hesperolinon congestum
Federal and California
Endangered Species
CNPS Inventory Rank 1B.1

The Marin dwarf flax (*Hesperolinon congestum*) is a diminutive annual forb from serpentine grasslands in Marin, San Francisco, and San Mateo counties. Most often found on barren microsites, it somehow garners enough water and nutrients from bedrock fractures to flower in late spring. The dwarf flax his-

torically occurred at Inspiration Point in the Presidio, but was last seen there in 1987. The last remaining population in the Presidio, located near the World War II Memorial at Lincoln Boulevard, was originally deemed too small to support seed collection.

In the mid-2000s, the Presidio Trust contracted with Dr. Will Russell from the United States Geological Survey to develop a reintroduction plan for Inspiration Point, using seed stock from Ring Mountain in Marin County. That effort succeeded in establishing a small population, but by 2008, only 170 plants persisted. Dr. Yuri Springer later conducted genetic analysis on Marin dwarf flax from extant populations throughout the San Francisco Bay Area for his doctoral thesis. In consultation with Dr. Bruce Baldwin, they recommended that all Marin dwarf flax established at Inspiration Point by seed collected at Ring Mountain be removed, for fear of irreversibly changing the genetic structure of the indigenous Presidio population. In consultation with the US Fish and Wildlife Service, Presidio staff removed the small number of remaining Marin dwarf flax individuals from Inspiration Point over several years in the late 2000s.

Between 2003-2007, the extant World War II Memorial population naturally increased to a size deemed safe for collection. The Presidio staff worked with Holly Forbes at the UC Botanical Garden to collect a small number of seeds and amplify them to over 2,000 seeds. Based on the success of the Presidio clarkia project described above, in 2009-2010 the Presidio Trust and Creekside Science tested three post-germination treatments—flame, scrape, and tarp—in a randomized block experiment in typical serpentine grassland, planting 50 seeds in each plot. The intent was to reduce nonnative annual grass, increase bare ground, and break down thatch that inhibits forb germination.

The results in spring 2010 were mixed: Out of 24 treatment plots, 14 produced flowering plants, and the team observed a total of 87 plants (5.5 percent survival rate), which produced 1,622 flowers. A few large plants skewed measurements of flower output. Tarping resulted in the most plants per plot, but aggressive annual grass reinvasion in year two negated 2010's positive results, and Marin dwarf flax disappeared. Unlike Presidio clarkia, which can coexist with moderate grass and thatch cover in deeper soils, Marin dwarf flax cannot persist in such sites without continual treatments and seeding.

More optimistically, in 2009 the Presidio Trust and Creekside Science conducted a seed-versus-plug experiment in "The Quarry," a serpentine barren with virtually no annual grass. Placing 200 seeds in four 1 m² plots produced 35 plants and 164 flowers. Planting 200 seeds in 1 cm diameter x 4 cm deep cylinder trays resulted in 64 plugs which, when planted, produced 18 plants with 64 flowers. Direct seeding won the contest, hands down.

Seeding and planting at the Quarry ceased in 2009. By 2011, the population had increased to 135 plants and survived the subsequent drought at low numbers (9 and 13 in 2014 and 2015, respectively). The population's subsequent fluctuations have been strongly correlated with precipitation, declining from nearly 100 to 59 plants from 2016 to 2018, and rising to 917 plants in 2019. Seed amplification has been a challenge, due to overwatering, but once Presidio Nursery staff solves this problem, we anticipate that Marin dwarf flax will fill the Quarry and other serpentine barrens at Inspiration Point by the thousands.

SAN FRANCISCO LESSINGIA: RESTORE DUNES AND IT WILL COME



Lessingia germanorum
Federal and California
Endangered Species
CNPS Inventory Rank 1B.1

San Francisco lessingia (*Lessingia germanorum*) is an annual sunflower that inhabits sparsely vegetated sand dunes. It grew throughout the once-extensive dune sheet of San Francisco, but urbanization has restricted it to the dunes of the Presidio and to one site in Daly City.

The stabilization of the last remnant dune habitats allowed for exotic trees, annual grasses and scrub to establish and outcompete

the plant. By the early 1990s, the CNPS Yerba Buena Chapter counted fewer than 200 individual plants remaining in the Presidio.

After the Presidio became a national park in 1994, dune restoration began in earnest. A sewer failure caused a mansion to collapse on the edge of the core lessingia population, and the National Park Service imported tens of thousands of cubic meters of local sand to create new dunes over the sewer-pipe repair. The agency broadcast San Francisco lessingia seed collected from the adjacent remnant dune over the new dunes, and the population exploded to over 1.5 million individual plants within three years. However, for the species to recover, the Presidio Trust needed to create much more of the dynamic dune habitat mosaic that once covered most of San Francisco.

In the late 19th century, the Army planted trees such as blue gum eucalyptus, Monterey pine, and cypress, which have now escaped their designed plantation boundaries and colonized adjacent dunes. The Presidio Vegetation Management Plan identified the need to remove these trees from over 8 ha designated for dune restoration. The legacy effects of those invaders persist to this day: oils leached from tree needles and leaves coat individual sand particles, creating water repellent sand that persists well after tree removal.

Early attempts at restoring sand dune habitat from exotic tree plantations resulted in significant erosion and perpetual hydrophobic conditions that favored invasive annual grasses over desirable native species. Inverting, or “flipping” the soil profile by excavating hydrophilic, weed-free sand from depth, and then spreading 1 m or more of it over the top of the hydrophobic sands, has the additional benefit of burying weed seeds beyond the depth at which they can germinate.

While significantly more expensive, this “sand flip” has had long-lasting beneficial effects for broadcast-seeded San Francisco lessingia collected from wild populations and 10 other rare annual dune species. Since 1994, more than 10 ha of dunes have been restored in this way throughout the urban national park. As of 2019 the restored habitat supported more than one million San Francisco lessingia individuals in five remnant populations and three reintroduced populations as members of a desirable early successional sand dune community.

FRANCISCAN AND RAVEN’S MANZANITAS: MORE THAN MUSEUM PIECES?



Arctostaphylos franciscana
Federal and California
Endangered Species
CNPS Inventory Rank 1B.1

[Photograph by Michael Chassé]

The diversity of manzanitas in California is extraordinary (Kaufman et al 2015), with numerous narrow endemics in maritime chaparral. The rediscovery and rescue of the last wild Franciscan manzanita (*Arctostaphylos franciscana*) were eloquently presented in *Fremontia* a decade ago (Gluesenkamp et al. 2010). Biologists transplanted the rescued plant, known informally as “Francie” or “The Danzanita,” along with a large divot of original soil into a rocky serpentine site in the Presidio. The story caught the imagination of many conservationists, and generated some controversy over the cost.

In 2012 the federal government listed Franciscan manzanita as endangered, and in 2013, the US Fish and Wildlife Service designated 93 ha of critical habitat for the species. Presidio biologists took cuttings at the time of rescue and distributed them to several botanical gardens, and also collected and stored more than 1,000 seeds. It took Francie several years of careful tending to adjust to its new home, as it shed branches and reestablished an equilibrium between leaf area and site water availability.

Now that the singular plant has survived, the next phase is to diversify the genetics of restored Franciscan manzanita populations, through propagation of plants salvaged from the former Laurel Hill Cemetery where the plant was originally collected and described. These plants, preserved ex situ in botanic gardens for the past 70 years, represent different genetic individual plants that may cross-pollinate with the Presidio genotype and each other, producing viable seed to sustain the restored populations. In 2018, the Presidio Trust planted 124 individual plants representing at least three separate genotypes into eight Presidio locations, with an overall 23 percent survival in 2019. It will be several years before we know if these clones crossed to produce viable seeds. More serpentine habitat adjacent to Francie has been cleared of non-native trees and shrubs, to make room for resurrecting a future stand of Franciscan maritime chaparral.

Raven's manzanita (*A. montana* subsp. *ravenii*), discovered by Peter Raven in the 1940s, poses even more challenges. Only one genetic individual remains perched on a serpentine outcrop overlooking the Pacific Ocean in San Francisco, and the original plant suffers from *Phytophthora* and tussock moths. Biologists have planted clones nearby. The long term fate of Raven's manzanita as a sexually reproducing lineage is uncertain; perhaps the only path forward is to cross it with *A. montana* subsp. *montana* from Marin, and plant it next to Danzanita in resurrected Franciscan maritime chaparral.



Planting a Franciscan manzanita clone in the Presidio.
[Photograph by Michael Chassé]

LESSONS AND INSIGHTS:

Based on our collective conservation and restoration experiences, we offer the following thoughts and insights about imperiled species restoration:

1. **We must act immediately to prevent total extinction.** As exemplified by the cases of San Mateo thornmint, Presidio clarkia, San Francisco lessingia, and Franciscan and Raven's manzanitas, immediate interventions are required to prevent extinction of the last small populations or even individual plants. The seeds and living specimens at botanical gardens, collected decades ago by farsighted people such as James Roof and Bruce Pavlik, are critical resources. While a surprisingly high percentage of imperiled species cannot tolerate the drying process needed to freeze seeds for banking in ex situ storage facilities (Wyse et al. 2018), those rare species that can be seed banked should be, through efforts such as California Plant Rescue.
2. **Establishing natural population growth is the key to recovery.** Extant populations need to be stabilized, increased, and maintained. In many cases new populations must be created, producing self-sustaining populations (with some management as needed) to meet USFWS and California Department of Fish and Wildlife (CDFW) recovery goals. Allowing plants to express their awesome reproductive powers in quality habitat is the key to restoration success. The San Mateo thornmint and Marin dwarf flax illustrate the importance of finding quality microsites within larger habitats, while the Presidio clarkia shows how a rotational patchwork of management can produce appropriate microsites.
3. **Patience and persistence pay off.** Most of the taxa described above exist today thanks to decades of effort and experimentation. The learning curve can be steep, and initial failures can be instructive, as the story of San Francisco lessingia shows. Practitioners should expect temporary setbacks, as in the San Mateo thornmint, Metcalf Canyon jewelflower, and Marin dwarf flax. Rigorous experiments are the surest way of documenting what works, and importantly, what does not work. It is also important to fund the time necessary for publishing peer-reviewed papers (i.e. Niederer et al. 2014), rather than rel-

egating project reports to the unpublished “gray literature,” where they are difficult to find.

4. **Prepare for climate chaos.** Increasing aridity and variability at all temporal scales is the new abnormal. The examples of San Mateo thornmint, Metcalf Canyon jewelflower, Presidio clarkia, and Marin dwarf flax drive home the fact that annual species have good and bad years, a reality that recovery plans must reflect. Perennial species such as Tiburon paintbrush may also have highly intermittent recruitment from seed, so spreading weather and climate change risks across years and spatial gradients (Ackerly et al. 2010) is fundamental to success in both annuals and perennials.
5. **Funding, funding, funding.** The dedication of practitioners and volunteers can make minimal funding go a long way, but this work cannot be done for free or on long-term shoestring budgets. It can make a huge difference when institutions such as the Presidio Trust and National Park Service take “ownership” of a plant’s recovery. The regulatory imperatives of HCP/NCCPs, such as in the cases of the Tiburon paintbrush and Metcalf Canyon jewelflower, can also play a vital role.
6. **Use prodigious numbers of seeds.** Population biology is a numbers game, and low establishment rates are a basic fact of life. Using large numbers of seeds in field plantings is important to rapidly establish robust populations and run well-replicated trials. It may be possible to use wild stands as in situ seed sources, as in the examples of Presidio clarkia and San Francisco lessingia. But ex situ seed amplification is often necessary, as it was in the case of San Mateo thornmint, Tiburon paintbrush, Metcalf Canyon jewelflower, and Marin dwarf flax. Establishing a soil seed bank in restored populations is key to long-term success. Botanical gardens and native plant nurseries can provide facilities and expertise for seed amplification and vegetative propagation.
7. **We must deliberately, and sometimes severely, disturb habitats.** Invasive species and lack of disturbance drive the declines of many imperiled species. Undoing the legacy of adverse habitat alterations is a critical first step, even when it means employing extreme, expensive measures such as the “sand flipping” used to restore San Francisco lessingia. In the smallest sites, manage-

ment approaches the scale of habitat gardening, as demonstrated with the San Mateo thornmint and Presidio clarkia examples. Balancing the needs of other species may require adjustments of grazing regimes, as with Metcalf Canyon jewelflower, or patchy rotational treatments (Presidio clarkia). Non-native annual grasses are a pervasive challenge. All of the grassland and dune taxa require some form of annual grass control, an issue exacerbated by chronic atmospheric nitrogen deposition downwind of urban and agricultural sources (Fenn et al. 2010).

8. **Be judicious and practical with genetics.** The spectrum of opinion on genetic mixing ranges from using only the most local genotypes to preserve “pure” lineages, to judicious mixing of populations to overcome inbreeding risk while maintaining local adaptations, to freely maximizing genotypic variation to cope with rapid environmental change and letting natural selection “work it out.” Strict adherence to the most local genotypes can lead to pulling out established plants, as in the case of Marin dwarf flax, and restarting seed amplification beds for Tiburon paintbrush. Reintroductions to unoccupied habitats can use a judicious mix of source populations, as with Metcalf Canyon jewelflower, and there may be no choice but to cross subspecies if a viable lineage is to be restored, such as in the case of Raven’s manzanita. Given the urgency of restoration and known risks of inbreeding versus potential outbreeding depression that can be purged by selection (Frankham et al. 2002), we come down on the side of judicious mixing. While desirable, genetic studies are not always available or practical given available resources. There is an ideological aspect to this issue, even with genetic information, and we will not resolve it here.
9. **Keep in mind that taxa are part of a web of life.** Biotic interactions are diverse and complex. Host plants are critical for hemiparasites such as Tiburon paintbrush. Pollinator limitations have not been an obvious issue for the taxa discussed here, but may come into play for others. Facultative self-pollination is advantageous both in the field and in the nursery, as shown by San Mateo thornmint and perhaps other species. Mycorrhizal inoculation may be important in the establishment of Franciscan manzanita and Raven’s manzanita, as well as other plants.

Herbivory can limit seed production (Tiburon paintbrush, Metcalf Canyon jewelflower), as can “predation” (dodder on San Mateo thornmint). Disease may limit outplanting plugs or impact established plants, as demonstrated by Tiburon paintbrush and Raven’s manzanita.

10. **It takes a village and beyond.** Coordination and cooperation among multiple agencies, institutions, scientists, landowners, and funders is foundational and simultaneously inspiring and frustrating. Advocacy groups such as CNPS set the socio-political-cultural milieu, and provide willing, skilled volunteers. Good relationships with government agencies built through rigorous science and reporting ease land access, permitting, and regulatory issues. Institutions such as universities, museums, park/open space agencies, and botanical gardens provide support and facilities. Scientists past and present collectively contribute specialized expertise. Funding comes from many sources.

Pragmatic flexibility and Leopold’s “intelligent tinkering” are critical to achieving our ultimate objective—increasing the distribution and abundance of the “tiny cogs and wheels” imperiled by humanity’s “mindless demolition” of biodiversity.

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RECENTERING ECOLOGICAL RESTORATION WITH TRIBAL PERSPECTIVES

Jonathan W. Long, Ron W. Goode, and Frank K. Lake

Ecological restoration is central to the well-being of Indigenous communities, who have tended, burned, and harvested a variety of resources across diverse ecosystems in California for millennia. Despite having more tribes and more Native Americans than any other state, California has less land under tribal control than most of the states west of the Continental Divide. Consequently, tribes in the state disproportionately depend on public lands for their well-being (Long and Lake 2018). However, through “ecocultural restoration,” both ecosystems and their interconnected Indigenous communities can once again flourish.

Here we describe several examples that show how expanding the scope and vision of ecological restoration can support the interests of American Indian Tribes and Indigenous communities in California. Through examples of meadow, oak grove, and cul-

tural resource restoration projects, many of which have been led by the North Fork Mono Tribe (Fig. 1), we highlight several themes that illustrate how restoration can be broadened to recognize, include, and value Indigenous people and their relationships to ancestral lands in California.

WELCOMING TRIBAL PERSPECTIVES

Proponents of restoration have often reinforced the perspectives and priorities of privileged groups while discounting Indigenous influences in the past and devaluing Indigenous priorities in the present (Leonard et al. 2020). In particular, the contribution of California Indian cultural stewardship practices to

Above: During a cultural burn in Southern Sierra Miwuk territory, a young Native American guest explores an ancient rock mortar used to process food. [Photograph by Jonathan Long]

the productivity and diversity of conditions prior to European colonization has long been under acknowledged (Anderson 2005).

By rapidly altering ecosystems and displacing the holders of Indigenous knowledge most familiar with past conditions, colonization has accelerated the downward ratcheting of expectations for restoration, also known as “shifting baseline syndrome” (Jardine 2019). This dynamic may lead to distorted targets for restoration that fail to meet the needs of Indigenous people today.

The Society for Ecological Restoration (SER) and other conservation groups have been revising their internal policies to redress colonialism, stating a commitment to “promoting practices that respect cultural diversity and support sustainable livelihoods in the same way we respect ecological diversity” (Society for Ecological Restoration 2020).

BRINGING BACK WHOLE SYSTEMS AND SUPPORTING WAYS OF LIFE

A particular challenge to restoration proponents is to consider the “why” of restoration as well as the “what” (Martin 2017). Ron Goode, one of the authors of this article and chairman of the North Fork Mono Tribe, has noted, “As we strategize our plans to rejuvenate the forest and bring back the water, we have to look at the whole picture, not just how we preserve our land for those that are endangered or threatened in their existence.” Tribal people are part of the larger system, and Goode explains that ecological conditions should be evaluated based upon whether you could “live off the

land.” This view reinforces that tribes are concerned with reviving their capacity to harvest foods and other resources, which in turn support continued tending and gathering activities (Long and Lake 2018).

Tribal restoration efforts emphasize the need for traditional foods and materials within a broader context of sustaining the larger human and non-human communities. Plants and other living things are regarded as kin, and maintaining reciprocal relationships within this system promotes the well-being of all members. Goode characterizes this view as “bringing back community life,” starting by raising water levels in meadows to support wetland plants as well as oaks that make acorns, which feed the deer, which in turn feed the mountain lion. His tribe purposefully restores oak groves in ways that not only promote mature trees that produce acorns, but also recruit young trees that are browsed by deer.

Sustaining the well-being and dynamism of the system is more important than promoting entirely native species. As an example, Goode recounts a meadow restoration effort in which patches of invasive bull thistle were intentionally retained in order to support butterflies and bees until more diverse native floral sources came back (Long et al. 2020). He explained the cultural underpinnings of this practice: “All the species on the meadow and in the forest are considered relatives in the tribal lifeway. The cultural practice is to always take food when visiting a relative and when you do visit a relative they will always feed you. They (your relatives) may talk about you after you leave but food will always be shared.”



[Photograph by Jonathan Long]



[Photograph by Ron Goode]

Figure 1: The North Fork Mono Tribe has been working to restore a meadow and oaks at Crane Valley on the Sierra National Forest, where tribal members harvest plants such as California mint (Na-gu-du-pee-wi, *Pycnanthemum californicum*), shown above.

Many tribes have advocated for reducing forest tree density and canopy cover to recreate more open forest conditions, which Goode has described as a “see-through” forest. Such conditions maintained productivity of key resources and made it easier to hunt deer and keep watch over children. Researchers have reinforced these views of historical conditions by studying historical survey information from the early twentieth century; their studies indicate that forests within North Fork Mono aboriginal territory were far more open then, with canopy cover averaging only 12 percent in ponderosa pine forests and 25 percent in mixed conifer forests (Stephens et al. 2015).

ADDRESSING TENSIONS WITH WESTERN CONSERVATION SYSTEMS

Western conservation approaches have conflicted with tribal perspectives in both the targets and tools of restoration. Many plant species that are important to tribes may be discounted under management systems that target rare and declining species for conservation and monitoring. For example, the Yurok Tribe has expressed concern about the impact of climate change on coastal redwood, coastal spruce, alder, cedar, madrone, black oak, tanoak, pepperwood, Douglas-fir, manzanita, grey willow, hazel, mushrooms (multiple edible species), huckleberry, salmonberry, thimbleberry, maidenhair fern, deer brush, Woodwardia fern, bear grass, wolf moss, Oregon grape, California wild oat, wild potato, wild lilac, and tobacco (Sloan and Hostler 2014).

Many of these species grow in the forest understory and in meadows and other openings. While most remain relatively common and widely distributed, the supply and condition of such species have often degraded to levels that no longer adequately support tribal uses for foods, basketry, medicines, etc. For example, black oaks and tanoaks are widespread, but the condition of these hardwoods is often unsuitable for reliable nut harvest (Long et al. 2017).

While many societies can shift to substitutes when populations of useful species decline, deeply rooted Indigenous communities may be less willing or able to adapt when animals and plants such as salmon and oaks decline due to the communities’ deep connections to such cultural keystones (Norgaard 2019). The California Native Plant Society (CNPS) policy statement on oaks recognizes many of the ecological services provided by those trees, as well as the need to protect them from losses due to land use and for-

est management. But the long-standing, integral connection of oaks and Indigenous people in California requires consideration of how to bring back the productivity of oak communities, not simply ensure their continued existence (Long et al. 2016).

National forest managers often focus on overstory tree species, which have long been a source of forest products in the form of timber. Increasing reliance on monitoring using remote sensing similarly emphasizes the trees rather than the diversity, abundance, and quality of understory plants such as berry plants, edible geophytes, grasses, and organisms that are particularly important to tribes (Long et al. 2018b). It may be possible to infer understory quality from overstory conditions, but explicitly considering key understory species can help restoration efforts better promote tribal goals (Sowerwine et al. 2019).

Some Western conservation policies and environmental organizations have resisted restoration treatments based upon perceived risks to environmental values such as air quality, water quality, and rare wildlife, despite apparent congruence between traditional tribal perspectives and Western biophysical research on reference or desirable conditions. For example, some groups have contested proposals to thin forests to more open conditions, particularly within areas where old forest-associated species such as owls and fishers reside. However, recent research suggests that maintaining large trees may be more important to owl habitat than maintaining high canopy cover itself (North et al. 2017). In particular, large oaks, which need openings within conifer-dominated forests, are important to conserving such rare species (Long et al. 2018a).

As another example, concerns that burning and digging might cause unacceptable soil disturbance have similarly complicated tribal meadow restoration efforts. In response, Goode has explained that both burning and digging are appropriate restoration tools in meadows. Researchers have noted that Indigenous peoples in California have used such methods for millennia (Anderson 1997, Anderson and Barbour 2003).

RESTORING FIRE IN SOCIAL AND ECOLOGICAL SYSTEMS

Fire has long been an indispensable tool for Indigenous people in stewarding landscapes (Kimmerer and Lake 2001). Tribes continue to emphasize the essential role of fire in promoting the well-being of socio-ecological systems, particularly through cultural burning. Continuing the ancestral tradition of actively using fire



Figure 2: Ron Goode oversaw a cultural burn in spring 2020 to restore blue oaks (Pa-wi-yap; *Quercus douglasii*) and sourberry (Ta-ka-te, *Rhus trilobata*) plants at the Jack Kirk property near Mariposa, California. [Top photograph by Jonathan Long, bottom photographs by Ron Goode]

promotes many values that go far beyond the objectives of typical burn “prescriptions,” which often focus on reducing fuels and minimizing damage to overstory trees. The current CNPS policy on use of fire currently reflects a narrow emphasis on minimizing “damage to native plant species and their habitats.”

Many California tribes have evolved fire-dependent cultures (Lake and Christianson 2019). They rely on cultural burning to increase the quality and quantity of plants, limit pests, enhance germination or resprouting, and promote desirable forms of growth (Lake and Long 2014). As Goode has explained, North Fork Mono people could not afford to leave their families and travel for miles to gather food every day, so they ensured their larder was full by burning close to where

they lived. Such cultural burn efforts are underway throughout California, including one in a blue oak/meadow system near Mariposa, California, led by the North Fork Mono Tribe and members of other local tribes (Fig. 2). At such events, Goode reminds people to ask, “What are you burning for?” Tribal practitioners consider the relationships among fire, land, water, people, animals, and plants.

REESTABLISHING RELATIONSHIPS RATHER THAN SHOWCASING SPECIES

Western approaches to restoration often try to address tribal concerns by identifying species of cultural importance and targeting them for replanting and pro-



Figure 3: A plaque (top photo) located within a degraded and fire-suppressed oak grove at a community park in the Central Valley mentions past use of soaproot (So-o-sibe; *Chlorogalum pomeridianum*); in contrast, signs and plaques at the Tending and Gathering Garden (bottom photo) explain that soaproot and other plants remain priorities for many California tribes today.

[Photographs by Jonathan Long]

tection. In natural areas, they sometimes feature botanical specimens along with their Indigenous names and uses written on plaques (Fig. 3). Some of these displays, like outdated exhibits in a zoo or museum, can obscure the vital and present-day interests of particular tribal communities in restoration. Both species lists and specimen displays can be valuable tools—Goode maintains lists of species observed each year at their meadow restoration projects—but tribes have a much more expansive and inclusive restoration vision. For example, a recent collaboration with the Washoe Tribe considered a list of culturally important species in the Lake Tahoe basin that might be monitored as part of restoration efforts. Through several meetings and field visits, cultural practitioners described a broader vision in which mixed groups of elders and youth would be encouraged to burn, tend, and gather species of particular value for food, basketry, and other practical applications. (For more on the Washoe Tribe's restoration work in the Lake Tahoe basin, see: ceqanet.opr.ca.gov/2018112063/2.)



Figure 4: Cultural burning at the Tending and Gathering Garden at the Cache Creek Preserve near Woodland, California, January 2020.

[Photograph by Jonathan Long]

A good example of this deeper engagement is the Tending and Gathering Garden at the Cache Creek Nature Preserve in Woodland, California. A former river mining reclamation area, the garden features culturally important plants that are managed by native people using practices such as cultural burning (Fig. 4) (Ross et al. 2008). This demonstration area illustrates the importance of reinforcing tribal relationships with their ancestral lands through traditional burning and gathering processes. Formal partnerships between tribes and agencies have developed to foster these restoration efforts, including designation of special cultural management areas within national forests (Long et al. 2018b).

CONCLUSION

Restoration efforts can successfully address tribal concerns when they spring from the understanding that ecosystems and Indigenous communities are integral to each other. Rather than setting a goal of ecosystems

that sustain themselves without human interventions, ecocultural revitalization can promote systems in which people meet their traditional needs while supporting their non-human relations. Such goals can be evaluated in terms of the capacity for areas to support harvest of desired resources by tribal members. Such partnerships will take time to develop, but will ultimately help people live better with the land. As Goode has noted, “Restoring one meadow may very well take ten years.”

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SEED-BASED RESTORATION: SCALING UP FOR THE FUTURE

Matthew Garrambone and Sunny Saroa

Ecological restoration is the process of assisting in the recovery of degraded, damaged, and destroyed ecosystems (Society for Ecological Restoration 2004). While it can have benefits at any spatial scale, ecologists increasingly recognize the value of working at the landscape scale, at which a relatively consistent mosaic of local ecosystems or land uses repeats across a large area, such as a watershed or basin. Working at this scale can provide cumulative gains for multiple taxa by enhancing ecosystem processes as well as habitat quality and connectivity (Hobbs et al. 2014; Aavik and Helm 2018). In California and elsewhere, restoring ecosystems at the landscape scale requires adaptive, cost-effective, and spatially appropriate strategies for native plant establishment (Kildisheva et al. 2016; Pedrini et al. 2020).

For the Irvine Ranch Conservancy (IRC), a non-profit organization that works on behalf of Orange County Parks, the City of Irvine, the City of Newport Beach, and various other agencies to restore degraded landscapes throughout Orange County, scaling up restoration efforts has meant a wholesale adoption of seed-based restoration. This article explains the rationale behind our use of functionally diverse, locally adapted seed mixes for landscape- and sub-landscape-scale projects. It also highlights the challenges associated with acquiring sufficient seed of local provenance for restoration and the steps our organization took to address them. Lastly, it showcases efforts being made to improve access to genetically appropriate native plant materials in Southern California.

SEED-BASED RESTORATION

Since 2005, IRC's restoration program has worked to restore thousands of acres of open space in Orange County that have been degraded by a history of grazing, frequent fires, and invasive species. Our projects target large patches of degraded land within a watershed or canyon, and seek to restore multiple habitat types such as coastal sage scrub, chaparral, riparian, oak woodland, and native grassland. Restoration goals and metrics for success vary across projects, but IRC's restoration program generally aims to restore ecosystem function and enhance resilience to disturbance. To restore habitats, we use native plants of various functional groups (e.g., forbs, shrubs, and graminoids) as the building blocks.

Due to a long history of degradation, many of the sites we aim to restore are likely seed limited, meaning the native seed bank has been partially or completely depleted. Without a functional native seed bank, these habitats are less resilient to climatic variability and natural disturbance (Poschlod et al. 2013; Ma et al. 2019). Because the seed bank is such an important component of the systems in which we work, a passive restoration approach involving weed removal without seed addition is insufficient. Instead, we work to deplete the non-native seed bank in the first phase of the project, and install native seed afterward. This approach allows us to reintroduce a diverse suite of early successional species, specifically those with adaptations such as seed dormancy. This important adaptation ensures that a fraction of the seed from each year remains dormant in

Above: A view of IRC's Bee Flat Canyon restoration, a 64-acre landscape-scale, seed-based project focused on restoring coastal sage scrub, chaparral, native perennial grassland, and oak woodland habitats in the Santa Ana River Watershed. [All photographs courtesy of IRC]

soil, contributing to the development of a functional native seed bank over time (Venable and Brown 1988, Angert et al. 2009).

Overcoming seed limitation, replenishing native soil seed banks, and reestablishing natural regeneration processes are only some of the benefits of a seed-based restoration approach. Distributing diverse seed mixes across the landscape can also help address the issue of microsite variation. Instead of placing container plants where we believe they might perform well, a widely distributed seed mix allows natural filtering processes to determine which species establish in a particular area (Grman et al. 2015; Hulvey and Aigner 2014). Distributing seed widely is fairly efficient, given that seeds are small and can be easily installed by hand or through the use of specialty equipment such as seed imprinters and drill seeders. Once in the ground, those seeds can also establish through seasonal precipitation instead of a costly irrigation system, which can provide significant cost savings over the life of a project (Brooks et al. 2019).

Considering all of these factors, the decision to implement a seed-based restoration program was easy. The challenge, we have learned, lies in supporting that program with a consistent supply of plant material for each of the many species we want in our mixes.

PLANT MATERIAL DEVELOPMENT

Establishing consistent access to native plant materials can be difficult, especially for restoration practitioners committed to local provenance, which refers to seed collected from plants growing in environmental conditions similar to those of the restoration site. When our restoration program was smaller, we could supply projects by collecting from wild populations in the vicinity of our project area, but as the program grew, so did our demand for seed. Thus, we needed a solution that would minimize the amount of seed taken from those populations while still providing adequate quantities for large-scale restoration. We also wanted to build a supply of native plant material over time in case we needed to mobilize a restoration or revegetation effort in response to an emergency such as a catastrophic fire.

For these reasons, in 2009 we decided to implement a program focused on the development of locally sourced plant materials. Establishing our 8-acre seed amplification farm allowed us to focus our wild collection efforts on assembling small, genetically diverse, site-specific collections that could then be “bulked” into the large amounts needed to support our resto-



Volunteers and public participants assist in the maintenance of common goldfields (*Lasthenia gracilis*) at IRC's native seed farm.

ration efforts. This farmed material became the primary source of seed for our restoration and nursery production efforts, with supply matching demand in most years.

These days, we maintain a rotating crop of approximately 50 native species on the seed farm that represent multiple functional groups. Investments in refrigerated seed storage have allowed us to build up a seed inventory of more than 150 species. Overall, the program has helped us maintain a consistent supply of material for our most commonly used restoration species; allowed us to integrate an ever-growing list of local species into our plant palettes; and reduced the amount of wild seed removed from the land over time, effectively lowering the impact of our restoration program on our natural populations.

This model has been successful largely due to support from our landowner and agency partners, a relatively consistent stream of restoration projects, and a slow and deliberate growth strategy. However, acquiring locally sourced native plant material remains an issue for most practitioners. This problem needs to be addressed to support a growing restoration industry whose demand for locally sourced seed will only increase in time.

A VISION FOR THE FUTURE

The federal government's “National Seed Strategy for Rehabilitation and Restoration 2015–2020,” developed by the Plant Conservation Alliance, a public/private partnership chaired by the Bureau of Land Management (BLM), provides a conceptual framework for this effort. Its stated goal is to “ensure the availability of genetically appropriate seed to restore viable and productive plant communities and sustainable ecosystems” by establishing “a nationwide network of native seed collectors, a network of farmers and growers working to develop seed, a network of nurseries and seed storage facilities to supply adequate quantities of appropriate seed, and a network of

restoration ecologists working on the ground” (Plant Conservation Alliance, 2015).

While many of the elements listed above exist in California, only select ecoregions benefit from established networks working together to ensure that future resources are genetically appropriate. California’s rich diversity of plant species, large geographic area, and high degree of environmental variation at the landscape scale make establishing such networks challenging. That said, efforts to address this challenge are already underway, including projects aimed at conserving the genetic variation of our flora, establishing seed transfer zones, and developing collaborative networks. Below, we highlight just a few of the many programs and organizations working to establish the foundation upon which California’s sustainable native seed future will be built.

SEED CONSERVATION

Conserving the genetic variation of our flora is of utmost importance if we’re to be prepared for future restoration and recovery efforts, especially under the threats of climate change, catastrophic fire, and invasive species. California Plant Rescue (CaPR), a consortium of California botanic institutions, is working toward the long-term goal of securing the state’s entire flora in conservation collections such as botanic gardens and seed banks. Their work is currently focused on California’s rarest species, 75 percent of which they hope to have conserved by the end of 2020. The collaborating institutions work in partnership to monitor wild populations, make genetically diverse seed collections, and establish *ex situ* seed banks. The seed banks are maintained primarily as a buffer against extinction, though a portion of the materials is intended to support research, as well as future restoration and recovery programs (California Plant Rescue 2019).

SEED TRANSFER ZONES

A seed transfer zone is defined as an area within which plant material can be moved from one location to another with minimal genetic risk to the population or species (Bower et al. 2014; McKay et al. 2005). Collecting from an area that is environmentally similar to where seed will be planted increases the likelihood that the material will be adapted to local conditions. It also increases the odds that the restored plant community will possess the genetic diversity necessary to successfully adapt to future conditions (Kettenring

and Tarsa 2020).

Generally, two types of seed zones exist for native plants. The first, more common type is a provisional seed zone based on climatic or other environmental factors (Bower et al. 2014). The second type is referred to as a genetic seed zone, and is based on empirical studies that characterize factors such as genetic diversity or variation (Conservation Biology Institute et al. 2020; Hufford et al. 2016). Genetic seed zones based on empirical studies are generally more accurate; however, given the significant research investment associated with delineating them, few have been established for native California species.

One group working to address this problem is the Mojave Desert Native Plant Program (MDNPP), a BLM program in the Mojave Desert Ecoregion that has been operating since 2016. The MDNPP “coordinates seed collection, research and development of seed transfer zones, and research on restoration techniques for priority native plant species.” In collaboration with the US Geological Survey and California Botanic Garden, the program is currently using common garden studies combined with genetic studies to develop seed transfer zones for priority restoration species. In these studies, researchers collect seed of each target species, from multiple provisional seed zones across the species range within the Mojave Desert. They grow plants from each collection in a common garden and assess their performance. Then, the teams combine data from these studies with those from DNA sequencing efforts to develop empirical seed transfer zones (Simpson and Webb 2018).

COLLABORATIVE NETWORKS

As with all complex issues that span geographic boundaries, regional collaboration will be absolutely necessary to improve access to genetically appropriate plant materials and promote their use. One promising example of such a collaboration is the Seed LA project, a group of six nonprofit organizations in Los Angeles County working to “enhance ecosystem resilience in the greater Los Angeles region.” The group is working to develop a consistent supply of locally adapted native seed to support landscape restoration projects implemented by public and private entities, and establish public support for the use of native seed throughout the region (CNPS South Coast Chapter 2019).

In Orange County, we need a similar collaborative if we are going to implement restoration at the scale necessary to address the current challenges facing our

native habitats. While a collaborative is still in its preliminary stages, most local organizations recognize that multi-partner collaboration is critical to achieving regional conservation and restoration goals, and interest in formalizing a regional native seed network is growing.

Improving access to genetically appropriate native plant material in support of California's restoration industry will not be easy, but momentum is building and progress continues to be made. With this in mind, we look forward to a future where the vision described in the National Seed Strategy can be realized.

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USING NATIVE SEED IN HABITAT RESTORATION

Patrick Reynolds

As the general manager of Hedgerow Farms in Winters, California, I oversee the production of native seeds and germinated seedlings, or plugs, of known genetic origin, meaning that they can be traced back to an original wildland population. This article addresses how to effectively use native seed of known genetic origin in habitat restoration, focusing on proper design, implementation, maintenance, and management.

DESIGN

The goals for a restoration project drive its design and vary considerably between sites. In a mine reclamation project, erosion control and development of modest vegetative cover might be the goal (Busnardo et al. 2017). Alternatively, a restoration project designed to provide habitat for rare or listed species might have very specific goals, such as sustaining a population of a particular species.

Once a project's goals are clear, one must determine what is possible, given conditions at the site. Regional reference sites can serve as natural, intact analogs for the target habitat, providing useful data on important site characteristics such as plant species composition and vegetation structure. Since reference sites are not always available, however, professional judgment is often the primary driver in the restoration design process.

CHOOSING SEEDS

When designing a seed mix, the first step is to ask which native species are already present on the site. When regional reference sites are available I examine them, then look at the natural distribution of native species in the vicinity. Maps on the website Calfora.org provide good general information about the distribution of common native species. After putting together a species "wish list," I typically refine it based on which plants are compatible with the site's hydrology and soils. Then I compare the list to best-fit, commercially-available ecotypes: seeds or plugs of known genetic origin that have evolved adaptations to an area's soils, geology, climate, elevation, pests, diseases, and other local characteristics.

At Hedgerow Farms, we do not recommend using seed of unknown origin, commonly referred to as "variety not stated" (VNS). Such seed can come from anywhere and may not be adapted to local site conditions; this can result in less successful establishment and maladaptation of existing native stands in or adjacent to restoration sites (McKay et al. 2005). Maladaptation may occur because the seeded material cross-pollinates with existing native stands, altering the genetics of natural populations in the vicinity. Thus, to the extent possible, it is important to use best-fit ecotypes when designing habitat restoration sites.

Above: **A diverse native seed mix displayed at Hedgerow Farms.**
[All photographs courtesy of Hedgerow Farms]

Hedgerow Farms maintains a database that lists commercially available native species ecotypes (www.hedgerowfarms.com/species-database). This database provides important background information for restoration designers' consideration when they are determining potential best-fit ecotype seed for particular projects. When desired species or ecotypes are not available, we sometimes use seed collected from wildlands by professional seed collectors, including organizations such as Pacific Coast Seed. If a project requires more seed in large quantities, Hedgerow Farms can take relatively small quantities of locally collected stock seed and increase it in seed production plots, a process known as seed amplification.

We collect stock seed when it's ripe, generally 1 to 12 months before planting, then clean the seed by separating the target seed from all other material. Next, we send it to a laboratory for germination testing, determining the number of live seeds present. When stock seed is very limited, we grow the seeds we have into plugs and plant them, and when stock seed is adequate, we sow the seed directly into the fields. We generally plant seeds or plugs in the fall, and harvest them between late spring and early fall the following year, depending on when the seed for a particular species is ripe. Then we dry, clean, and test the seed before we provide it to a client.

I generally recommend designing seeding projects with application rates measured in pounds sown per acre, using Pure Live Seed (PLS) pounds as opposed to bulk pounds. PLS is a more accurate measure than bulk pounds of the viability of the seed that you are using, as it counts only your target live seed (the quantity of living seed of the species you are purchasing) in the weight that you purchase. Unlike bulk pounds, PLS pounds exclude chaff, dirt, dead seed and non-target seed from the overall weight.

The number of live seeds per pound is generally included in laboratory seed test results for any native plant seeds that you purchase. Seed application rates have a direct influence on the vegetation that establishes, with high application rates generally resulting in denser stands. When designing seed mixes, I look at the number of live seeds per square foot as the primary design parameter. This number generally varies



Native California poppies (*Eschscholzia californica*), tidy tips (*Layia platyglossa*), and sky lupine (*Lupinus nanus*), established from seed of known genetic origin at the Sacramento River National Wildlife Refuge.

between 50 and 200, depending upon the application method used, the goals for the project, and the anticipated weed pressure and the size of the seed sown.

Including diverse plant species in seed mix designs can improve outcomes by hedging against the many soil, hydrologic, and topographic features present on different sites that favor particular species. Restoration projects face many unknowns, such as temperature, rainfall patterns, fires, floods, and human disturbance. The presence of a structurally diverse mixture of tall, short, wide, narrow, dense, and thin vegetation types will also generally support a more diverse animal community.

Many seed mix designs include species that do not typically establish well from seed, such as sedges (*Carex* spp.), rushes (*Juncus* spp.), and warm-season grasses that have very narrow germination requirements. I try to minimize or eliminate these species in mixes and instead suggest that they be started as plugs under controlled nursery conditions. Plugs can have surprisingly high survival and growth rates, and can supplement what establishes from your seed mix. It can also be advantageous to install these species in patches that naturally expand if conditions are favorable.

Nurse crop species tend to germinate very quickly, providing good initial cover to crowd out weeds and assist with the establishment of foundational slower-growing, long-lived species. These foundational species will initially establish in the understory of the nurse crop before they eventually become dominant. In grassland mixes, Pacific fescue (*Festuca micro-*

stachys) works well for upland sites and meadow barley (*Hordeum brachyantherum*) for wetter sites. In flower mixes, miniature lupine (*Lupinus bicolor*) can serve as a good nurse crop.

SITE PREPARATION

Without a methodical weed control program implemented well in advance of seeding and maintained during vegetation establishment, the chances of having a highly successful sustainable project diminish significantly. **Good weed control is essential to establishing native herbaceous vegetation.**

It is difficult to establish native vegetation from seeds without adequate seed bed preparation. The previous season's partially decomposed surficial plant material generally needs to be substantially reduced or eliminated. The surface of the soil also needs to be loose enough that the seed does not blow away and can germinate without immediately drying out between rain events. The target area within this loosened soil is generally the very uppermost layer (the top inch when possible). This approach minimizes the chance of bringing up weed seed that may be present. If the site does not have a weed seed bank, loosen soil several inches deep to give germinating seedlings a friable surface to root into. Pulverize clods that are an inch or greater in size to prevent seed from falling into the cracks and ending up too deep. Irrigation or natural rainfall can also reduce clods and create a more uniform seed bed.

SEEDING METHODOLOGY

Three commonly used native species seeding methods are drill seeding, broadcast seeding, and hydroseeding. On large, flat sites, a native seed drill often produces the best results and requires the least amount of seed. Native seed drills are designed to maximize native seed establishment by planting the seed very shallowly (generally less than $\frac{1}{8}$ th of an inch) while at the same time providing good seed-to-soil contact.

Planting with a native seed drill is more precise than other methods, and thus significantly reduces the amount of seed needed. Native seed drills are designed to accommodate the non-uniform shapes and sizes of native seeds to ensure proper seed flow. They also include special features such as agitators and picker wheels that help to prevent seeds of various shapes and sizes from becoming lodged together and getting stuck, an advantage not shared by standard agricultural grain drills. However, drill seeding requires heavy equipment, including a tractor to pull the drill



A native seed drill at Hedgerow Farms in Winters, CA.

and the expertise necessary to ensure the correct seed application rates are used and the seed is planted at the appropriate depth. Native seed drills also tend to slip on slopes that exceed 4:1 (horizontal: vertical), so there are topographic limitations to where a drill can be used.

On smaller sites (generally less than 5 acres), where the costs and logistical issues associated with drill seeding make it impractical, many restoration experts prefer broadcast seeding. Broadcast seeding can be accomplished with a “belly grinder,” a manual seeder that spreads seed with a hand-powered crank spreader, or a drop seeder that simply drops seed on the ground as it is pulled across a site. For effective establishment, broadcast-seeded areas need to be worked with a chain harrow, a cultipacker or another tool to obtain good seed-to-soil contact.

Hydroseeding is often used on slopes that are steeper than 4:1 and where access with all-terrain vehicles and tractors is limited. The seed is applied with an aqueous solution that can be shot out of hoses or sprayers over long distances. The process generally involves multiple steps such as spraying native seed, then applying wood fiber mulch, fertilizer, tackifier (resin adhesive to glue materials to slopes), and straw. Because hydroseeding does not promote good seed-to-soil contact, the pounds of seed applied often double the amount needed on drill-seeded sites to effectively establish native herbaceous vegetation.

LONG-TERM MAINTENANCE AND MANAGEMENT

Nearly all forms of habitat restoration require at least some long-term maintenance and management. This



Showy milkweed seed pods (*Asclepias speciosa*) ready for cleaning.

is particularly true of seed-based restoration efforts, which generally target herbaceous vegetation that is in near-constant competition with non-native species. Maintenance and management often mean controlling non-native species with a significant competitive advantage over natives during the early establishment period. Thus, habitat restoration does not end when the seed is sown.

An adaptive approach allows for changes in how a site is maintained, based on lessons learned. Where allowed, grazing can reduce or limit invasive species, increase biodiversity, and otherwise improve habitat functions. In a now-classic 10-year study of natural vernal pool grassland habitat, for example, researchers found that grazed plots had higher native species vegetative cover and more native plant species, and that the duration of ponding in the vernal pools was much longer, compared to ungrazed vernal pool grasslands (Marty 2015).

In the right setting, herbicides can be an effective tool for successful native grass establishment. Herbicides that target fast-growing annual broadleaf weeds can knock back competition and give the slower growing natives a better chance at establishment. Other long-

term management tools used to establish or maintain native species can include properly timed mowing and controlled burns. Each of these management techniques requires precise timing and proper implementation, and must be tailored to specific site conditions. Their use is often dictated by limitations such as the inability to get permission to conduct a controlled burn or use herbicides.

CONCLUSION

Although the use of native seed is an effective habitat restoration tool, proper implementation is the key to success. It requires a restoration design that includes aggressive pre- and post-planting weed control and a seed design based on the desired post-restoration conditions at the site. If the seeding design includes best-fit, commercially available ecotypes applied with proper seeding methodologies, and appropriate long-term maintenance and management, native seed-based restoration projects can be highly successful.

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RESTORING CONNECTION TO PLACE

John C. Hunter

Throughout California, California Native Plant Society volunteers restore natural communities and help others to do the same. As volunteers, they don't do this with heavy equipment or much public funding; rather, they do this by laboring on public lands and their own lands, leading restoration efforts, growing plants, and sharing know-how.

Based on 2018–2019 annual activity reports, CNPS chapters organize or participate in about 850 restoration activities per year, most focused on removing invasive plants. These chapter activities improve dozens of sites, the vast majority of which are in parks or on other accessible public lands. Thus, not only do CNPS restoration activities provide hundreds of volunteers with the personal experience of stewardship, but they enable thousands of people outside of CNPS to experience the native vegetation restored and sustained by the volunteers. In an era when interactions with nature are diminishing, the experiences of the volunteers and the broader public help stave off this “extinction of experience” (Soga and Gaston 2016; Pett et al. 2016).

DECADES OF INVESTMENT

A large portion of this restoration work happens on public lands and focuses on weed removal. Public lands, even when “preserved,” have been losing expansive areas of native vegetation to the spread of invasive non-natives (Randall 2011). CNPS volunteers work to reverse this process by removing invasive weeds and helping native plants take their place.

Many of these efforts have lasted for decades: During the past 32 years, for example, volunteers from the Santa Clara Valley Chapter have been working to remove more than 80 species of invasive plants from San Mateo County's Edgewood Park. When the chapter began this work in 1988, invasive plants dominated the 467-acre park's grasslands. In 2001, yellow starthistle (*Centaurea solstitialis*) was still abundant in the park's grasslands, infesting about 78 acres, but the cover of native plants has since expanded thanks to volunteer efforts.

Above: CNPS Sanhedrin Chapter volunteers working on the Great Redwood Trail in Ukiah. [Photograph by Neil Davis]

CNPS volunteers treated these areas by hand-pulling and, where possible, mowing the thistles. They have eliminated nearly three-quarters of the dense starthistle infestations. Volunteers have also removed Fuller's teasel (*Dipsacus sativus*), bristly ox-tongue (*Helminthotheca echinoides*), Italian thistle (*Carduus pycnocephalus* subsp. *pycnocephalus*), French broom (*Genista monspessulana*), tocalote (*Centaurea melitensis*), stinkwort (*Dittrichia graveolens*), little robin (*Geranium purpureum*), and fennel (*Foeniculum vulgare*). With the removal of these competitors, native plants such as purple and foothill needle grass (*Stipa pulchra* and *S. lepida*, respectively) and narrowleaf milkweed (*Asclepias fascicularis*) have become more abundant.

The Santa Clara Valley Chapter's work illustrates the large amount of change that can accrue from small but persistent efforts. It also exemplifies a durable process by which volunteers gain understanding of, and personal connection to, a place, underpinning stewardship and community support for restoration and for conservation in general.

The long duration of work at Edgewood Park is not atypical for a CNPS effort. At Sunset Beach State Park in Santa Cruz County, CNPS volunteers worked with park staff for more than a decade to restore native dune vegetation. Volunteers pulled European beachgrass (*Ammophila arenaria*) from areas where it was degrading habitat for western snowy plovers and displacing native plants including the endangered robust spineflower (*Chorizanthe robusta* var. *robusta*). Subsequently, park staff applied herbicide to new sprouts. After volunteers constructed fire breaks to protect the existing natives, park staff burned European beachgrass areas to promote recruitment of native plants.

Another example of this long-term effort is Quail Hollow Ranch County Park in the sandhills of Santa Cruz County, where for about 18 years CNPS volunteers have been incrementally eliminating French broom, a shrub forming dense stands that shade out the diverse assemblages of herbaceous plants characteristic of the sandhills. And at Skyline Gardens in the East Bay hills, volunteers have been removing weeds and promoting the growth of natives for 25 years (Ueda 2020).

A COMMUNITY EFFORT

Often these efforts start with one or a few people pulling out an invasive plant here and there. Then the effort turns into a more formal chapter activity, with a core group of consistent participants supplemented by

occasional participants drawn from the larger group. Frequently, these restoration endeavors involve community groups such as school classes and Girl Scout troops.

Some groups secure funding from outside CNPS, and some have multiple public and private partners. For example, the San Diego Chapter has partnered with the US Fish and Wildlife Service, San Dieguito Conservancy, Natural Resources Conservation Service, San Dieguito Fire Protection District, CAL FIRE, San Dieguito River Joint Powers Authority, San Diego County, the Urban Corps, two homeowners associations, and more than 40 private property owners in its restoration efforts. Thus, the initial actions of a few chapter members can grow into an organizing force that accomplishes significant restoration.

The success of restoring invasive plant-dominated land to native vegetation depends not only on effective removal of invasive plants but on the recruitment and growth of native plants. Frequently, CNPS volunteers seed or plant native plants in cleared areas to aid recruitment. East Bay Chapter volunteers did this to augment natural recruitment of the local native species and to establish these species at Skyline Gardens (Ueda 2020). And in the Sepulveda Basin, Los Angeles/Santa Monica Mountains Chapter volunteers have been removing non-natives for more than a decade (Hartman 2019).

In the Sepulveda Basin, volunteers are now planting narrowleaf milkweed (*Asclepias fascicularis*), Pacific aster (*Symphyotrichum chilense*), and other native plants to provide pollinator habitat. Along the Great Redwood Trail in Ukiah, volunteers from the Sanhedrin Chapter have been removing non-natives and planting acorns from adjacent valley oaks (*Quercus lobata*), seedlings of deer brush (*Ceanothus integerrimus*), and manzanitas (*Arctostaphylos* spp.) transplanted from dense patches of post-fire seedlings nearby. They've also planted plugs of purple needle grass, California oat grass (*Danthonia californica*), blue wild rye (*Elymus glaucus*), and Idaho fescue (*Festuca idahoensis*), all grown from local seed.

THE BRADLEY METHOD

Some CNPS restoration efforts rely entirely on the growth of remnant native plants and their seedlings to fill the space vacated by non-natives. A systematic approach to facilitating this native regeneration, called the Bradley method, has been applied at Skyline Gardens in the East Bay, and by the San Diego Chapter at multiple sites. The three principles of the Bradley



CNPS volunteers pull out European beachgrass (*Ammophila arenaria*) at Sunset State Beach in Santa Cruz County. [Photograph by Linda Brodman]

method are:

- Work outwards from areas rich in native species to areas dominated by weeds.
- Minimize disturbance.
- Do not over-clear (i.e., let the rate of native plant regeneration dictate the rate of weed removal) (Bradley 2002). (See the San Diego Chapter's website for a more detailed description of the Bradley method.)

In the past 15 years, CNPS volunteers from the San Diego Chapter have had success with this approach at five sites, most of which are publicly accessible, such as Blue Sky Reserve and Lusardi Creek. By applying the Bradley method, the San Diego Chapter has restored at least 1,100 acres of vegetation at these diverse sites, which encompass riparian corridors, a freshwater marsh, oak woodlands, coastal sage, chaparral, and grasslands.

At San Diego County's Artesian Creek, for example, hillsides had become a mosaic of scattered native plants such as black sage (*Salvia mellifera*), California sagebrush (*Artemisia californica*), and California buckwheat (*Eriogonum fasciculatum*), mixed with a host of non-native invasive plants, including artichoke (*Cynara cardunculus* subsp. *cardunculus*), mustard (*Brassica* spp.), tocalote, pampas grass (*Cortaderia seloana*), and garland daisy (*Glebionis coronaria*).

CNPS volunteers systematically removed the non-natives, starting in the areas nearest homes and working outward, then working outward from the creek. Volunteers mostly worked in pairs, using a combination of techniques, including hand-pulling in areas closest to native plants; hand sawing to cut down non-native trees; string trimming occasionally (primarily on mustard); and spot-applying herbicides

in large areas dominated by non-native plants. They cleared rings around California sagebrush and other natives, and removed the lower limbs of laurel sumac (*Malosma laurina*) plants near homes for fire safety.

Each growing season, the islands of native plants that volunteers tended grew bigger, and the intervening areas of non-natives grew smaller. As a result, over the course of a decade, recruitment and growth of native plants has transformed the site to approximately 300 acres of native vegetation, supporting a rich assemblage of wildlife such as California gnatcatchers, road-runners, quail, deer, and even a mountain lion or two.

The Bradley method, which the San Diego Chapter has employed so effectively, was developed in Australia not by professional scientists or resource managers, but by two avid amateur naturalists known as the Bradley sisters. In the 1960s, Eileen and Joan Bradley developed a method for restoring native vegetation based on their observations at a local park. After demonstrating their method's effectiveness, they trained others in it. Over the next 30 years, their method spread widely in Australia and overseas, including to California (Fuller and Barbe 1985). The method became popular in part because they had distilled it to three key principles and some pithy guidance, all readily understood and applied.

Because of its incremental, responsive nature, the Bradley method requires continuity of effort and observation for a prolonged period. But the effort need not be extensive at any one time, as Joan Bradley herself describes:

We have not overworked at it. We are both over fifty, able-bodied but by no means Amazonian. My sister takes the dog for a walk on most mornings, and I do the same in the afternoons. On these walks we might average, between

the two of us, about three-quarters of an hour spent actually pulling up weeds. Done in our way, the regeneration of weed-infested bushland is an easy and fascinating part-time occupation (Bradley 1971). (Later, she noted that they didn't do this weeding in the rain, when the soil was soggy, during drought, or when "inclined to go for a good long walk instead" [Bradley 2002]).

SHARING KNOWLEDGE

Like the Bradley sisters, CNPS members share both their enthusiasm and their expertise. Besides providing hands-on education at restoration work days, CNPS members give public talks and technical presentations, provide training, and publish guidance. Their demonstration gardens, garden tours, and chapter nurseries provide inspiration and plants not only for gardens and landscaping but for restoration. Whether it happens in a yard, park, or preserve, growing native plants represents the reclamation of space for native plants and the animals that depend on them—the goal of the CNPS "Habitat Revolution" campaign to support native pollinators and local ecosystems (Morrison 2019).

To feed this revolution, CNPS chapter nurseries and plant sales put local native plants in people's hands and gardens. During 2019, CNPS chapters held approximately 50 plant sales, attended by more than 16,000 people who collectively provided homes for nearly 50,000 plants. In addition to the thousands who acquired plants and advice at these sales, hundreds of volunteers gained experience and some expertise by propagating these plants and staffing the sales.

CNPS volunteers also disseminate restoration materials and guidance during times of crisis. After the catastrophic North Bay fires of 2017, CNPS volunteers and staff collected, propagated, and distributed tens of thousands of acorns to thousands of landowners in the North Bay. Oaks are a keystone species that support hundreds of animal species (Tietje et al. 2005). In addition to distributing acorns, CNPS staff produced a fire recovery guide specific to the North Bay, followed by a statewide guide that they distributed by the thousands (CNPS 2019). The guides focus on post-fire land care, but also describe the basics of fire ecology and share the latest advice on preparing for fire and protecting properties. By widely distributing oaks and guidance, CNPS volunteers and landowners aided the post-fire recovery of oaks and other species across large swaths of California's landscape.

In sum, CNPS volunteers not only restore natural communities but people's connection to place, by nurturing stewardship and increasing awareness and

knowledge of the plants and animals we share land with. They provide models, materials, and guidance for people to restore habitat in their own yards or on public lands. This combination of ecological and societal restoration is the strength of volunteer-based restoration.

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RESTORATION: REINTRODUCING DISTURBANCE AND VARIABILITY

An Interview with Lech Naumovich by David Loeb

Lech Naumovich has been working in the fields of botany, restoration ecology, and conservation science for 20 years. He founded the Golden Hour Restoration Institute in 2007, while serving as the staff conservation analyst for the CNPS East Bay Chapter. The Institute provides training in botanical restoration and leads a number of restoration projects in the Bay Area. Lech is also coauthor of the *Annotated Flora of the East Bay*. In early July, I met with Lech over Zoom to discuss his experience in restoration ecology and his big-picture perspectives on that practice.

The organization you founded is called the Golden Hour Restoration Institute, so you must have had in mind some definition of “restoration.”

LN—From an academic standpoint, the term restoration has always meant ecological processes and how we maintain the dynamic rhythm that natural systems go through. I think it’s important to come to terms with the fact that restoration doesn’t have a typical endpoint; it’s a journey of discovering the past, present, and future of a particular landscape and removing inhibiting factors that don’t allow natural processes to happen. Restoration, in its purest sense, is the removal of human-generated inhibitors that don’t allow an ecosystem to live.

The “golden hour” part of our name is significant too. It’s a medical term referring to a short window of time when you can revive a patient. Land management is time-specific and there are strategic touch points at which there can be potential damage or potential benefits, when systems can be pushed back to a place where they can have functioning ecological processes.

What kind of processes are we talking about?

LN—Let’s take the example of grasslands. In dry years there is this phenomenal response with flora that does very well. The wet year flora germinates but dies

back, either because it’s not getting enough precipitation, or because it’s not cool enough. Meanwhile, the dry year flora finally gets its chance to exert itself. The same thing, in reverse, happens in wet years, or intermediate years. So you have this whole suite of species that have certain conditions where they function really effectively, but those conditions may only only present themselves every, say, 10 years. Giving a system that opportunity to access those vegetation expressions in dry years and wet years is really important in restoration. That’s what we’re talking about with the concept of resiliency, having these landscapes or ecosystems that are able to function at both ranges and to bounce back and forth between those different steady states. I think that’s the definition of a healthy ecosystem.

So is restoration an effort to help ecosystems get to that resilient state?

LN—It’s about restoring the processes that allow landscapes to have natural variability. We are restoring the potential for landscapes to wander, to evolve, to change. I think we get this idea of these climax systems, of these sweeping beautiful oak ecosystems, and that’s

Above: Volunteers searching for mission blue butterfly (*Icaricia icarioides missionensis*) larvae on San Francisco’s Twin Peaks.
[All photographs by Lech Naumovich unless otherwise noted]

what folks think of as restoration, producing that climax state. I'm saying no, it's actually that journey and everything in between. Having those different "seral" states, as we call them, is exceptionally important. It's the grassland next to the creek that gets scoured and turns into wildflowers, then transitions back to perennial grasses, and then maybe some willows start to move in as the stream changes.

We as land managers, as humans invested in landscapes, are scared of disturbance. Disturbance can bring uncertainty, yet it is a process that is absolutely fundamental to almost all of our natural systems. There are very few systems that do well with no disturbance, and a lot of these mechanisms that create disturbance...we've really buffered ourselves against those. Wildfire is one that's pertinent in California. Another is landslides: There's always concern about erosion, but there's a healthy erosive process that happens and that needs to happen in a lot of landscapes. It uncovers seeds; it causes nutrient cycling; it creates spaces for ground-nesting bees and other pollinators. We need to feel comfortable shaking up our systems. And with that comes a paradigm shift.

People who are out on these landscapes, and who are in love with them, have to understand that this is a positive process, though it may look terrible for 10 years, even 40 years. Disturbance is being extracted out of our urban areas and even our wildlands with fire suppression, reduced logging, and flood avoidance. But these big fires, landslides, and floods allow for our systems to reset, stay healthy, and eventually flourish.

Given time, won't fire and other forms of disturbance come back and start the process over again?

LN—But that's an element we're missing in our systems, right? For fire, we have more and more fire suppression. Ideally, we won't have a firestorm in the East Bay hills again, right? There's a whole lot of political pressure, a whole lot of life and property on the line. In terms of our wildland urban interfaces, we're losing access to some of those landscape scale tools. Then, when it finally happens, it gets way too hot, and it causes a catastrophic change in the system.

Where does restoration meet stewardship?

LN—I consider restoration as kind of the spark, where you're recognizing there's an issue with your natural resource value system that needs to be addressed. Stewardship is when you already have a relationship, where you continue to do work that maintains the system. Restoration gets you there; it's all the excitement—you get a whole lot of people out there, get your funding. Stewardship is those little things that



Lech Naumovich (left) with Golden Hour Restoration Institute staff members Kate Ferroggiaro and Wyllie Clayson on Twin Peaks after a scrub removal workshop, 2017. [Photograph by Mission Blue Crew volunteer]

happen year after year, that maintain a system's health.

To me restoration has an end; stewardship does not. Another important element to consider in restoration is how to create positive human engagement. Restoration is a realization, a call to responsibility, where you come around and say, "Look, I'm part of a species that's having a lot of negative impact on the earth. And you can either sit around and cry about it, or I can get out there and do something."

Let's switch gears and see what this looks like on the ground. Let's start with your work on Mount Umunhum near San Jose.

LN—At almost 3,500 feet, Mount Umunhum is the second highest mountain ridge in the Santa Cruz Mountains, with some interesting high-altitude plant habitats. It also has arguably the best south to north view of the entire Bay Area, which is probably why the US Air Force plopped an early detection military radar system right atop the summit in 1959. Still, the summit wasn't flat enough, so the military leveled it.

In 1980 the defense system was retired and the mountain quietly fell into obscurity. The Midpeninsula Regional Open Space District purchased the 43-acre summit to be part of its Sierra Azul Open Space Preserve, and, in 2009, started planning its rebirth. With great credit to MidPen, they planned the restoration with members of the Amah Mutsun tribe, for whom the mountain plays a central role in their creation story. The summit area now includes a ceremonial circle and cultural conservation easement for the tribe.

The ecological restoration mandate from the Open Space District was, "Let's restore the summit back to historic, pre-radar conditions." And so it was this fantastic process of rebuilding the top of a mountain at the top of a mountain range. When the military graded the summit, they pushed a lot of material off to the side, so most of the soils weathered and moved downslope, and we were left with all the rocky rubble and larger fragments. We had a lot of conversations about how to rebuild the summit so it could start to regain some

ecological function. We had these barren rocky soils; it was basically a desert up there. We started by looking at nearby summits, and figured out a plan to re-contour the top. We had to figure out how much material we had on site and how much to bring up.

Was there much growing there?

LN—There were a few survivors, because the site does get a lot of rain and moisture. Sites that are wetter tend to recover a little more quickly. We knew the first thing was to start the pedogenesis process; that is, to get the soil creation process going. We knew there'd be some weathering up there, but it would be slow, that it would take forever to get enough organic matter for things to really start growing. We needed to supplement that with our own soils and organic matter.

We amended the soil pretty heavily with *Phytophthora*-free compost to get a start. With the help of Vic Classen, a fantastic soil scientist out of UC Davis, we made these lenses, these islands of fertile soil, and buried them and basically blended them into the landscape so you couldn't see any of that rich dark topsoil. We planted in those areas, and let those plants start to develop. Then those plants would go through a process of dropping leaves, dropping seeds. Insects, butterflies, and bees would start coming through, starting to build that functioning community.

So we literally started from the ground up, and we were impressed by how quickly some nutrient addition helped to get the plants established. It's a highly exposed peak, but within a year, we were getting around 5 to 10 percent vegetative cover, which is pretty amazing. And through the third year some of those sites were upwards of 30 percent cover.

How did you decide which plants to bring in?

LN—We spent a lot of time on reference and reconnaissance work, along with some diehard CNPS volunteers and Grassroots Ecology staff. We circumnavigated that summit, in areas that had been less disturbed, and looked at adjacent summits. The other high peak nearby, Loma Prieta, is accessible, so we were able to get up there and do plant surveys to see what was growing. Species were cataloged, seeds were collected, and we grew the plants from those seeds at a local nursery.

Without having seen the peak before it was leveled, were you able to recreate a summit with some variability?

LN—Yeah, that was key. And that was a struggle with the engineers, who want everything laid back at a certain grade, like 14.52 percent, plus or minus 0.2, while

those of us on the ecological and soils side say, "Let's make it a little steeper over here, and let's follow the contours up from the slopes and valleys below." We had three months of just pushing rocks around for eight hours a day. It was an incredible amount of work. But in the end, I think we created something that has the feeling of a true mountain summit.

As the vegetation comes in, that's really where we're trying to be thoughtful. For instance, there was a little group of foothill pines on one side of the site. So we took that stand of pines, and extended it into the new area, planting a bunch of pine seedlings in the shadow of the mature trees. Now that part of the site is getting pine needle litter naturally, and it will help weave those two landscapes together.

Any other lessons learned on this project?

LN—One of the most interesting was working with the engineers and figuring out how some of the restoration techniques we were using—such as folding soil into a landscape—fit their engineering specs. They don't have a computer program that allows for that. Or for instance, we're trying to revegetate an area, and they're putting down three layers of geotextile fabric to hold the soil in place, but it won't allow plants to root through it. No seedling is going to be able to go through, but that's outside of their construction specs. So there's this whole world of restoration engineering that hasn't quite blossomed yet.

Also, being able to collaborate some with the Amah Mutsun, to create that ceremonial space for them. We're hoping to work more with them as they develop a vision and layout of a native learning garden, where visitors will be able to learn about Indigenous people's management of native plants in the landscape to provide sustenance, both nutritional and spiritual.

Are the people you worked with on this project happy with the results?

LN—Sometimes the hardest people to convince are the people who are closest to the site, in terms of being patient with the vegetation. There's this huge push to put in so much vegetation, to make it look incredible on day one. And yet this needed to be a natural process, that started up with that soil, with the critters coming back, and so that's still a continuing conversation. Another challenge was to convince the project partners that we want to do this phased over three to five years. That was scary to them. They'd prefer to have it done in year one or year two. There's this cultural thing of wanting to check the box and be able to say, "This project is done."

But this is our bridge into stewardship. Taking a project that takes five years to install, we used a lot of volunteer labor, we gained the community interest, and there are now volunteers up there who are feeling fully responsible for the site. This is their site! And so instead of paying some expensive contractor—folks who are out the door once the money is gone—we figure out how to create that bridge, retain that institutional knowledge, so we have people there who have been around since it was a flat parking lot, to now, where it's a restored undulating summit.

It's a lifetime project. It will develop slowly. Being able to sit with non-immediate gratification—it invites a unique audience.

Since we're talking now about volunteer engagement, can you talk about the Mission Blue Butterfly Project?

LN—This is a project where need was identified at a high level by scientists, park managers, and the US Fish and Wildlife Service, saying that mission blue butterflies are disappearing from their former range on the San Francisco Peninsula, and we need to create habitat for them, to bring them back. The scientists were doing the more technical aspects of handling the butterflies and translocating them from San Bruno Mountain, just south of San Francisco, to Twin Peaks, in the middle of the city. And so in 2014 we created the Mission Blue Crew to specifically steward the mission blue habitat on Twin Peaks.

It's a one year volunteer requirement and it's eight workshops over eight workdays. People need to stay with us a full year to go through the whole butterfly life cycle, from dormancy to larval state to pupae, to adult, eggs, and so on. It's sort of a master's level course on mission blue butterfly ecology and habitat. We do it at an accessible level; we're trying to slowly ramp people up with hands-on information and understanding and experience.

Now the restoration has been done and we're mostly doing stewardship. We're slowly trying to transition from coyote brush scrub to grasslands that have lupine, which are the host plants for the mission blue. Lupines were once more common in the grasslands, but scrub encroachment has eaten away acres of grassland. There's little natural disturbance maintaining the grasslands and thus the decline of the lupines. Coyote brush scrub, even though it's native, doesn't have as many host plants for the butterflies.

We have a great series of aerial photos of San Francisco from 1946, that we used to create a historic map to see where the scrub was in the 1950s and then we used that as a guide for where we want to shrink



An aerial view of the Mount Umunhum construction site as the summit was being rebuilt.

the scrub back to. We don't want to totally eliminate it; we're just pushing it back, little by little, workday by workday.

What kind of training does the crew get?

LN—We teach them sampling, we teach them habitat management, and removing weeds. We train them in planting of host plants; we've done trials where we scarify lupine seeds and plant them one by one. If you talk to any nursery, they always have a hard time getting their lupines going. And even when you get them going, they're really hard to transplant. So, what solution do we have for that? Well, we train volunteers to take a pocket knife and nick a seed and then stick it in a crack. Times one thousand. It's maybe not the most glamorous task, but for someone who might work at a computer all day, this can be very engaging.

We also show them how to look for larvae, how to do egg surveys, adult surveys, and different identification techniques. The biggest part of it is you get people walking by—it's a highly visible site—and they ask, "Hey, what are you guys doing?" And the volunteers are jumping in and telling the story. At the end of the year, we get a bunch of emails saying, "Can we come back next year?"

Would you say that you've transformed that habitat on Twin Peaks?

LN—I would say we've increased the amount of habitat for the mission blue. In addition, we've learned a lot about how to increase the quality of that habitat. That touches on something really important in restoration science, which is that there's habitat, and then there's "quality habitat." In San Francisco, where you have finite acreage, the quality of habitat really becomes paramount.

This is one of those remarkable stories where we have individuals giving 30-40 hours a year to us, and we tell them, "Oh, by the way, you might not see a single butterfly this year." It takes a certain amount of patience. It's not just picking up trash; we're trying to get people to engage at a spiritual level.



ETHICS OF PLANT REINTRODUCTION IN THE 21 ST CENTURY

Naomi Fraga

In the decades leading up to the 21st century, few biologists could have imagined how the landscape of rare plant conservation would change over the subsequent 20 years, including the urgent need to advance ethical considerations and codes of conduct for scientists and practitioners in the face of a global extinction crisis (Hahs et al. 2009).

Today, the accelerating threats to plant diversity have come into sharp focus, and the field of plant conservation as we know it is adjusting to the increased pace and scale of threats. However, despite numerous published studies demonstrating the impacts of climate change (Niskanen et al. 2019; Zhang et al. 2017) and continued threats from habitat modification and invasive species (Bernardo et al. 2019), we as a conservation community have continued to operate mostly under the status quo from the previous century.

Now more than ever, scientists, conservation practitioners, and land managers need to revisit and reframe our professional codes of conduct as they pertain to conservation of the most vulnerable and rarest plant species. We need to reaffirm our values to combat extinction, to uphold protections guided by science, to make scientific recommendations that have meaningful conservation outcomes, and to consider the harmful effects of participating in a system that continues to emphasize mitigation strategies that have largely proven unsuccessful. We also need to reaffirm our roles as science-based conservationists, science communicators, and agents to promote the conservation of plant diversity.

My examination of the ethics of plant reintroduction (also known as rare plant translocation or restoration) took new shape when I became familiar with the precarious status of a rare buckwheat in Nevada, Tiehm's buckwheat (*Eriogonum tiehmii*). Tiehm's buckwheat is known only from a single population in a remote region of Esmeralda County, Nevada. The entire global population of this species is located within the boundary of a proposed industrial lithium and boron mine, the Rhyolite Ridge Lithium-Boron Project. An Australian mining company, Ioneer Ltd., is proposing to extirpate 65 percent of all known plants and 30 percent of total occupied habitat in Phase 1 of the project.

This level of impact for a species endemic to a single site should be immediately disqualifying, yet the Bureau of Land Management (BLM) in Nevada approved exploration to determine project feasibility. In a devastating turn of events in September 2020, up to 40 percent of the *E. tiehmii* population was damaged or destroyed as the project awaited environmental review (Wilkins 2020). This newly documented threat is currently undergoing investigation, but illustrates the extreme vulnerability of *E. tiehmii* and increases the projected total impact from the mine.

As the government investigates the new and emerging threat and reviews the project, the mining company continues to establish a plan to fund reintroduction

Above: Tiehm's buckwheat (*Eriogonum tiehmii*), a rare plant known only from a single population in the Silver Peak range in Esmeralda County, Nevada. [Photograph by Naomi Fraga]

trials on the buckwheat in unoccupied habitat. While this is intended to mitigate the impacts of their project on the buckwheat, it also seems to be an effort to cast the mining project in a positive light. The company asserts that the funded research will provide protection for the buckwheat in the form of seed collection, propagation, outplanting, seeding, and an attempt to salvage plants. Yet the company has determined that the project will remove over 50 percent of the global population and will industrialize its entire habitat (EM Strategies 2019;ioneer 2020).

That the company is promoting these reintroduction strategies as a mechanism of protection prior to project approval, rather than emphasizing the need for protection of plants in their native habitat, is concerning. Decades of scientific research support the need to protect plants in their native habitat as the best means of protection and long-term conservation, especially for single-site endemics (Harrison et al. 2008; Knapp et al. 2020). However, rather than accept this scientific evidence, the mining company has misused preliminary results from their funded research to promote the success of plant reintroduction, and to claim that the buckwheat can be protected through propagation and translocation to unoccupied habitat (Sonner 2020).

The company-funded research for Tiehm's buckwheat has brought to light several ethical questions surrounding plant reintroduction:

- Does the promotion of plant reintroduction undermine efforts to advocate for full protection for plants (e.g. emphasizing mitigation strategies over avoidance and protection)?
- Should project approval be contingent upon evidence of successful plant reintroduction strategies?
- What are the ethical considerations for scientists commissioned to conduct research on behalf of a company that has a stated objective that is in conflict with best practices for strong conservation outcomes?
- Are the scientists involved neutral parties, commissioned to gather data without consideration of how those data may be used regardless of their recommendations and analysis?

The Rhyolite Ridge Lithium-Boron Project highlights some of the ethical quandaries botanists and ecologists may face when they participate in industry-funded reintroduction research. The funding agent has project goals that are in conflict with conservation goals. If approved, the lithium-boron mine would

likely move forward regardless of research results. Thus, the funded research may have little influence on mitigation or conservation strategies.

The best conservation strategy for *E. tiehmii* is to protect it in its native habitat (in situ conservation) and to prevent mining and industrialization at this site (Guerrant et al. 2004). This raises the question of whether plant reintroduction research itself can undermine protection strategies and the highest priority conservation outcomes.

This type of conflict has plagued the world of botanical consulting for decades, and is compounded in a world reeling from the effects of climate change and an extinction crisis. Climate change is no longer a distant future threat: It is here. The stakes for rare plant conservation are that much higher because, in the face of climate change, no population is fully protected.

How do we adjust our gauge to evaluate ethical considerations in our rapidly changing world when, for example, clean energy projects are pitted against the need to protect rare plant populations? Further, how do we advance plant conservation when we facilitate inadequate mitigation measures, population by population? These individual projects may not lead to immediate extinction, but collectively they will almost certainly result in extinction by a thousand cuts.

In the past, scientists, conservation practitioners, and land managers have referenced published position papers such as this one, and codes of conduct published by professional societies including the Ecological Society of America (2020) and the Society for Conservation Biology (2004). The California Native Plant Society created a Botanist's Certification Program that includes a Code of Ethics and Standards for Professional Conduct for Field and Consulting Botanists (2016). Some of the concerns listed above are covered in these codes of conduct. However, they do not fully cover additional considerations that are perhaps more difficult to address, due to nuance and perceived subjectivity. Here I present some of these considerations as we face accelerated threats to plant diversity.

In reviewing numerous examples of ethical guidelines related to rare plant species and codes of conduct for professionals in botany and conservation (CNPS 2016; ESA 2020; SCB 2004; NPT 2005; HRPRG 2020; CPC 2019), few provide clear statements on a duty to ensure welfare for biodiversity and to prevent human-mediated plant extinction. An exception is the Hawaiian Rare Plant Restoration Group, which has a mission statement that emphasizes the need to prevent the extinction of native Hawaiian plants and to provide

for their recovery (HRPRG 2020). A simple statement such as this reaffirms the prevention of extinction as an ethical guideline, which is important as reintroduction efforts are likely to increase.

Most published codes of conduct do not address the topic of rare plant reintroduction. The Center for Plant Conservation (2019) provides guidelines regarding justification for rare plant reintroductions; however, these should also be incorporated into a code of ethics for botanists. In the same vein, guidelines for the justification for assisted migration in a changing climate should be addressed.

Additionally, as we face issues related to the politicization of science, including anti-science movements and the degradation of federal environmental law, ethical guidelines addressing the role of scientists as advocates are needed. Much has been written about advocacy by scientists, but guidelines addressing responsible participation and the role of scientists in advocacy have not been outlined or considered in the ethical guidelines and professional codes of conduct explored here (CNPS 2016; ESA 2020; SCB 2004; NPT 2005; HRPRG 2020; CPC 2019).

Scientific research advances our understanding that plants are foundational organisms, supporting not only terrestrial ecosystems but our own human existence. Despite this scientific evidence, we must contend with the growing demands for development projects that place plant communities and rare species at great risk. A recent article evaluating plant extinction in North America (Knapp et al. 2020) stated that “Preventing extinction is the lowest bar for conservation success,” yet even preventing plant extinction is not explicit in our community codes of conduct. The ethics of plant conservation, including issues surrounding rare plant reintroduction, should not aim to meet this minimal standard. Instead, they should uphold science and the highest ethical standards to ensure the welfare of all biodiversity.

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PROTECTING RESTORATION PLANTINGS FROM PATHOGENS

Susan J. Frankel, Janice M. Alexander, Diana Benner, Janell Hillman, and Alisa Shor

Over the past six years, inadvertent plant pathogen introductions into restoration plantings have stunned and frustrated vegetation ecologists. Sticky monkeyflower (*Diplacus aurantiacus*), toyon (*Heteromeles arbutifolia*), sages (*Salvia* spp.), and other common restoration plants have been found to harbor soilborne *Phytophthora* species, relatives of the sudden oak death pathogen (*Phytophthora ramorum*).

Detections in native plant nurseries and restoration sites have included *Phytophthora* species new to the United States (*P. tentaculata*, *P. quercina*), previously undescribed species (*P. taxon agrifolia*), and new pathogen-host plant combinations that threaten restoration success and present numerous challenges for ecologists determined to keep restored habitats healthy and pathogen-free (Frankel et al. 2020). Since these pathogens infect roots and survive in soil, they are very difficult to eradicate once introduced; residual material from the organism may infect subsequent plantings. Native plants' summer drought adaptations, which may cause diseased plants to go unnoticed, can complicate the problem.

The sudden oak death pathogen arrived in California on infected ornamental nursery stock. Over the past three decades, it has spread and killed approximately 50 million trees (Cobb et al. 2020). Similar invasive species pathways threaten areas under restoration, where plants, compost, soil, and other potentially infested materials are transported to sites of high ecological value. Studies and observations demonstrate that they present a threat to wildland health in California and worldwide.

To prevent introductions and manage infestations, the Phytophthoras in Native Habitats Work Group has developed best management practices (BMPs) for restoration nurseries and plantings. These BMPs have been incorporated into Accreditation to Improve Restoration, a voluntary program that combines

careful plant monitoring with systematic sanitation to prevent pathogen development in restoration nurseries. The program is currently being piloted in the San Francisco Bay Area and in Southern California; several participating nurseries have grown *Phytophthora*-free plants for more than three years.

Additionally, restoration project design can incorporate prevention strategies to minimize the likelihood of pathogen introduction and spread, such as reduced plant density and selecting upland sites with good drainage. Use of natural regeneration and direct seeding, where practical, also reduces risk. Proactive measures can prevent pathogen introductions and thereby sustain habitat health. For more information, see the Phytophthoras in Native Habitats Work Group website, www.calphytos.org.

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Above: Madrone mortality on Old Cañada Road near Woodside, CA. [Photograph courtesy of Phytosphere Research]

Beauty and the Beast: California Wildflowers and Climate Change

by Rob Badger and Nita Winter

Matt Ritter and Dena Paolilli

If you aren't already awed by California's wildflowers, you will be after looking through *Beauty and the Beast: California Wildflowers and Climate Change*, by Rob Badger and Nita Winter. This spectacular book is packed with hundreds of gorgeous photographs, 18 inspiring essays, a glossary, a map of California's ecological regions, and an index to both plants and places. As Dan Gluesenkamp, former executive director of the California Native Plant Society, points out in the first of three introductions, California has more native plants than any other state, comprising a remarkable diversity that Badger and Winter beautifully capture in their captivating photos.

When first paging through this large, coffee-table format book, you'll be drawn in by the photographs, yet it's the essays from prominent botanists and other scientists, nature writers, environmental leaders, and educators that will hold your attention. In Badger's introduction to the project, he invites each of us to join him and Winter on their mission to document and preserve California's rich botanical diversity. They asked the authors to engage a wide audience through science and inspiring human stories, and they have achieved just that.

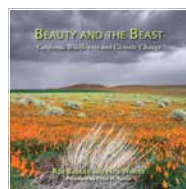
The essays are organized in three sections: "The Gift of Beauty," "The Human Connection," and "Ensuring the Future." Topics range from educating the reader about botanical wonders to relating personal stories and reflections, all aimed at inspiring action toward conserving and sustaining California's floristic treasures. Beginning in "The Gift of Beauty," Susan Tweit writes evocatively about California desert ecosystems, unlocking a deeper understanding of this special landscape. In "The Human Connection," Robin Wall Kimmerer and Gordon Leppig write about the importance of a relationship to the land. Kimmerer expands

on how this connection relates to the history of naming plants, from Indigenous people to Linnaeus. Wendy Tokuda and Amber Pairis, in "Ensuring the Future," offer personal anecdotes for action in a time of climate change. Tokuda shares her firsthand experience with habitat restoration, following her retirement from her job as a TV news anchor, while Pairis offers practical advice on how to stay positive while brainstorming creative solutions to climate change with children.

Complementing these inspirational essays are the book's striking photos, from close-up images of iconic flora to picturesque vistas of broad landscapes. Badger and Winter take particular care with their photos, using only natural light and capturing all the subjects in their natural habitats. Few photographers have done a better job of documenting our state's rich flora. The "Behind the Scenes" section, one of the most interesting in the book, reveals their methods.

It's easy to see why *Beauty and the Beast* and the talented conservation photographers behind it have won so many awards, including the Sierra Club's 2020 Ansel Adams Award for Conservation Photography. It's a significant and captivating book. There's little doubt that the essays and enchanting photos will inspire many readers to "become a voice for wildflowers."

—Matt Ritter and Dena Paolilli, *Cal Poly University Botany Dept., San Luis Obispo, CA*



Beauty and the Beast: California Wildflowers and Climate Change

Rob Badger and Nita Winter. 2020.

WinterBadger Press, 264 pp., hardback. \$60. ISBN# 1733104402

Above: Peace Valley, Tehachapi Mountains, Gorman.

[Photograph by Rob Badger]

Primer of Ecological Restoration by Karen Holl

Michael Vasey

Habitat restoration is both a science and an art. It begins with a scientific understanding of the ecological patterns and processes that underlie desired outcomes of a restoration project. Based on that science, one must use informed imagination to design and construct the project. Place and particulars matter, as do values and goals. The practice of habitat restoration is still young, but patterns emerging from projects completed in different ecosystems and habitats are leading to a growing consensus regarding the best restoration ecology practices.

Against this backdrop, the publication of Dr. Karen Holl's *Primer of Ecological Restoration* is a timely and important contribution. Professor Holl is a devoted restoration ecologist and former chair of the Environmental Studies Department at UC Santa Cruz. She is an Aldo Leopold Leadership Fellow, a fellow of the California Academy of Sciences, a 2017 co-winner of the Theodore Sperry Award of the Society for Ecological Restoration, and a faculty director of the Kenneth S. Norris Center for Natural History at UC Santa Cruz. She completed her PhD at Virginia Tech, where she examined forest recovery from mine disturbance. After she came to UCSC, she worked on coastal prairie restoration, restoration of valley riparian habitat along the Sacramento River, and forest regeneration in Costa Rica.

I had the good fortune to join Dr. Holl's lab to pursue my PhD in 2006. I ended up focusing on maritime chaparral and manzanitas—not restoration ecology—but I imbibed a great deal about the theory and practice of restoration ecology from Dr. Holl and my lab mates. The lessons learned in her lab have profoundly affected my engagement with tidal wetland restoration in the San Francisco Estuary over the past several years. Many of these lessons are encapsulated in Dr. Holl's slim and concise book, which also has an excellent glossary to help explain technical terms and a great list of up-to-date references for those who want to dive more deeply into this topic. Let others extoll the many virtues of restoration. Dr. Holl's text gets to the meat of restoration ecology early and retains its focus all the way through.

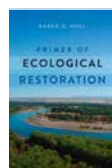
The first four chapters of her book focus on the purpose of restoration; defining restoration; project planning; and the need for monitoring and adaptive management. Dr. Holl addresses the core questions

facing the field: How can practitioners learn science-based lessons if projects are not designed to track how a habitat or ecosystem is responding over time? How can we detect problems early enough to generate remedies? What if, as is often the case, not one but multiple restorations are key to landscape-scale recovery? This is the realm of monitoring, special studies, and adaptive management. It can take many years of observation and analysis, and is all too often neglected and underfunded. But, as Dr. Holl makes clear, it is of vital importance to recovering healthy ecosystems, habitats, and sensitive species over time.

The fifth chapter is the anchor for the book and addresses the need to apply ecological knowledge to restoration. The following chapters cover knowledge of physical processes such as hydrology and landforms, of soils and water quality, of invasive species, of revegetation, and of fauna. The final two chapters address the regulatory environment and funding challenges. These human dimensions to habitat restoration are critical barriers but can also be important catalysts. Through our values and politics, we can influence the amount of restoration, its extent, and its ultimate contribution to the recovery of ecological health. Each of these 12 chapters is packed full of helpful figures, tables, and examples to illustrate the topics at hand.

Primer of Restoration Ecology does not address all of the many topics that fall within the realm of ecological restoration. For example, it does not cover reintroduction of endangered plant species to critical habitats. However, the concise framework introduced by this volume provides a solid approach to restoration that can and should be applied in the vast majority of cases. Dr. Holl's book is already being adopted as a text for college restoration ecology classes. Given the widespread application of restoration ecology projects in our impaired landscapes, however, her work should become part of an industry approach to this field. *Primer of Restoration Ecology* belongs on the bookshelves of all conservationists, as we try to influence restoration outcomes through informed advocacy.

—Michael Vasey, PhD, is director of the San Francisco Bay National Estuarine Research Reserve, Estuary and Ocean Science Center, San Francisco State University



Primer of Ecological Restoration.

Karen Holl. 2020. Island Press, 224 pp., paperback. \$35. ISBN#: 9781610919722



The newest CNPS Fellow Jean Struthers (right) on site with the late Sally Casey (left), also a CNPS Fellow, at the nursery that Jean and her husband David founded. [Photographs by Vivian Neou]

Jean Struthers planted herself in the Los Altos Hills more than 50 years ago and has since helped thousands of native gardens bloom. In June, CNPS awarded Jean its highest honor, naming her a CNPS Fellow in recognition of nearly 40 years of service as a leader of the CNPS Santa Clara Valley Chapter and champion for the California landscape.

From her protection of local wildlands, to the creation of the chapter's productive native plant nursery, Jean's history demonstrates her remarkable sense of place and stewardship. A third generation Californian, Jean grew up in the Bay Area and spent summers at her family's forest service cabin at Kirkwood. Her father was a plantsman and gardener, perhaps explaining Jean's talents in plant propagation and selection.

Jean attended Pomona College and UC Berkeley, where she received a BA and MA in fine and studio art. Jean drew artistic inspiration from the natural world, often focusing on botanical drawings and scenes from the Bay Area and the Sierra Nevada. An artist with many local gallery exhibits, she donated her artistic talents to help create interpretive materials, chapter posters, and the logo for a campaign to preserve and restore Edgewood Park – a ruby chalice clarkia (*Clarkia rubicunda*).

Jean joined the Santa Clara Valley Chapter in 1985, and today she continues to volunteer with the chapter's nursery and conservation activities. Her service includes two terms as the chapter president, field trip chair, co-chair of the wildflower show, plant sale co-chair, and management of the chapter's nursery. Jean founded the chapter's nursery in 1995, overseeing

CNPS FELLOW Jean Struthers

its construction with her husband, David, and managing it for 20 years. Under her leadership, the nursery grew into the chapter's top source of funding, providing support for scholarships and other chapter services.

Jean's knowledge of native plants made it possible for the chapter to sell plants that were not easy to find elsewhere, note her chapter colleagues in their nomination letter: "Jean is always on the lookout for plants that would make good garden specimens." The *Ribes malvaceum* 'Monterey Wine' cultivar was one of Jean's finds during a CNPS field trip on the Monterey Peninsula.

She is perhaps most admired for her mentorship, "tireless support," and enthusiasm, whether training volunteers at the nursery or recruiting new leaders for the chapter. Chapter member Georgia Stigall recalls Jean once speaking to the topic of chapter leadership: "Jean said, 'We agreed that if we all just take a turn, then it's covered.' She stated it so clearly, so simply, and so congenially. I have quoted Jean on this many times over the years, in hopes of having potential leaders feel the same level of inclusiveness and teamwork."

—Liv O'Keeffe, with contributions from Vivian Neou and Carolyn Dorsch



Jean and David in action, repairing a greenhouse roof at the nursery.

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Westervelt Ecological Services (WES) is dedicated to providing mitigation and conservation solutions across the United States.

WES has conserved over **27,000 acres** of habitat for the benefit of over **50 federally or state protected plants and animals**. To reach our conservation goals, WES collaborates with private landowners, businesses, land trust organizations, non-profits, and government entities.

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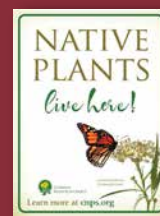
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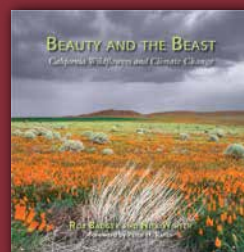
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