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Contents



Introduction to this Special Issue on the Flora and Vegetation of the Islands of the Californias.....3

By John J. Knapp and John M. Randall



Remarkable Flora of the California Islands.....5

By Matt Williams, Benjamin Carter, Martha Lizeth Ceceña-Sánchez, Jose Delgadillo, Barbara Holzman, Steve Junak, Denise Knapp, Luciana Luna-Mendoza, and Sula Vanderplank



Early Botanical Personalities of the Channel Islands.....12

By Steve Junak



Resilience Of Unique Island Vegetation18

By Thomas Oberbauer, Martha Lizeth Ceceña-Sánchez, Steve Junak, Denise Knapp, Lyndal Laughrin, Luciana Luna-Mendoza, Kathryn McEachern, Bryan Munson, Ken Niessen, Dirk Rodriguez, and Peter Schuyler



Remarkable Recoveries and Fantastic Discoveries.....24

By Bryan Munson, Peter Dixon, Emma Havstad, Emily Howe, William Hoyer, Steve Junak, Denise Knapp, Luciana Luna-Mendoza, Kathryn McEachern, Sarah Ratay, Jon Rebman, Dirk Rodriguez, Peter Schuyler, Sula Vanderplank, and Dieter Wilken



The New Baja California Pacific Islands Biosphere Reserve Sets A Conservation Benchmark: All Mexican Islands Are Now Protected.....27

By Alfonso Aguirre-Muñoz and Federico Méndez-Sánchez



The Struggle for Recovery.....32

By Kathryn McEachern, Peter Dixon, Emma Havstad, William Hoyer, Denise Knapp, John Knapp, Luciana Luna-Mendoza, Bryan Munson, and Heather Schneider



Restoration and Protection of the Archipelago's Flora and Habitats: A New Era.....37

By David Mazurkiewicz, Josh Adams, Morgan Ball, Ryan Carle, Peter Dixon, Karen Flagg, Emma Havstad, Emily Howe, Bill Hoyer, John Knapp, Kathryn McEachern, Luciana Luna-Mendoza, Bryan Munson, Ken Niessen, Ken Owen, Julia Parish, Paula Power, and Andrew Yamagiwa



The Future of California Islands Conservation in a Changing World.....44

By Denise Knapp, Donaxi Borjes-Flores, Peter Dixon, William Hoyer, John Knapp, Luciana Luna-Mendoza, Kathryn McEachern, Julio Hernández-Montoya, Bryan Munson, Paula Power, and John Randall

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INTRODUCTION TO THIS SPECIAL ISSUE ON THE FLORA AND VEGETATION OF THE ISLANDS OF THE CALIFORNIAS

John J Knapp & John M. Randall

The islands off the Pacific coast of the states of California and Baja California Peninsula, from the Farallones in the north to Isla Natividad in the south (see map), are within the California Floristic Province. Their shared flora is distinctive and rich in endemic genera, species, subspecies, and varieties not found on the mainland. Together these 18 islands are home to 1,239 native plant taxa. Island vegetation types resemble those on the mainland, but island endemic taxa are prominent in most of them.

Unfortunately, these islands were severely damaged by human use within the past two centuries, and particularly by introduced animals—against which many island endemic plants were poorly defended. As a result, many endemic plants are now thought to be extinct, have been reduced to the brink of extinction, or are extirpated from one or more islands. Fortunately, botanists who recognized the extraordinary nature of the island flora collected specimens, described the vegetation, and identified endemic taxa starting in the

mid-1800s. In some cases, they lost their lives doing it, but their explorations provided early records of what the islands looked like.

Today most of the islands are managed for conservation or include large areas that are protected. The Farallones are a National Wildlife Refuge, five of California's eight Channel Islands are within Channel Island National Park, two others are managed by the U.S. Navy, 48 percent of Santa Catalina Island is managed the Catalina Island Conservancy, and 76 percent of Santa Cruz Island is owned and managed by The Nature Conservancy. In December, 2016 the Mexican government announced the establishment of the Reserva de la Biosfera Islas del Pacífico (Baja California Peninsula Pacific Islands Biosphere Reserve) encompassing 21 islands, including all of those within the California Floristic Province (see Aguirre-Muñoz and Méndez-Sánchez article).

The agencies and organizations responsible for these islands have had remarkable success in eliminating the most damaging introduced animals, many invasive plants and invertebrates. Plans are still in the works to remove several of the most damaging

Above: Old-growth lemonade berry shrubs (*Rhus integrifolia*) which escaped nearly a century of overgrazing by sheep, dot the hillsides of East Santa Cruz Island, along with recovering coastal scrub. West Anacapa in the background. Photo by Morgan Ball.

remaining invaders. Land uses that threatened native plants have also been eliminated or curtailed. Some of these successes involved remarkable cooperation among government agencies and non-government organizations, great feats by individuals and teams, and advanced technology. Some have become justly famous in conservation circles worldwide and are examples taught in conservation biology courses. In 2016, the Secretariat of the Convention on Biological Diversity and the Aeon Environmental Foundation awarded the MIDORI Prize for Biodiversity to the leader of Grupo de Ecología y Conservación de Islas which spearheaded eradications of damaging invasive animals on 39 islands in Mexico.

Better yet, the vegetation of the islands has made an astounding recovery. On Santa Cruz Island where feral sheep were eliminated roughly 30 years ago, and feral pigs were eradicated in the mid-2000s, scrublands dominated by native species have increased from 5% in 1985 to over 50% in 2015, while Mediterranean annual grasslands have decreased by similar proportions. On Guadalupe Island, where feral goats were eliminated in the mid-2000s, large areas that were barren or completely dominated by invasive grasses just a decade ago are now cloaked with beautiful island endemic shrubs including some never-before recorded there. Seedlings are now abundant in endemic Guadalupe Island pine and Guadalupe Island cypress groves where reproduction was unknown for decades until the goats were removed. Similar successes can be found on almost all of the islands.

The flora and vegetation of the islands aren't out of the woods yet, however. Many taxa have yet to recover,

over 20 endemic taxa have fewer than 10 populations left, and large areas stripped of soil by erosion during the grazing era, or other anthropogenic disturbances, remain barren.

Fortunately, interest in protecting and restoring the flora has gained strength recently. Island managers and mainland partners are working formally together on a variety of invasive and native plant projects and, in 2016, formed the binational Islands of the Californias Botanical Collaborative. Through this program we expect to achieve our island plant conservation objectives more rapidly, at less expense, and on more islands.

Each island differs from the others, sometimes wildly. Human presence on some extends back at least 13,000 years and many have been sites of rich archaeological finds of complex, long-lived cultures. Their history over the past 200 years is also full of interest and sometimes intrigue. They have proven to be ideal sites for field research and demonstration projects on subjects ranging from animal behavior to invasive species ecology and control, to geological fault movement and more. They have served as settings for memoirs, novels, TV shows, and movies. In short the islands have mystique combined with a fascinating and ecologically valuable flora, fauna, and natural history.

The other chapters in this volume provide far greater detail on key points we have made here. Guillems et al. focus on just how remarkable and distinctive the flora of these islands is and the evolutionary processes taking place. Junak et al. offer a sampling of the unique personalities who botanized the islands, from early botanical explorers to recent times. Oberbauer et al. share personal stories of witnessing the remarkable recovery of the vegetation of the islands, while Munson et al. celebrate the recovery of rare and island-endemic taxa. Aguirre-Muñoz and Méndez-Sánchez highlight the recent protections of the Mexican islands and the power of binational collaboration. McEachern et al. remind us some taxa have not yet recovered and remain at risk of extinction. Mazurkiewicz et al. discuss efforts to restore and protect the flora, and D. Knapp et al. divine what is being learned about climate change on the islands and the influence it will have on the future of the flora.

As you read this issue, you may notice that the list of authors is long and representative of a broad partnership. All of them share a passion for the flora of the islands and its ongoing recovery. There are many others in the US, Mexico, and beyond who share this passion. If you aren't already, we hope you will become one of them.

-John Knapp: John J. Knapp: jknapp@tnc.org



Roughly 30 botanists representing island owners and managers, conservationists, and mainland partners have formed the Islands of the Californias: Botanical Collaborative or Islas de las Californias: Colaboración Botánica to advance shared conservation priorities for the botanical resources of the Archipelago. Each year partners meet on one of the California Islands during the "Extravaganza." Pictured is the 2015 Extravaganza held on San Clemente Island. Photo by Morgan Ball.



THE REMARKABLE FLORA OF THE CALIFORNIA ISLANDS

C. Matt Williams¹, Benjamin Carter², Martha Lizeth Ceceña-Sánchez³, José Delgadillo⁴, Barbara Holzman⁵, Steve Junak¹, Denise Knapp¹, Luciana Luna-Mendoza⁶, and Sula Vanderplank⁷

Island systems have long been celebrated as remarkable natural laboratories. By studying the biota of island systems, Charles Darwin and Alfred Russel Wallace independently arrived at the theory of natural selection as the mechanism of evolution. It is no coincidence that these pioneering biologists each had this breakthrough while studying islands, as several island characteristics make them well-suited to showcase nature's evolutionary handiwork. Perhaps most importantly, islands are often small land masses with clear natural boundaries. They may be near continents, as is the case with our California Islands, or truly remote, as in the case of the Hawaiian archipelago. These characteristics, particularly island size and distance to the mainland, were explored in foundational work by MacArthur and Wilson (1967), who articulated mathematical relationships between island size, distance from the mainland, and number of species expected on an island. They found that smaller

islands situated farther from the mainland support, on average, fewer species than larger and closer islands. As discrete land masses with relatively few species, islands may be less ecologically complex than continental settings at similar latitudes. Ultimately, these relationships may make it easier for scientists to untangle the “story” of how island communities formed through time and how constituent species evolved.

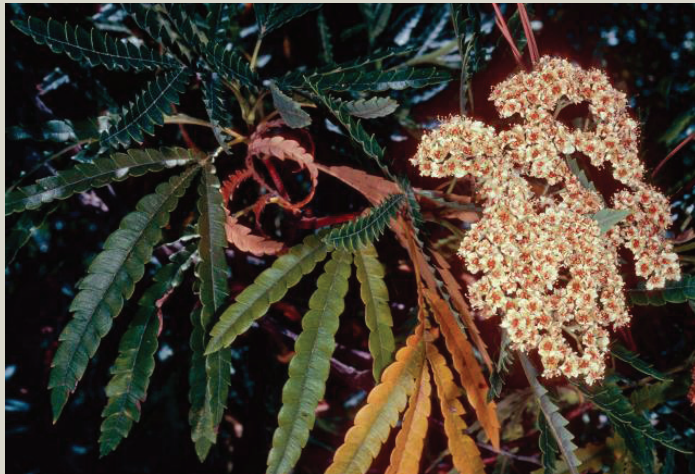
For islands never connected to the mainland, the story of its flora begins with the voyage of a single seed, spore, or structure capable of generating a new plant. What is the long-term fate of a potential colonist after making this voyage across the ocean? Certainly most propagules fail to establish new populations and, of those that do survive, most will establish popula-

Above: A view across the Torrey pine (*Pinus torreyana*) grove on Santa Rosa Island with Santa Cruz Island in the distance. Photograph by Rick Halsey.

-
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PALEO- AND NEO-ENDEMISM ON THE ISLANDS

PALEO-ENDEMISM



Left: Miocene age fossil leaf of *Lyonothamnus parvifolius* (Axelrod) Wolfe from Stewart Valley, NV (UCMP 38654). Photograph by Diane Erwin. Right: Showy inflorescence of the paleo-endemic genus *Lyonothamnus*, island ironwood (*Lyonothamnus floribundus* subsp. *aspleniifolius* shown here). Photograph by Steve Junak.

NEO-ENDEMISM



Clockwise from top left: Examples of neo-endemism on the California Islands include *Cistanthe guadalupensis*, endemic to Guadalupe Island (Photograph by Jon Rebman). *Eriogonum grande* subsp. *timorum* is endemic to San Nicolas Island. *Galium catalinense* subsp. *acrispum*, is endemic to San Clemente Island. *Malacothrix junakii* is endemic to Middle Anacapa Island. Last three photographs by Steve Junak.

tions that continue to resemble their close relatives on the mainland. In the case of our near-shore California Island flora, the majority of species differ in minute ways or are morphologically identical to mainland conspecifics. However, many island systems support species that are remarkably different from mainland relatives, and islands are cherished in part for these special plants and the evolutionary stories they tell.

EVOLUTIONARY PATTERNS: ENDEMICISM AND DIVERSIFICATION

The study of insular floras has revealed a number of intriguing evolutionary patterns. Perhaps the most notable commonality among many island systems is endemism. An organism is said to be endemic when it occurs in one region, for example an island or island archipelago, and nowhere else. Evolutionary biologists have found it useful to differentiate between two types of endemism that result from different historical scenarios. Paleo-endemic species are narrowly distributed organisms in the present day that were formerly widespread when historical conditions permitted. With a mild climate buffered by the moderating influence of the ocean, island systems may provide ideal conditions for the persistence of paleo-endemic plant lineages. A textbook example for the California Islands is island ironwood (*Lyonothamnus floribundus*). The fossil record shows that the genus *Lyonothamnus* was formerly distributed across the southwestern United States in the early Miocene (ca. 16.1 million years ago). With broad changes in climate since the Miocene, the ironwood is presently restricted to portions of the Channel Islands where suitable climate conditions persist. Not surprisingly, paleo-endemic taxa tend to be relatively old lineages; in the remarkable case of the ironwood, a recent study suggests that the lineage giving rise to *Lyonothamnus* diverged from its common ancestor with other extant Rosaceae in the Cretaceous, between 83 and 92 million years ago (Chin et al. 2014).

Islands may also promote the evolution of neo-endemic species, defined as those that occupy in a relatively small region and have historically never been widespread. The physical boundaries around islands can be a formidable barrier to the exchange of genetic material. Over time, island populations may diverge from those on the mainland, either through natural selection in novel insular environments or through the slow accumulation of new genetic mutations. In contrast to paleo-endemics, neo-endemics are recently diverged from their common ancestors with other



The Guadalupe Island neo-endemic tarweeds (*Deinandra frutescens*, *D. greeneana* subsp. *greeneana*, and *D. palmeri*) arose since the late Pliocene, well after the origin of Guadalupe Island and diversification of annual, mainland Californian lineages of *Deinandra* (Baldwin 2007). Top: *Deinandra frutescens* photograph by Reid Moran. Middle: *Deinandra palmeri* photograph by Jon Rebman. Bottom: *Deinandra palmeri* photograph by Steve Junak.

species, and are therefore often “young” in a geologic sense. Discussed in greater detail in the sections that follow, the California Islands are home to many neo-endemic species.

The colonization of an island or island system may result in a burst of diversification resulting in the formation of a group of closely related, neo-endemic taxa. Increased rates of biological diversification yielding a number of species over a short period of time is called a radiation. When these species diversify into novel ecological settings, this burst of diversification

is often called an adaptive radiation, one of nature's most celebrated phenomena. The shrubby tarweeds (*Deinandra*; Asteraceae) provide the most thoroughly studied example of adaptive radiation across the California Islands, displaying both recent diversification (within the last 1.9 $\pm$ 0.6 million years) and ecological differentiation on Guadalupe Island (Baldwin 2007).

The California Islands are also home to a number of species radiations that may or may not include adaptation to novel ecological settings. Our native western North American *Malva* taxa (Malvaceae) provide an excellent example of diversification across the California Islands, with 5-6 recognized taxa scattered from the northern Channel Islands to Asunción Island off the coast of Baja California Sur, Mexico. These plants differ in a number of features including overall stature, leaf shape and pubescence, and petal color, size, and margin. Evolutionary biologists have also presented strong evidence for the radiation of two groups of trefoils—*Acmispon argophyllus* (Fabaceae; three island taxa) and *A. dendroideus* (a separate colonization and diversification comprising three island taxa) as well as two groups in the buckwheats—the *Eriogonum grande* group (Polygonaceae; four island taxa) and the *E. giganteum* - *E. arborescens* group (a separate colonization and diversification comprising four taxa). Further phylogenetic study will likely reveal insular diversifications in the live-forevers (*Dudleya*, Crassulaceae; 14 island-endemic taxa), island malacothrix (*Malacothrix*, Asteraceae; nine island-endemic taxa), and the bed-straws (*Galium*, Rubiaceae; eight island-endemic taxa).

PHYSICAL FEATURES OF ISLAND PLANTS

The physical features of island plants are often different from their closest relatives on the mainland. One recurring pattern is secondary or insular woodiness, first noted by Darwin (1859) and greatly elaborated upon by Carlquist (1965). Island plants are said to be secondarily woody when it can be demonstrated that they evolved from an herbaceous ancestor. Secondary woodiness is thought to be favored in island settings for a variety of reasons, including a mild, stable climate and the absence of large herbivores. Excellent examples of secondary woodiness can be seen in Guadalupe Island rock daisy (*Perityle incana*, Asteraceae) and in the shrubby tarweeds mentioned earlier. Prolonged growth and woodiness may lead to insular gigantism, a phenomenon aptly displayed by the spectacular Santa Catalina Island buckwheat (*Eriogonum giganteum* var.



Malva lindsayi is endemic to Guadalupe Island. Photograph by Reid Moran.

giganteum, Polygonaceae), which can grow to a staggering 12 feet tall.

In the absence of browsing pressure from large herbivores, island plants may lose energetically costly defensive traits such as spines, tough leaves, and chemical deterrents. After comparative study of island-mainland species pairs, Bowen and Van Vuren (1997) found a loss of leaf defensive traits in island Catalina cherry (*Prunus ilicifolia* subsp. *lyonii*, Rosaceae) and northern island bush poppy (*Dendromecon rigida* subsp. *harfordii*, Papaveraceae). An on-going study at UC Davis shows that plants of the genus *Stachys* (Lamiaceae) on the northern Channel Islands have lost much of their chemical defenses when compared to plants of the same species that grow on the mainland (Freedman, personal communication).

THE CALIFORNIA ISLANDS: REGIONAL FLORAS

The California Islands are world-renowned as centers of endemism and as locations that exhibit many of the morphological patterns observed in insular plants. What follows are sections highlighting the floras of three major groups of California Islands.

The Farallon Islands

The Farallon Islands are a small group of rocky islands located approximately 48 km (30 mi) west of San Francisco. The archipelago includes four islands which are part of the 0.85 km² (0.33 mi²) Farallon National Wildlife Refuge managed as a partnership between the US Fish and Wildlife Service and Point Blue Conservation Science. Of granite and quartz diorite parent material, the islands are conspicuously rocky and uneven, with only minor soil layering in



Left: Maritime goldfields (*Lasthenia maritima*) and gulls on Southeast Farallon Island. Photograph by Quentin Clark.
Right: Close up of *Lasthenia maritima*. Photograph by Barbara Holzman.

the low-lying marine terraces. Due to the harsh environment, the flora of the Farallon Islands includes only 46 plant taxa, only twelve of which are native to California. Of the 34 non-native taxa, twelve are listed as invasive by the California Invasive Plant Council. The most common native plant is the annual maritime goldfields (*Lasthenia maritima*, Asteraceae), a guano specialist occurring on offshore rocks and seabird nesting islands from Central California to Vancouver Island, British Columbia. Other prominent native species include miners' lettuce (*Claytonia perfoliata* subsp. *perfoliata*, Montiaceae) and the stout herbaceous perennial, sticky sand-spurrey (*Spergularia macrotheca* var. *macrotheca*, Caryophyllaceae). Together, maritime goldfields and sticky sand-spurrey constitute a fairly distinct vegetation assemblage on the northwestern marine terrace of Southeast Farallon Island, with dense mats of low-growing sand-spurrey interspersed with maritime goldfields and non-native species. The peak of vegetative growth and flowering coincides with the beginning of the seabird breeding season from March through April, during which time the goldfields are collected by cormorants and gulls for ground nest building material. Later in the summer, dried goldfields are used as hiding cover for gull chicks.

Anthropogenic disturbance is a major issue on the Farallons, with Southeast Farallon Island having a record of human activity dating to 1579 (White 1995). Human impacts include seal hunting, egg collection, plant cultivation, and building construction. Humans have also introduced non-native species like domestic cats (*Felis catus*), European rabbits (*Oryctolagus cuniculus*), and Eurasian house mice (*Mus musculus*). Recent eradication efforts successfully eliminated cats and rabbits (USFWS 2009). Today, introduced plant species out-

number native species 3:1, with the most prominent being New Zealand spinach (*Tetragonia tetragonoides*, Aizoaceae), which forms extensive mats, reducing species richness and hindering seabird burrowing and nesting efforts. Major efforts are underway to eliminate *Tetragonia* and restore native habitat.

The California Channel Islands

The eight Channel Islands are situated off the coast of southern California between Santa Barbara and San Diego. The islands are described as having two subgroups: the near-shore northern Channel Islands of San Miguel, Santa Rosa, Santa Cruz, and Anacapa, and the more widely-spaced southern Channel Islands of Santa Barbara, San Nicolas, San Clemente, and Santa Catalina. Islands in the archipelago range in size from Santa Cruz Island at 250.0 km² (96.5 mi²) to Santa Barbara Island at 2.6 km² (1.0 mi²) and distance to the mainland ranges from 19 km (12 mi) to 99 km (62 mi). Although none have been connected to the mainland, evidence suggests that the northern islands were historically connected to each other during the early Holocene (ca. 9,000 thousand years ago) when global sea levels were lower.

The flora of the Channel Islands is well studied, owing to a long history of botanical collecting (See Junak, this volume). Nearly all of the islands have been the subjects of detailed floristic and taxonomic work, which recently has included important studies of non-vascular plants (mosses, hornworts, and liverworts; Carter 2015) and lichens. Taxon richness across the islands ranges from 150 natives on Santa Barbara Island to 662 natives on Santa Cruz Island, corresponding well to predictions based on island size. The most common families across the islands are Asteraceae (162 taxa, ~16.5% of the flora), Poaceae

ENDEMIC PLANTS OF THE BAJA CALIFORNIA PACIFIC ISLANDS

The Baja California Pacific Islands are home to a large number of endemic plants. While insular endemics occur on each island or island group, Guadalupe Island is a botanical marvel. It has more island endemic plants than the other seven Baja California Pacific Islands combined. Images below feature Guadalupe Island endemics. Photographs © GECI Archive/J.A. Soriano.



From left to right: Guadalupe Palm (*Brahea edulis*, Arecaceae), Guadalupe cypress (*Hesperocyparis guadalupensis*, Cupressaceae), and Guadalupe Island phacelia (*Phacelia phyllomanica*, Hydrophyllaceae).

(97 taxa, ~10% of the flora), Fabaceae (78 taxa, ~8% of the flora), and Brassicaceae (41 taxa, ~4% of the flora).

Mirroring patterns seen in island systems across the world, the Channel Islands are rich in endemic species, with the 98 insular endemic taxa representing a precious but threatened part of our natural heritage. These taxa have been historically imperiled by the human introduction of invasive animals. Since most non-native animals have been removed, some of the insular endemic taxa are now recovering (see Munson et al. this issue). Other taxa have not been observed since the time of the early collectors such as *Diplacus traskiae* and *Lycium verrucosum*, and are now the targets of rediscovery programs.

The Baja California Pacific Islands

The Baja California Pacific Islands comprise eight islands or island groups. Seven of these are near-shore continental islands, while Guadalupe is a true oceanic island approximately 260 km (161 mi) offshore. Guadalupe Island is part of the Guadalupe Island Biosphere Reserve, Natividad Island belongs to the El Vizcaíno Biosphere Reserve and the other six islands or island groups are included in the Pacific Islands

of the Baja California Peninsula Biosphere Reserve (see Aguirre-Muñoz and Méndez-Sánchez this issue). All islands are managed by the Natural Protected Areas Commission (CONANP), the Mexican Navy (SEMAR), the Ministry of Interior (SEGOB) and the Ministry of Environment (SEMARNAT).

The islands range in size from San Jerónimo, at just 0.5 km² (0.2 mi²) and home to seven native plants, to Cedros which is the largest of all the California Islands at 350 km² (135 mi²) in area and with 276 native plants. The vegetation of the northernmost islands is dominated by maritime succulent scrub and species typical of the California Floristic Province, which slowly gives way to an increasing number of arid-adapted species south through the archipelago. The larger islands exhibit this same gradient from their northern to southern extremes, and the southernmost island (Natividad) is dominated by cacti and arid-adapted species. All but two of the Baja California Islands are home to single island endemic plants and all eight are home to specialized insular plants that are endemic to multiple islands.

Of the near-shore islands, it is unsurprising that the largest (Cedros) has the greatest number of endemic

plants, while the smaller island complexes of the San Benito Islands (3.9 km²; 1.5 mi²) and the Coronado Islands (1.7 km²; 0.6 mi²) have three endemic plants each (Vanderplank et al. 2017). The oceanic Guadalupe Island is quite unique, with almost one-third of its native flora being found nowhere else on earth. It has more endemic plants than the other seven islands combined and the known flora includes at least 176 native plants. Researchers continue to discover plants that were presumed extinct, plants that are new records for Guadalupe Island, and some that are new to science.

The removal of non-native herbivores from the islands has been key to the survival of many endemic island plants, particularly on the near-shore islands, but Guadalupe Island suffered several plant extinctions prior to the eradication of the goats. Of the 34 taxa endemic to the island, 3 are now considered extinct, including the paleo-endemic *Hesperelaea palmieri* (Oleaceae), *Castilleja guadalupensis* (Orobanchaceae), and *Pogogyne tenuiflora* (Lamiaceae). When considering the entire flora of the island, 26 native species have been lost. The population of California juniper (*Juniperus californica*, Cupressaceae) is on the way to extirpation with fewer than ten individuals, all in poor condition. This species and many others are the focus of ongoing restoration projects.

THE FUTURE OF CALIFORNIA ISLAND BOTANY

We are currently in a critical time for plant science and conservation on the California Islands. Prudent conservation decisions such as removing non-native herbivores have resulted in vegetation and species recovery, however not all communities and individual taxa have recovered to the same extent. It is clear that there is more to learn about these biological systems and more conservation work yet to be done. Scientists and conservationists have important roles to play in the coming years.

Effective conservation planning relies upon the availability of high quality scientific data. This means it is critical to focus on understanding biological diversity across the archipelago and across taxonomic groups. While the vascular plant flora of the Farallon and Channel islands has been relatively well-studied, the California Islands continue to yield new discoveries. Timely improvements in our knowledge of marine algae, bryophytes, lichens, and biological soil crusts have occurred in the last decade. Of course, these organisms do not exist in isolation—each is connected

to others in a complicated ecological network. As a result, conservation of a target species may involve studying its ecological relationships and taking action to preserve an important pollinator or to reduce the effect of a seed predator.

Plant science across the archipelago will continue to benefit from new technologies and innovative study approaches. Genetic techniques are now routinely applied to questions ranging from the distribution of genetic variation on the landscape within a species to understanding the evolutionary history of entire floras. Distribution modeling can be used to predict the occurrence of rare species, sometimes with impressive accuracy. These new tools are needed now more than ever, as we continue our stewardship of the remarkable flora of the California Islands.

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EARLY BOTANICAL PERSONALITIES OF THE CHANNEL ISLANDS

Steve Junak

European naturalists began exploring central and southern California in the 1760s, but the history of botanical discovery on the California Islands did not begin until decades later. The first botanical collections were made in 1842 on Santa Catalina Island and not until the 1860s and 1870s on several other islands. The collective story of these collectors is rich in cultural and natural history.

William Gambel (1821-1849) was the first scientist to collect botanical specimens on the California Islands and the first trained naturalist to spend significant time in California. In addition to plants, he discovered many new birds in the western United States, including Gambel's quail.

As a young man, Gambel had the good fortune to become an apprentice to Thomas Nuttall, one of America's leading naturalists. He spent time in the field with Nuttall, and in 1841, had the opportunity to travel west with a group of trappers to collect scientific specimens for his mentor. On this trip he first described the Gambel oak (*Quercus gambelii*). In 1842 he reached Santa Catalina Island when California was

still Mexican territory. Among Gambel's discoveries on Santa Catalina was the island snapdragon (*Gambelia speciosa*).

Gambel eventually returned to the east coast where he completed his medical training and got married. With a new degree and wife, he planned to begin his medical career. As fate would have it, there was a great need for medical care in California due to the Gold Rush. In 1849, traveling West with a group of settlers, hardship beset the caravan as they traversed the Sierra Nevada in winter. Tragedy struck most of the group, but Gambel survived, finally reaching California again at Rose's Bar on the Yuba River. Soon after, however, Gambel came down with typhoid fever and died in December of 1849.

Since Gambel's trip to Santa Catalina Island, hundreds of individuals have collected herbarium specimens on the California Islands. In this article, some of their stories are told and some of the island plants named for these explorers are highlighted.

FIRST BOTANICAL EXPLORERS ON THE NORTHERN CHANNEL ISLANDS

In 1870, William G.W. Harford was the first to collect botanical specimens on San Miguel Island. On that trip, he landed on Prince Island, an islet situated in

Above left: Blanche Trask, image courtesy of the University and Jepson Herbaria Archives, University of California, Berkeley, CA. Above right: Lorenzo Yates party collecting on Middle Anacapa, from the Bancroft Library, University of California, Berkeley, CA.

San Miguel's Cuyler Harbor, and discovered the iconic giant coreopsis (*Leptosyne gigantea*). In 1872, Harford made it to Santa Rosa Island and collected the first botanical specimens there as well. Among his discoveries on Santa Rosa was the Northern Island bush poppy (*Dendromecon harfordii*), which was named in his honor.

In 1874, Harford and his friend Albert Kellogg, were, again, the first botanical collectors on Santa Cruz Island. They were able to reach these northern islands with the help of the United States Coast Survey. Unfortunately, sheep were introduced to the islands before any comprehensive botanizing was completed there and little is known about the undisturbed vegetation. Some endemic plants may have been lost.

William G. W. Harford (1825-1911) was a naturalist who specialized in conchology (the scientific study of mollusk shells). He was the Director of the California Academy of Sciences in San Francisco from 1876 to 1886. The genus *Hartfordia*, which is endemic to Baja California, was named in his honor.

Albert Kellogg (1813-1877) was a physician and California's first resident botanist. He arrived in California in the summer of 1849 having traveled west by ship from the east coast. He had hoped to strike it rich as a miner in the gold fields but lack of success forced him to move to San Francisco where he opened a drugstore. In his time there he was one of the seven founders of the California Academy of Sciences.

Kellogg was fascinated by the trees that he saw in California. The first island plant that Kellogg described was the island tree mallow (*Lavatera assurgentiflora*), which had reportedly been collected on Anacapa Island prior to 1854. He also published several other papers describing new plants of the Channel Islands. In addition to his work on the islands, he initiated a detailed study of the giant sequoias and eventually published a manual of the forest trees of the state.

FIRST BOTANICAL INVENTORIES ON THE NORTHERN CHANNEL ISLANDS

Harford and Kellogg only collected a few specimens from the islands that they visited. It was not until the 1880s that two energetic and competitive field botanists, Edward L. Greene and Townshend S. Brandegee, began to systematically document the plants of the Northern Channel Islands.

Edward Lee Greene (1843-1915) was a deeply religious man who served as an Episcopal deacon and priest in the 1870s, converted to Catholicism in the 1880s, and eventually became a Professor of Botany at the University of California at Berkeley. During the Civil War, he served as a private in the Union Army and collected plants between battles! At six feet tall, he was a fearless, self-sufficient hiker who often walked 20 to 40 miles in a day. He "always went alone, afoot, unarmed, carrying but a portfolio, a notebook, and a dull knife for digging up the roots of plants." (McIntosh 1983).

On many of his journeys, he ventured into little-known regions populated by Native Americans. Once, while plant collecting in an isolated area, he encountered a party of about 100 mounted warriors. Rather than fleeing, he approached the group and challenged two of the riders to a wrestling match—winning one and losing the other.



Santa Cruz ironwood (*Lyonothamnus floribundus* subsp. *aspleniifolius*) on Santa Rosa Island. Photo by Michael Kauffmann

William Gambel, in 1842, was the first scientist to collect botanical specimens on the California Islands and the first trained naturalist to spend significant time in California.

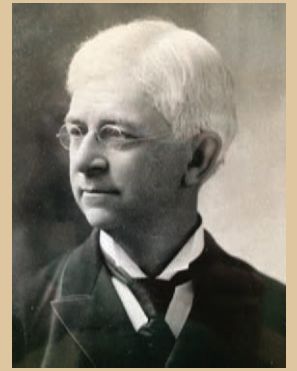


Gambelia speciosa



Dudleya greenii

Edward Lee Greene visited Santa Cruz Island in 1886. His research increased the known flora from five taxa to 321, with 20 previously undescribed.



1830

1840

1850

1860

1870

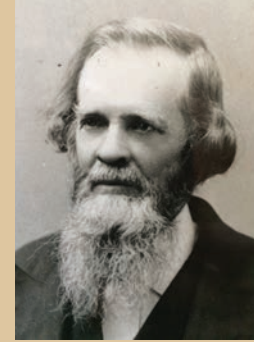


Harfordia macroptera



Dendromecon harfordii

William G. W. Harford, was the first to collect botanical specimens on San Miguel Island in 1870 and in 1872 he explored Santa Rosa Island.



Albert Kellogg often collected with his friend William Harford. He was a physician and California's first resident botanist.

Greene visited Santa Cruz Island in July and August of 1886. His research increased the known flora from five taxa to 321, of which more than 20 were previously undescribed. He was the first botanist to collect extensively on the island and this work led to the publication of the first annotated checklist. Much of his time was spent at the main ranch in the island's Central Valley from which he explored much of the island on foot—refusing to accept a saddle horse or guide from the Caire family who owned the island. He often botanized until after dark causing the Caires to fear he had lost his way on the unfamiliar terrain (Jepson, 1927).

After returning to the mainland he took advantage of an opportunity to visit San Miguel Island. On that occasion, the 30+ mile boat trip from Santa Barbara to the island took nine days! Once on the island, Greene spent two weeks thoroughly exploring and documenting 121 plant taxa, including several chaparral species that are now presumed extinct. Insular endemics named for Greene include island rush-rose (*Crocanthemum greenii*) and Greene's live-forever (*Dudleya greenii*) of San Miguel, Santa Rosa, Santa Cruz, and Santa Catalina islands, and Greene's tarplant (*Deinandra Greeneana* subsp. *greeneana*) of Guadalupe Island.

The first extensive botanical collections on Santa

Rosa Island were made by Townshend S. Brandegee (1843-1925) in June of 1888. After the visit, Brandegee reported about 200 plant taxa.

On Santa Cruz Island in 1888, he also made extensive collections—adding about 80 taxa to the known flora. Brandegee also made important collections on Santa Catalina and San Clemente islands. On the islands of Baja California he described several California Island endemic plants including island tarweed (*Hemizonia clementina*). At least two plants occurring on the Channel Islands have been named for him including *Mimulus brandegeei*.

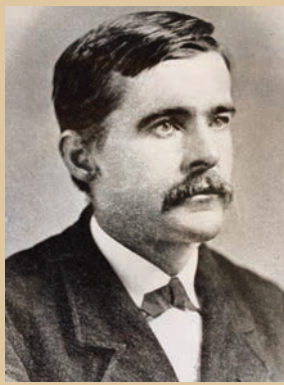
Trained as an engineer and surveyor, Brandegee was well-known for his travels in the western United States and Mexico. While on these trips, he never missed an opportunity to collect botanical specimens, finding a number of undescribed species in the process. After his excursions to Santa Rosa and Santa Cruz, he gave up engineering altogether and devoted his time to the collection and study of plants. In 1889, Brandegee married botanist Katharine Layne Curran, just after returning from his first trip down the Baja California

Above: Plant photos by Steve Junak. Edward Lee Greene, William G.W. Harford, and Albert Kellogg images courtesy of the Hunt Institute for Botanical Documentation, Carnegie Mellon University, Pittsburgh, PA.



Salvia brandegeei

Townshend S. Brandegee, in 1888, was the first to extensively collect plants on Santa Rosa Island, including adding 200 taxa to the known flora.



Blanche Trask collected extensively on the Southern Channel Islands during the late 1890s and early 1900s.



Eriodictyon traskiae subsp. *traskiae*

1880

1890

1900

1910

1920



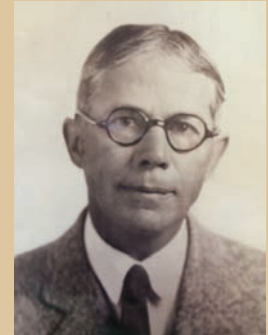
Lyonothamnus floribundus subsp. *aspleniifolius*

William S. Lyon made a number of plant collections on Catalina Island and reported 140 native and 11 non-native plant taxa.



Boechea hoffmannii

Ralph Hoffmann was the most active botanical explorer on the Channel Islands from the mid-1920s until the early 1930s.



peninsula. For their honeymoon, the newlyweds walked from San Diego to San Francisco collecting plants along the way!

Lorenzo G. Yates (1837-1909) was an English-born dentist, naturalist, horticulturist, and author who moved to Santa Barbara in 1882. He became president of the Santa Barbara Society of Natural History and had a wide variety of interests, including anthropology, botany, conchology, mineralogy, paleontology, and zoology.

Yates was the first to collect herbarium specimens from Anacapa Island in the late 1880s or early 1890s. Uncertainty exists around the date of his first visit because labels on his specimens are dated "about 1893" but photographs document his presence on Middle Anacapa Island in 1889.

A BOTANIST WHO DIED BEFORE COMPLETING HIS ISLAND INVENTORY

Ralph Hoffmann (1870-1932), ornithologist, educator, and botanist, was Director of the Santa Barbara Museum of Natural History from 1923 until 1932. He was the most active botanical explorer on the Channel Islands from the mid-1920s until the early 1930s.

A meticulous and brazen collector, he tragically fell

to his death on San Miguel Island 1932, while gathering plants on a series of steep cliffs. The flora he was compiling was never completed, however his unpublished checklist and published works contributed significantly to our current knowledge of botanical resources and the spread of invasive non-native plants during that era. Hoffmann's rockcress (*Boechea hoffmannii*), endemic to Santa Rosa and Santa Cruz islands, and Hoffmann's slender-flowered gilia (*Gilia tenuiflora* subsp. *hoffmannii*), known only from Santa Rosa Island, were named for him.

FIRST BOTANICAL EXPLORERS ON THE SOUTHERN CHANNEL ISLANDS

Before the year 1900, botanical explorers had reached all of the Southern Channel Islands. As mentioned William Gambel collected plants on Santa Catalina Island in 1842. Santa Barbara Island was explored by James G. Cooper in 1863, and then in 1871 by Albert Kellogg and William Harford. In the spring of 1885, William S. Lyon and Joseph C. Nevin collected plants on San Clemente Island. In 1897, Blanche Trask made

Above: Plant photos by Steve Junak. Townshend S. Brandegee: Library, Academy of Natural Sciences of Drexel University, Philadelphia, PA. Ralph Hoffmann: Library, Santa Barbara Museum of Natural History, Santa Barbara, CA

extensive plant collections on San Nicolas Island.

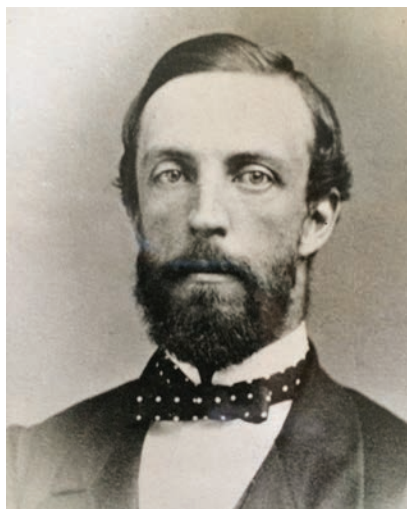
James G. Cooper (1830-1902) was a physician and field naturalist who visited Santa Barbara Island in 1863 while working as a zoologist for the California Geological Survey. He also explored San Nicolas, Santa Catalina, and San Clemente islands between May and July 1863.

William S. Lyon (1851-1916) was a nurseryman and horticulturist who was born in New York and moved to Los Angeles. He was appointed as head forester of the California State Board of Forestry in 1888. During the summer and fall of 1885, Lyon made a number of plant collections on Santa Catalina Island where he reported 140 native and 11 non-native plant taxa. He recognized the Catalina Island ironwood as a unique tree and sent a specimen to botanist Asa Gray, who named a new genus (*Lyonothamnus*) in his honor. Insular endemic *Phacelia lyonii*, known only from Santa Catalina and San Clemente islands, was also named for him.

Joseph C. Nevin (1835-1913) was a Presbyterian minister, accomplished linguist, and missionary to China. While he was in China in the 1860s and 1870s, he became interested in plants. Arriving in Los Angeles in 1878, he began to collect regional plants. He made significant botanical discoveries on the mainland (including *Berberis nevinii* and *Brickellia nevinii*). Nevin and Lyon discovered several insular endemics on their trip to San Clemente Island including *Astragalus nevinii*, *Constancea nevinii*, and *Gilia nevinii*.

SANTA CATALINA ISLAND'S RESIDENT BOTANISTS

One of Santa Catalina's well-known residents was Blanche Trask (1865-1916), who lived there from the early 1890s until about 1915. While living much of the year in the town of Avalon, she also had a house at Fisherman's Cove near the Isthmus. In 1909 it was reported that "Sixteen years ago Mrs. Trask came to the island an invalid, today she can out-walk nearly everyone here. Often during the winter she walks from the Isthmus, taking to the trails, and covers the journey of fifteen miles in a little over three hours." (Anonymous. 1909). Her husband, Walter J. Trask, was a promi-



James G. Cooper: Library, Academy of Natural Sciences of Drexel University, Philadelphia, PA

nent attorney in Los Angeles and divorced her in December 1895, after Blanche "deserted" him to live on the island.

Blanche Trask collected extensively on the Southern Channel Islands during the late 1890s and early 1900s. She collected vascular plants, lichens, Native American artifacts, minerals, and other natural history specimens. In the spring of 1897, she was the first to collect botanical specimens on San Nicolas Island. She published notes on the flora of Santa Catalina in 1899 and on the flora of San Clemente in 1904.

Willis Linn Jepson, professor of botany at the University of California at Berkeley, explored Santa Catalina Island with Trask in 1908 and they became friends. Jepson wrote about her in his journal:

*No one knows so much about [Santa] Catalina Island as Mrs. Blanche Trask, who has been here about 17 years... For the island as a whole, its rocks, cliffs and canons, as well as its plants, trees, and shrubs, this woman has a most remarkable love. ... I have never known anyone anywhere who knows the plants individually over such a large area as she does. She seems to know the individual trees and shrubs like old friends and knows whether they have changed in the last ten years and how much. If a *Dendromecon* shrub has disappeared from the flood plain of Swain's Canon, she misses it and finally locates the old stump... Mrs. Trask has lived so long in the open (she has a camp on the south side) that in appearance she does not suggest the woman she is, being bronzed by the desert sun. A heavy head of brown, slightly grey above the temples, good features, a happy smile when she is making some quaint joke, brown eyes (I think)—she is in her curious shepherd-like costume, with the blanket and staff or stock for climbing which she always carries, her short skirt scarcely reaching the knees, the lower part of the leg from the knee down encased in leggings of leather, a tall peaked straw hat with broad brim. The costume would be the wonderment of the Avalonians but that she departs on her trips early in the morning when only a few people are astir and returns in the watches of the night.*

Unfortunately, Trask's botanical specimens were deposited at the California Academy of Sciences and were destroyed during San Francisco's 1906 earthquake and subsequent fire. Her personal herbarium collection was also destroyed in a large fire at Avalon



Blanche Trask and a friend on Santa Catalina Island. Image courtesy of the University and Jepson Herbaria Archives, University of California, Berkeley, CA.

in November 1915, so only duplicate specimens distributed to other institutions can be examined today.

Seven plants restricted to one or more of the Channel Islands have been named in honor of Blanche Trask. They include *Acmispon dendroides* var. *traskiae* of San Clemente Island, *Astragalus traskiae* of Santa Barbara and San Nicolas islands, *Cercocarpus traskiae* of Santa Catalina Island, *Cryptantha traskiae* of San Nicolas and San Clemente islands, *Dudleya traskiae* of Santa Barbara Island, *Eriodictyon traskiae* subsp. *traskiae* of Santa Catalina Island, and *Mimulus traskiae* of Santa Catalina Island.

In November 1916, Blanche Trask died in northern California. Jepson attended her funeral in San Francisco and wrote:

"Mrs. Trask was, as Miss Eastwood expressed it, "a wild woman." She had given up all that wealth could afford and the pleasures of a social career to live her life on [Santa] Catalina! If she had died on [Santa] Catalina it would have seemed fitting. But she was buried in a great city with only two or three persons present who had known her and no relatives! It seemed tragic, and as the words of the service went on, my mind left the confines of the undertaking chapel and I saw Mrs. Trask, once again, standing on a high ridge beyond Avalon in the moonlit shadows far in the night in silent worship of the sea and air, completely controlled by love of strange beauty and mysticism. Mrs. Trask botanized ardently on her island. She took long journeys on foot, with a shepherd's staff and a bit of food. She discovered several new species and collected many rarities."

The other botanist who lived in Avalon was Meryl B. Dunkle (1888-1969), who was the principal of the Santa Catalina Island Schools from 1923 until

1932. Dunkle collected extensively on the California Channel Islands, beginning with specimens taken on Catalina between February 1928 and May 1932. As field botanist for the Los Angeles County Natural History Museum's Channel Islands Biological Survey, he visited the other seven Channel Islands between April 1939 and September 1941.

The combined efforts of the collectors listed above have provided vital information for understanding the botanical resources of the Channel Islands. Their publications and field notes, as well as the herbarium specimens that they collected, have provided us with the baseline data and tools needed to document changes in the natural resources of the islands over time. I appreciate their legacy and their observations on a daily basis!

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RESILIENCE OF UNIQUE ISLAND VEGETATION

Thomas Oberbauer¹, Martha Lizeth Ceceña-Sánchez², Steve Junak³, Denise Knapp³, Lyndal Laughrin⁴, Luciana Luna-Mendoza⁵, Kathryn McEachern⁶, Bryan Munson⁷, Ken Niessen⁸, Dirk Rodriguez⁹, Peter Schuyler³

The Islands of the Californias are well known for their unique vegetation comprised of numerous island specialist (See Guilliams et al. this issue) including ancient species like Catalina ironwoods (*Lyonothamnus floribundus*) as well as modern insular endemics like manzanitas (*Arctostaphylos*), buckwheats (*Eriogonum*) and tarplants (*Deinandra*). Until a couple of decades ago, these islands harbored only a shadow of their former biodiversity. Nearly all islands suffered century-long overgrazing and browsing which eliminated vegetation and eradicated many of their unique botanical components. The loss of vegetation caused a cascade of destruction including pollinator decline and erosion. Each island shares its own compelling story of the recovery and resilience of native flora and fauna.

THE CHANNEL ISLANDS

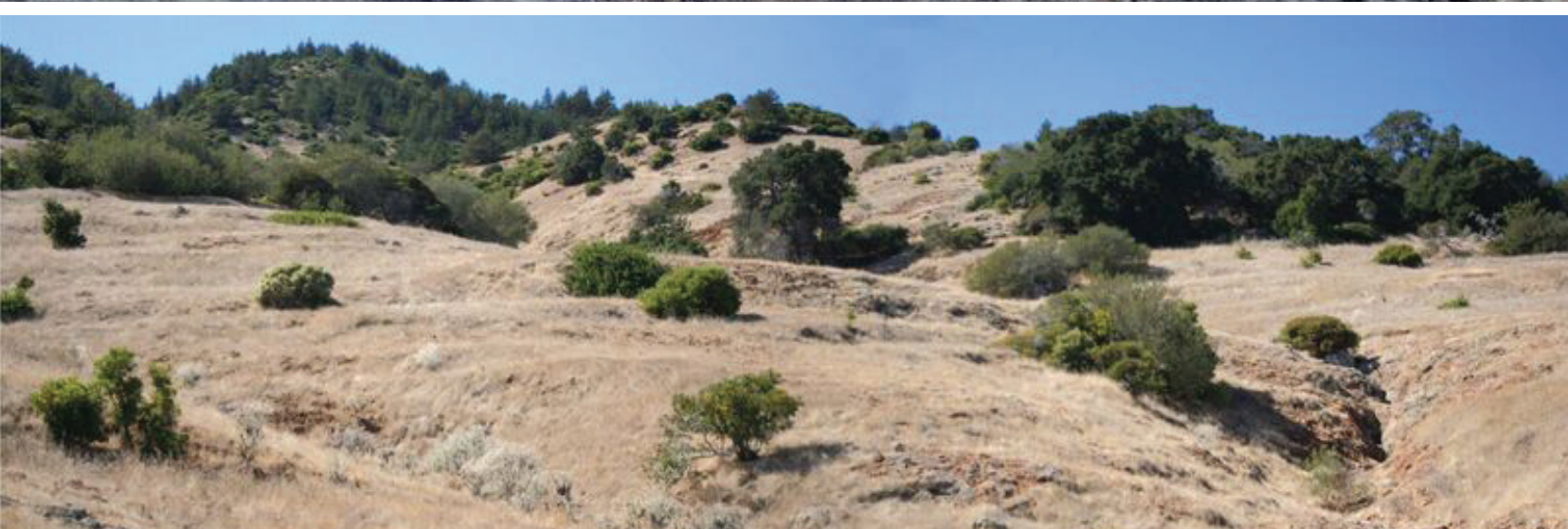
In the 1970's the Navy began efforts to remove feral animals on **San Clemente Island**. Before goat

removal for instance, much of the island was denuded of natives or dominated by non-native annual grasses. The lower terraces supported a sparse cover of maritime sage scrub and slopes in the canyons were barren. In 1975, a notable discovery was one San Clemente Island paintbrush (*Castilleja grisea*) on a cliff face in the midst of the protection of cacti. The only populations of San Clemente Island bush-mallow (*Malacothamnus clementina*) were found shielded amongst rusting metal scraps and debris of an old landfill and on an inaccessible cliff in China Canyon. So denuded was the island that there was little, if any, vegetation that could be classified as sage scrub habitat.

The last goat was removed from San Clemente Island in 1991 (Seward 1992), following the removal of feral deer and pigs which was achieved in the 1980's.

Above: By 1888 it is estimated, based on historical records, that there were only 100 Torrey pines (*Pinus torreyana*) on Santa Rosa Island. Today, after herbivore removal, there are over 12,000 trees—one-quarter of which are saplings. Photo by Michael Kauffmann.

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1. AECOM
 2. Universidad Autónoma de Baja California
 3. Santa Barbara Botanic Garden
 4. Santa Cruz Island Reserve Director
 5. Grupo de Ecología y Conservación de Islas
 6. U.S. Geological Survey
 7. Natural Resources Specialist, US Navy
 8. Mountains Restoration Trust
 9. Channel Islands National Park



Sheep removal on Santa Cruz Island has greatly affected vegetation as seen in these photos. Before (top) goat removal in early 1980s only a few Coast Live Oak (*Quercus agrifolia*) and Bishop pine (*Pinus muricata*) survive but after (bottom) in 2005 large shrubs like *Ceanothus arboreus* and *Baccharis pilularis* are returning. Photos by Peter Schuyler.

Now, sage scrub vegetation covers the upper terraces of the island and down into the canyons. Maritime desert scrub composed of Box-thorn (*Lycium californicum*) and cacti (*Opuntia littoralis*, *Cylindropuntia prolifera*, and *Bergerocactus emoryi*) has expanded along the lower terraces near the Pacific. New populations of San Clemente Island paintbrush have become a major component of the sage scrub vegetation. Giant coreopsis (*Leptosyne gigantea*) was re-discovered on the island indicating the potential that it could be re-established as a component of the vegetation. Island mallow (*Malva assurgentiflora*) has been planted to mimic its formerly extensive cover while woodlands plants like Catalina cherry (*Prunus ilicifolia* subsp. *lyonii*) and Santa Cruz Island ironwood (*Lyonothamnus floribundus* ssp. *asplenifolius*) have regrown in the canyons. Even the grasslands have shifted composition to include natives like Foothill needlegrass (*Stipa lepida*) and broom baccharis (*Baccharis sarothroides*) where non-native grassland previously dominated the landscape.

Santa Cruz Island was subjected to grazing until 2001 (Van Vuren 2014) with up to 50,000 sheep—nearly one per acre—by the late 1800s in addition to numerous cattle and feral pigs. Root crowns of chaparral shrubs more than half a meter above the existing ground level indicated extreme soil loss and pine logs lay on barren gravel in the 1970s above Prisoners Harbor—providing a hint of the former vegetation.

Beginning in the 1990s with herbivore removal Bishop pine (*Pinus muricata*) began to spread while chaparral shrubs, including island manzanitas (*Arctostaphylos crustacea* subsp. *insulicola*, *A. crustacea* subsp. *Subcordata*, and *A. insularis*), white-haired manzanita (*A. viridissima*), bigpod ceanothus (*Ceanothus megacarpus* var. *megacarpus*), feltleaf ceanothus (*C. arboreus*), and island ceanothus (*C. megacarpus* var. *insularis*) have expanded dramatically. There are now places on the island among the ironwoods where evidence of the introduced vertebrates is all but gone!

Santa Rosa Island, at the start of the 21st century, was mostly devoid of native vegetation due to a suite of introduced vertebrates. The island has seen a progression of herbivore removal initiatives including an early removal of sheep and cattle that remained until 1998. By 2011 all other ungulates including deer, elk, and pigs were removed. In the early days of island occupation when introduced herbivores were present, barren slopes seemed to be the natural environmental state with dry, open canyons lacking any riparian vegetation. Along a southern ridge, a remnant grove of Island oaks (*Quercus tomentella*) appeared to be on stilts with roots exposed two meters above the soil line.

Here too, after the removal of grazing animals, the vegetation has rebounded. Riparian canyons are filled with rushes and sedges (*Juncus* and *Carex*), southern cattails (*Typha domingensis*), arroyo willow (*Salix lasiolepis*) and flowing water. Bishop pine groves on Black Mountain are spreading and Torrey pines (*Pinus torreyana*) which by 1888 were estimated to number around 100 individuals are thriving—with an estimated 12,300 trees, one-quarter of which are saplings. Chaparral shrubs like toyon (*Heteromeles arbutifolia*) and California huckleberry (*Vaccinium ovatum*) have sprouted from rootstocks where no recent vegetation existed. Vegetation has expanded and coalesced, reducing fragmentation and providing habitat for plants that need shrub canopies, like the Coast paintbrush (*Castilleja affinis*) on Carrington Point. The native perennial bunch grass community is also rebounding near Becher's Bay and other locations.

The remarkable recovery of vegetation continues on **San Miguel Island**, which prominent botanist Edward L. Greene called “a huge sand dune” following only 40 years of intensive herbivory. The recovery has been remarkable and can be seen when comparing aerial imagery from 1929 to more recent aerial photos in Johnson (1980) article about erosion on San Miguel Island.

Santa Catalina Island has been exposed to the greatest variety of introduced ungulates, including bison and black buck antelope. After multi-year programs to remove goats and pigs, mule deer and bison are the last remaining large herbivores. However, the potential for recovery is evident. After a fire in a region protected from feral animals, native chaparral endemics such as feltleaf ceanothus, Channel Island tree poppy (*Dendromecon harfordii*), Santa Catalina Island bush-mallow (*Malacothamnus fasciculatus* var. *catalinensis*) and island rush-rose (*Crocanthemum greenei*) emerged from the seed bank.

Early island botanists described Island tree mallow (*Malva assurgentiflora*) as abundant, but it was subsequently eliminated from the main island to only survive on two offshore islets. Yet, when planted and protected with fencing on the main island, this plant responds vigorously. It is interesting that though it has not been recorded from Santa Cruz Island, it is found to the west on San Miguel Island, and to the east on Anacapa Island. This raises the question of whether or not it ever existed on Santa Cruz Island.



On Guadalupe Island, *Senecio palmeri* and *Lupinus niveus* recover on formerly bare slopes after goat removal. Photo by Thomas Oberbauer.



Young Guadalupe cypress (*Hesperocyparis guadalupensis*) recovering on Guadalupe Island. Photo by Thomas Oberbauer.

Santa Barbara Island, one of the smallest islands, hosts giant coreopsis (*Leptosyne gigantea*) which was historically so abundant that on a clear day in spring the island appeared as a yellow hill on the ocean when viewed from the mainland. With the introduction of European rabbits and hares the species declined but since their removal giant coreopsis, Santa Barbara Island buckwheat (*Eriogonum giganteum* var. *compactum*) and Santa Barbara Island dudleya (*Dudleya traskiae*) have rebounded.

MEXICAN ISLANDS

Off the western coast of Mexico, on **Coronado Sur Island**, the endemic Coronado Island dudleya (*Dudleya candida*) and western island mallow (*Malva occidentalis*) have spread since the goats and burros were removed. On **San Benito Oeste Island**, after the removal of goats, burros and rabbits, the endemic San Benito Island tarplant (*Deinandra streetsii*) recovered. The **Todos Santos Islands** were also subjected to the impacts of feral rabbits from the 1970s to 1998 as well as donkeys and cats (Donlan et al. 2003). Though the rabbits and donkeys have been removed, annual grassland composed of non-natives has expanded on both islands due rabbit herbivory but some native vegetation remains on the north island, which is once again a major seabird nesting area.

On **Guadalupe Island**, vegetation communities were decimated due to goats into the early 2000s. Endemic Guadalupe Island pine (*Pinus radiata* var. *binata*), Guadalupe Island palm (*Brabea edulis*), Guadalupe Island cypress (*Hesperocyparis guadalupensis*), and island oaks (*Quercus tomentella*) declined. Chaparral components were non-existent or surviving only on cliffs. Some species, such as the composite Guadalupe Baeropsis (*Baeriopsis guadalupensis*) and the endemic Guadalupe Cistanthe (*Cistanthe guadalupensis*) were extremely rare on the main island, surviving on goat-free islets. Reid Moran, the chronicler of the islands flora described the surface as “covered with rocks

that were too big to step over but too small to step around” meaning that the island was difficult to traverse because the surface was covered with ankle turning rocks, devoid of soil.

After only a dozen years, the removal of goats has allowed for tremendous change (Cecena-Sanchez et al. 2016). Three native taxa including the composite Estafiate (*Ambrosia camphorata*), the saltbush Galletilla (*Atriplex barclayana*), and Guadalupe globemallow (*Sphaeralcea sulphurea*) are reestablishing vegetatively. A suite of silver-leaved shrubs including Guadalupe Island ragwort (*Senecio palmeri*), Guadalupe Island rock daisy (*Perityle incana*) and San Clemente Island goldenbush (*Hazardia cana*) as well as the Guadalupe Island silver lupine (*Lupinus niveus*) are reclaiming large areas on the north end of the island. Even species not previously known to occur here, such as feltleaf ceanothus, have become abundant after goat removal.

Overall, the greatest action for the conservation of the California Islands has been the removal of introduced and feral herbivorous mammals. In the absence of these non-native animals each island has demonstrated an unprecedented resilience in vegetation recovery.

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Above: Elephant tree (*Bursera microphylla*) on Cedros Island.

Right: Coastal cholla (*Opuntia prolifera*) on Santa Catalina Island.

Below: Cedros Island Agave (*Agave sebastiana*) on Cedros Island.

All photos this page by Denise Knapp.





Above: Coronados liveforever (*Dudleya candida*) on South Coronados Island. Photo by Stephen McCabe.

Right: Botanist and botanist-in-training explore El Tigre Ridge on Santa Cruz Island. Photos by Denise Knapp.

Below right: On Santa Cruz Island, Wildlands Conservation Science employee Katrina Olthof is treating a remote population of the invasive carnation spurge (*Euphorbia terracina*) with the aid of helicopter transport. Photo by Morgan Ball.

Below: Federally endangered *Malacothamnus clementinus*, a San Clemente Island endemic, has expanded its range since the 1970s, when feral goats had eliminated all but one population. Photo by Dylan Neubauer.





REMARKABLE RECOVERIES AND FANTASTIC DISCOVERIES

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Across much of California, sensitive species are declining as habitats disappear. Many California Islands plants buck this general trend and show a proclivity for being different. After surviving years of onslaught from non-native herbivores, many of the California Island plants once in trouble are recovering and increasing in number and acreage—possibly more rapidly than anywhere else in California or Mexico.

Introduced vertebrates nearly obliterated the plants of the Channel Islands. Eating almost every bit of reachable vegetation and eroding the topsoil upon which the native plants depend, introduced vertebrates significantly reduced both the numbers of native plants and the locations where they could be found. Botanists often risked their lives and scaled steep slopes to glimpse native plants. Plants such as Channel Island bedstraw (*Galium buxifolium*) and giant coreopsis (*Leptosyne gigantea*) were once believed to be only cliff-dwelling species. Today, thousands of individuals have spread into a variety of habitats where the

species were not previously known.

Another example is the Santa Cruz Island lotus (*Acmispon argophyllus* var. *niveus*) that was known from only a few locations and individuals several decades ago. By the 1880s, this Santa Cruz Island endemic had been eaten to the verge of extinction but the species survived and today it is found in hundreds of small populations across the island thanks to the eradication of introduced vertebrates.

The live-forevers (*Dudleya* spp.), with spineless, succulent foliage, were a particularly susceptible target. Greene's liveforever (*Dudleya greenei*) had been almost extirpated from San Miguel Island in the 20th century. The Santa Barbara Island live-forever (*Dudleya traskiae*), endemic to Santa Barbara Island, was almost wiped out

Above: Sunrise over Hoffman Point on San Miguel Island. Photo by Morgan Ball.

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1. U.S. Navy, Naval Facilities Engineering Command Southwest
 2. Catalina Island Conservancy
 3. Soil Ecology and Restoration Group, San Diego State University
 4. Wildlands Conservation Science
 5. US Navy
 6. Santa Barbara Botanic Garden
 7. Grupo de Ecología y Conservación de Islas
 8. U.S. Geological Survey, Western Ecological Research Center
 9. San Diego Museum of Natural History
 10. Channel Islands National Park
 11. Botanical Research Institute of Texas

The Santa Cruz Island lotus (*Acmispon argophyllus* subsp. *niveus*) almost went extinct, but a few plants survived the introduced vertebrates for decades by growing on rocky cliffs and steep slopes—unreachable by the invaders. Now this plant is common across the island. Photo by Steve Junak.



by feral rabbits. Despite its common name, it was not found during a 1970 survey. Off the Baja Peninsula, on Isla San Benito Oeste, the rabbits and burros targeted an endemic dudleya (*Dudleya linearis*) and nearly extirpated it from the island. Since the introduced vertebrates were removed on many islands all of these species are again returning to the landscape. In fact, a new *Dudleya* taxon was recently discovered on Santa Cruz Island. This plant survived the non-native herbivores and avoided botanist's detection for decades by clinging to vertical cliffs that are now guarded by peregrine falcons. This new taxon is currently only known as "white star," based on the shape and color of its foliage. It will receive an official name once it is published (McCabe personal communication).

On Isla Guadalupe, island ceanothus (*Ceanothus arboreus*), a species never documented on the island, was found within a goat enclosure designed to protect cypress trees. After a recent fire in a cypress grove on Guadalupe, more *Ceanothus* were discovered as well as an undescribed *Arctostaphylos*. The new plants that emerged after this particular burn did not appear to belong to one of the previously reported species (*Ceanothus crassifolius* and *Ceanothus cuneatus*). *Ceanothus* experts are currently analyzing this plant for classification as a new species. Because many *Ceanothus* taxa are fire-obligate, fertile seeds lie dormant in the seedbank and germinate when proper conditions break their dormancy.

Santa Cruz Island rock cress (*Sibara filifolia*), was col-

One lone San Clemente Island bush mallow (*Malacothamnus clementinus*) was known in the 1970s. This lone individual survived the introduced vertebrates in a canyon dump, inadvertently protected by a large debris pile. Underground root structures across the island survived the onslaught of the introduced vertebrates, and today there are dozens of colonies spread over much of San Clemente Island Photo by John Game.





Botanists often had to climb or rappel to find native plants that were out of reach of the introduced vertebrates, such as the San Clemente Island Indian paintbrush (*Castilleja grisea*). In 1973, there were only a few hundred individuals of this plant remaining on San Clemente Island, and it was one of the first plants protected by the then-newly-created Endangered Species Act. Today, there are tens of thousands of individuals of this plant across much of San Clemente Island and it was recently down-listed to "threatened." Photo courtesy of San Diego State University SERG database.

lected on Santa Cruz and Santa Catalina Islands at the turn of the 19th century but has not been seen on Santa Cruz Island since 1932 or Santa Catalina since 1973. This small, pink-flowered member of the mustard family was believed extinct until 1986, when two plants were discovered on an exposed sea terrace on the southern part of San Clemente Island—where it was not previously documented. Now thousands of plants are found on the dry, open south-facing slopes of that Island due to restoration efforts. Additionally, the species was rediscovered on Santa Catalina Island's Wild Boar Gully in 2001. This area was fenced to exclude introduced vertebrates in 1999.

Botanists on Santa Catalina Island and San Clemente Island developed a spatial distribution model that predicted potential habitat where new populations might be found. In 2015 the model helped locate approximately 500 more individuals in several new populations outside of the Wild Boar Gully enclosure. Finding this plant outside of the enclosure gave botanists evidence that *Sibara* and other extirpated taxa are persisting undetected on the Channel Islands. Botanists will continue to hone spatial models to assist in finding new populations. On Santa Cruz Island, they are using the model in hope of rediscovering locations where this beautiful crucifer may survive, so that the rock cress might live true to its name.

California dissanthelium (*Poa thomasi*) is another example of the rediscovery of a plant that had been presumed extinct. It is an annual known only from Santa Catalina, San Clemente, and Guadalupe islands. Not recorded since Blanche Trask collected it in 1903 on San Clemente Island, it was presumed extinct. During monitoring in 2005, California dissanthelium was discovered growing in seven diverse locations on Santa Catalina Island. Since no one living had ever seen the plant, specimens were sent to the Santa Barbara Botanic Garden for comparison

with a specimen collected on Guadalupe Island in 1875—which indeed confirmed the discovery. In 2010, it was discovered on San Clemente Island as well. While not yet relocated on Guadalupe Island, botanists from the three islands are working to identify locations where this grass species might persist.

By surviving and now thriving after decades of damage from the introduced vertebrates, many native plants of the California Islands have withstood one of the most destructive forces imaginable. To accomplish this feat, plants persisted in spatially restricted microsites like cliff faces or amongst cactus patches. Seeds and underground root structures remained protected from introduced vertebrates and at the same time were hidden from human's view. With introduced vertebrates removed, the most imminent threat to the plants' survival was eliminated and plants are now successfully colonizing adjacent areas. The seedlings and shoots are now emerging, once again, to successfully reestablish for native fauna that depend upon them—as well as for botanists' enjoyment. Plants of the California Islands are truly remarkable and only time will tell if these unique species can continue to surprise us and survive the future challenges all Earth's species will face.

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THE NEW BAJA CALIFORNIA PACIFIC ISLANDS BIOSPHERE RESERVE SETS A CONSERVATION BENCHMARK: ALL MEXICAN ISLANDS ARE NOW PROTECTED

Alfonso Aguirre-Muñoz and Federico Méndez-Sánchez

Mexico has 4,111 islands that host 8.3% of the country's vascular plants and land vertebrates, including 14 times more endemic species per square kilometer than the mainland. Setting a benchmark for island conservation in Mexico—with relevant benefits to global biodiversity—during the United Nations Biodiversity Conference held in Cancún, Quintana Roo, Mexico in December 2016, Mexico's President announced the creation of four new protected areas (Dibble 2016). Published in the Official Gazette of the Federation on December 7, 2016, President Enrique Peña-Nieto's Decree established the 1,161,447.79 ha “Baja California Pacific Islands Biosphere Reserve” [*Reserva de la Biosfera Islas del Pacífico de la Península de Baja California*] (DOF 2016).

THE RELEVANCE OF THE NEW RESERVE

This Decree comes 13 years after the Mexican non-profit conservation organization *Grupo de Ecología y Conservación de Islas, A.C.* (GECI), together with artisanal fishing cooperatives, particularly the Cedros Island-based *Pescadores Nacionales de Abulón* represented by their regional federation FEDECOOP, and backed by the Senate and the Congress of the Republic,

requested Mexico's federal government to protect these islands and their surrounding waters. This new Biosphere Reserve consists of 21 islands and 97 islets located within the California Current, including (from north to south): Coronado (four islands), Todos Santos (two islands), San Martín, San Jerónimo, Adelaida, Cedros, San Benito (three islands), Bahía Magdalena complex (four islands), and Los Alijos (three islands). It comprises 68,796.56 ha of land that correspond to the islands' surface, and 1,092,651.23 ha of ocean waters surrounding the islands, with the exception of the southernmost ones (i.e., Magdalena Bay). This new reserve adds to the region's islands that were already protected and have their own Biosphere Reserve decree: Natividad, Asunción, San Roque and Guadalupe, creating a comprehensive conservation management framework. The overall regional conservation approach includes active restoration of islands' vegetation communities—once the herbivores and most of the invasive rodents have been eradicated.

Above: Plants, including many endemic species such as the Cedros Island Monterey Pine (*Pinus radiata* var. *cedrosensis*) and the San Benito Islands Liveforever (*Dudleya linearis*), will greatly benefit from the protection conferred by the Decree of the Baja California Pacific Islands Biosphere Reserve. Photo © GECI Archive / J.A. Soriano.

BOTTOM-UP PARTICIPATORY GOVERNANCE

Organized civil society—fishing cooperatives from the productive sector and conservation organizations from the environmental sector—is at the roots of this new Biosphere Reserve. The cooperative *Pescadores Nacionales de Abulón*, the federation of cooperatives FEDECOOP, and GECI—working together with the National Commission of Natural Protected Areas (CONANP)—were instrumental in the design, promotion and establishment of the Baja California Pacific Islands Biosphere Reserve. The formulation of the Technical Justificatory Study for the Reserve's creation was done by GECI and presented in 2005 to the CONANP. Backing the initiative, the Senate of the Republic—attending a request posted by GECI in 2003—made a formal call asking CONANP to initiate the legal process to create the Reserve. As a result, in 2005 the Ministry of Environment and Natural Resources (SEMARNAT) published its intention to create this protected area in the Official Gazette of the Federation (*Diario Oficial de la Federación*). Since the beginning, the overarching rationale behind this Reserve has been the effective protection of the extraordinary biodiversity of these islands while securing the livelihoods of local communities (i.e., fishing cooperatives) that rely on sustainable artisanal fisheries, particularly of lobster and abalone.

Since its inception, the cooperatives—which retain fishing rights from 80 years ago—understand that the new protected area will benefit them because it will be an additional legal measure to further secure its access rights to their leased-resources. This is especially true given that a Biosphere Reserve—an internationally recognized category of natural protected area—explicitly seeks to harmonize the sustainable use of natural resources by local communities with the effective conservation of biological diversity. Therefore, the decree recognizes the historic exclusive rights that local communities have over the natural resources. As expressed by Mario Ramade-Villanueva (personal communication, 14 October, 2011), a member from FEDECOOP:

“The protected area will give us an additional insurance (...). This is because one of the benefits from a protected area is that the natural resources are to be used only by the local communities. Therefore, I believe that in conjunction with our concession titles, the protected area will strengthen the community development on the islands. I believe it will have that extra benefit.”



With the creation of the Baja California Pacific Islands Biosphere Reserve, all islands in Mexico are now protected areas. This is a decision that greatly contributes to both the Convention on Biological Diversity's Aichi Biodiversity Targets, particularly target 11, and the goals and objectives of the Programme of Work on Island Biodiversity. Image © GECI Archive / J.A. Soriano.

FAR BEYOND A PAPER PARK

Far from the common concern of having one more “paper park,” this new Reserve's decree validates and embraces the strong and ongoing comprehensive conservation and tangible restoration actions that have been implemented during the past 15 years. Throughout this time, and grounded on scientifically-based priorities, GECI has been systematically tackling threats that span from invasive mammals and guano mining to development projects such as the potential installation of a liquefied natural gas regasification plant near Coronado Sur Island (Aguirre-Muñoz et al. 2011a). Again, with a bottom-up approach, organized civil society achieved the cancellation of this project after a binational legal defense effort that reached international instances like the Commission for Environmental Cooperation. To date, GECI, in collaboration with the Mexican federal government, and with support from national and international donors, has removed 17 populations of invasive mammals from nine islands that are now

part of this Biosphere Reserve (Aguirre-Muñoz et al. 2011b). Therefore, almost all of the islands within the Reserve are free of invasive mammals.

The eradication of feral dogs and donkeys from Cedros Island is the next key priority to protect its flora and the endemic Cedros Island Mule Deer. Beyond attending the threats successfully, GECI is implementing an important long-term seabird restoration program in partnership with NOAA, FWS, Cornell Lab of Ornithology, the National Audubon Society from the USA, and the support of the Alianza World Wildlife Fund Mexico-Fundación Carlos Slim and the Mexican Fund for the Conservation of Nature from Mexico. This program includes habitat restoration like invasive plant removal, soil enhancement and planting native plants, and seabird colonies restoration using social attraction techniques. There is also progress being made by GECI in the implementation of a program on island biosecurity and environmental culture which aims to maintain the Baja California Pacific Islands pest-free by preventing the introduction of invasive alien species, particularly introduced mammals. This initiative is being supported by the National Commission on Knowledge and Use of Biodiversity (CONABIO) and the Global Environment Facility.

KEY PRIORITY ACTIONS AND OPPORTUNITIES

Strengthened by the new decree, maintenance and consolidation of ongoing tangible conservation actions is of utmost importance. Ideas include keep-

ing positive momentum by accumulating more conservation and sustainable management results. The ulterior objective is the unfolding— as a participatory social construction—of an exemplary model with a concerted integration of conservation and sustainable development. The implementation of formal governance of the new Reserve being a challenge in and of itself. In that regard, the recent recruitment (July 2017) of a capable and experienced director and professional staff of 12 specialists for the everyday operation of the reserve is a very promising fact. The coordination and collaboration schemes for participatory management, including the integration of the Advisory Board (Consejo Asesor) with the legitimate social actors, and stable funding to manage the reserve and to enforce the regulations are still pending tasks.

It will also be of utmost importance not only to recognize potential threats but to be prepared with successful strategies to tackle them, including: (1) Guano mining, with a direct negative impact to threatened marine birds (e.g. habitat destruction and disturbance to the colonies) and the ongoing restoration efforts; (2) Unsustainable aquaculture practices with derived negative impacts on the islands' surrounding waters due to the introduction of exotic species, high densities, intensive supplementary feeding, benthic deposition, and nutrient release; (3) Industrial fisheries (e.g. sardine, anchovy and shrimp) that use non-selective fishing methods thus harming the resource base of artisanal fishing cooperatives (e.g. abalone and lobster), and also impact the overall environmental health of the coastal ecosystems; and (4) unsustainable tourism.



Artisanal fishing cooperatives have been sustainably harvesting abalone and lobster on the waters surrounding the Baja California Pacific Islands for almost a century, thus exercising a form of sovereignty in these territories by means of protecting natural resources both on land and in the ocean. Photo © GECI Archive / J.A. Soriano.

A UNIQUE LIVE FOREVER THREATENED BY ILLEGAL EXTRACTION AND INTERNATIONAL TRADE

The Cedros Island Live Forever (*Dudleya pachyphytum*) is a rare plant found only in a small area on Cedros Island, Mexico. This plant forms groups of individuals and has wide and rounded farinose leaves. It is precisely this snow-white foliage which makes it special and valuable on the illegal horticultural market. Over the years, unlawful international trade done by poachers



The endemic Liveforever (*Dudleya linearis*) now thrives on San Benito Oeste Island thanks to the eradication of introduced donkeys and rabbits. Photo © GECI Archive / J.A. Soriano.

became a serious threat for this species, including the associated destruction of its habitat. Massive extraction—in the amount of thousands of individuals per shipment—started in 2010 and increased during 2016 and 2017. The plants are being sold mostly in South Korea. The extraction of Live Forever plants from Cedros Island is a criminal activity because: (1) it is an endemic species; and (2) it is distributed within a protected area, the recently created Baja California Pacific Islands Biosphere Reserve. According to Mexican regulations, poachers can be sentenced to nine years imprisonment for trafficking endemic flora.

Fortunately, in June 2017, on an intelligence operation from Mexican Federal Government Agencies—including the Environmental Protection Federal Agency (PROFEPA), the Secretariat of National Defense, and the Natural Protected Areas Commission (CONANP)—poachers were caught in the act transporting a shipment of nearly five thousand plants. A press release in Spanish can be found here*. The plants, in poor conditions, had to be rehabilitated on the mainland and are to be taken back to Cedros Island. A specific project to restore the *Dudleya* population on Cedros Island was developed as a coordinated effort between CONANP, PROFEPA, Grupo de Ecología y Conservación de Islas, A.C. (GECI), the local fishing cooperative Pescadores Nacionales de Abulón, and committed people from the local community. This ongoing project has three components: surveillance to avoid poaching; monitoring of the wild population; and in vitro propagation in an on-site nursery. The overall goals are to stop poaching and to fully restore the Live Forever wild population by creating awareness through participatory conservation activities.

*<https://tinyurl.com/Dudleya-pachyphytum>

Another vital challenge is the continuation of the long-term funding for conservation and restoration projects that GECI executes, retaining experienced personnel, and reinforcing the relationship between GECI and local communities and authorities—particularly with CONANP and the Mexican Navy (SEMAR). Together, it is also important to create infrastructure, have the equipment to implement conservation projects, and facilitate the continuous presence of conservation biologists.

As it has already done, continued investment in applied and interdisciplinary research focused on ecology, biology, evolution, conservation, and resource

management will pay high dividends. The creation—as a US-Mexico collaborative effort—of a binational World Heritage Site linking the Channel Islands and the Baja California Pacific Islands will be highly beneficial to better conserve all these closely related islands, interconnected beyond political boundaries by the California Current System. This vision builds upon the ongoing binational (US and Mexico) and trinational (Canada, US and Mexico) collaboration initiatives known as the Trilateral Islands Initiative (LOI 2014) and the Bering to Baja California Marine Conservation Initiative (Morgan et al. 2005), all this under the overall framing given by the North American Agreement



The eradication of feral dogs and donkeys is a priority conservation action to protect the endemic Cedros Island Mule Deer. This will have positive outcomes for the complex ecological interactions with native vegetation communities. Photo by John Knapp.

on Environmental Cooperation, a supplement of the Tri-national North America Free Trade Agreement (NAFTA). By working together, we will ensure an island legacy for generations to enjoy.

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THE STRUGGLE FOR RECOVERY

Kathryn McEachern¹, Peter Dixon², Emma Havstad³, William Hoyer⁴, Denise Knapp⁵, John Knapp⁶,
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Some of the traits that make the flora of the 18 California Islands so distinctive and remarkable also make it highly vulnerable to extinctions (Guilliams et al, this volume). We have compiled a list of more than 100 plants that are now rare on the islands, ranging from species formerly widespread and dominant to those that have always been rare and specialized. In most instances these species were reduced to a handful of populations, and in a few cases, only one to five individuals through the direct and indirect effects of grazing, browsing, and other land uses. Although some of these species are on trajectories that suggest recovery is occurring, others continue on a slow slide towards extirpation from their islands, and even extinction.

The threatened taxa include a variety of growth forms and variability of life histories. Each of the California Islands has a suite of vulnerable species, regardless of how long it has been since conservation management began. Our islands are not alone as others worldwide have some of the highest known extinction rates for both plants and animals (Courchamp

et al. 2003, Ricketts et al 2005, Reaser et al. 2007). Plants on islands have no escape from land use pressures because there are no nearby source populations to “rescue” failing populations through dispersal of seeds or pollen, and some endemics have low genetic diversity or slow growth rates to maturity that limit their ability to respond to rapid environmental change. Essentially, the self-help options are constrained by environmental change, low population numbers, and an innately poor capacity to deal with rapid change.

Through surveys and research studies, we have been working to identify the plant species that are at the greatest risk of near-term extirpation and extinction in order to actively manage for their survival. Of particular concern are species that persist as only a few individuals or in small and isolated populations and those that are vulnerable to extinction by catastrophic events like landslides, flash flooding, or climate change. The

Above: Ken Niessen surveys the rolling hills of Santa Rosa Island, where recovery projects are rebuilding island oak (*Quercus tometella*) habitat. Photo by Michael Kauffmann.

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6. The Nature Conservancy (TNC)

7. Grupo de Ecología y Conservación de Islas (GECI)

Some islands still have feral animals. For example, Santa Catalina Island still has introduced mule deer and bison, with some clear patterns in species recovery when compared to islands that have been feral vertebrate free for even a short period of time. Feral vertebrates disproportionately impact certain endemic insular taxa, often those that would be dominant in the absence of these herbivores. On Santa Catalina these effects are illustrated by the genera *Eriogonum* (e.g. *E. giganteum* var. *giganteum*), *Ceanothus* (*C. arboreus*), and *Cercocarpus* (*C. traskiae*), which are preferentially browsed and generally scarce outside of feral animal enclosures. Photo by Amy E. Catalano.



good news is that by sharing field observations, expert knowledge, and research results across the islands we are better able to identify problems these species are experiencing and thus tailor recovery plans accordingly. The bad news is that some actions are expensive in the long-term and funding for this work is a struggle. Thus, we are devising creative ways to streamline costs by sharing workloads and nursery facilities while forming partnerships to share the workload. What fol-

lows are examples of some plants in need of stewardship, their vulnerabilities, and how plant lovers can help.

The stories that species on the California Islands tell are compelling. Take island mallow (*Malva assurgentiflora*), which occurs naturally four islands. It is a beautiful shrub with juicy stems, palatable leaves and large showy pink flowers that attract diverse pollinators. Once a dominant member of the island floral community, it is now reduced to only a handful of small isolated sites such as offshore rocks that have remained inaccessible to goats. Populations are often so isolated that there is no cross-pollination which results in low genetic diversity and seed production with limited population expansion. Island mallow is easy to grow in protected experiments and botanic gardens. The key to recovery, then, is to understand patterns of extant genetic diversity so plants can be bred and reared for out-planting on the islands to repatriate lost territory. With careful management, the reestablishment of island mallow could bring a host of other species to similar recovery. If the hands-on recovery success of the related Santa Cruz Island bush-mallow (*Malacothamnus fasciculatus* var. *nesioticus*) is an indicator (Mazurkiewicz, this volume) there are good prospects



Island mallow (*Malva assurgentiflora*) once dominated stands of vegetation on four of the California Islands, but is now reduced to just a few small populations that survived in places inaccessible to feral animals. Photo by Morgan Ball.

TABLE 1 Island Plant Vulnerabilities Across the California Islands Archipelago

Species with innate issues that limit population growth: slow growth to maturity, naturally low reproductive rates, genetic limitations on seed production.

Trees and shrubs with low genetic diversity, low seed numbers

- Berberis pinnata* var. *insularis* – SCI, SRI, AI
- Malva assurgentiflora* – All islands except SCI and SRI
- Lycium brevipes* ssp. *brevipes* – SNI, SClem

Dioecious species with limited gene flow

- Baccharis emoryi* – SBI
- Juniperus californicus* – GUA
- Populus balsamifera* ssp. *trichocarpa* and ssp. *fremontii* – SCI, SRI, SCat

Recent colonists, or species at the limits of their ranges

- Arbutus menziesii* – SCI
- Bergerocactus emoryii*, *Cylindropuntia prolifera*, *Vitis girdiana* – SCat
- Euphorbia misera* – SCI, SCat

Species in such altered habitats that they cannot recruit new individuals; viable seeds are produced but the seedlings die.

Trees and shrubs living in altered habitats

- Lyonothamnus floribundus* ssp. *floribundus* and ssp. *aspleniifolia* – SCI, SRI, SCat, SClem
- Arctostaphylos confertiflora* – SRI
- Acmispon argophyllus* var. *adsurgens* – SClem

Herbaceous perennials and annuals

- Castilleja mollis* – SRI
- California macrophylla* – SCat, SCI

Species with specialized and rare habitats that have always been rare, now made more rare because their habitats have been greatly altered or reduced, limiting opportunities for expansion on the landscape.

Rock outcrops, canyons, thin soils

- Boechera hoffmannii* – SCI, SRI
- Pentachaeta lyonii* – SCat
- Cistanthe guadalupensis* – GUA
- Sibara filifolia* – SCI, SCat, SClem

Species of streams, springs and seeps

- Anemopsis californica* – SCI, SNI, SCat, SClem, Cedros
- Epipactis gigantea*, *Holodiscus discolor* – SCI, SCat
- Salix exigua* – SNI, SCat

Marsh inhabitants

- Batis maritima*, *Jaumea carnosa*, *Pluchea odorata*, *Spergularia marina* – SCat
- Atriplex watsonii*, *Salicornia virginica* and *subterminalis*, *Suaeda taxifolia* – SNI, SCat

Dune plants

- Abronia umbellata* – SRI, SNI, SCat
- Calystegia soldanella* – SNI, SCat

Species that rely on certain ecosystem properties or interactions that are now impaired or missing.

Fire-following herbs

- Acmispon grandiflorus* var. *grandiflorus* – SCI, SRI, SCat, GUA
- Eremalche exilis* – SCI, SBI, SCat, SClem, Todos Santos, San Benito, Natividad
- Papaver californicum* – SCI, SRI
- Phacelia grandiflora*, *Mentzelia* spp. – SCat

Fire-adapted shrubs

- Arctostaphylos catalinae* – SCat
- Eriodictyon traskiae* – SCat
- Solanum wallacei* – SCat, GUA

Lacking fire and pollinators or seed dispersers

- Malacothamnus fasciculatus* vars. *nesiotucus*, *catalinae*, *clementinus* – SCI, SCat, SClem
- Dendromecon harfordii* – SCI, SRI, SCat, SClem

Changed fog regime

- Pinus muricata* – SCI, SRI
- Pinus radiata* – Cedros, GUA
- Quercus tomentella* – AI, SCI, SRI, SCat, SClem, GUA

Changed rainfall regime resulting in altered germination cues

- Gilia tenuiflora* ssp. *hoffmannii* – SRI
- Malacothrix indecora* – SCI, SRI
- Phacelia insularis* – SRI, SMI

Island abbreviations: San Miguel Island, SMI; Santa Rosa Island, SRI; Santa Cruz Island, SCI; Anacapa Island, AI; San Nicolas Island, SNI; Santa Barbara Island, SBI; Santa Catalina Island, SCat; San Clements Island, SClem; Isla Guadalupe, GUA; Isla Cedros, Cedros; Islas Todos Santos, Todos Santos; Islas San Benito, San Benito; Isla Natividad, Natividad

for stopping the island mallow extinction as well.

Several other island plants tell a story similar to the beautiful island mallow. The Cedros and Guadalupe Island pines (*Pinus radiata* var. *binata*); California juniper (*Juniperus californica*) and Guadalupe Island cypress (*Hesperocyparis guadalupensis*) on Guadalupe Island; island oak (*Quercus tomentella*) on five of the six islands where it occurs; island ironwood (*Lyonothamnus floribundus*) on the four largest US islands; felt-leaf ceanothus (*Ceanothus arboreus*) on the three US islands are all now very rare where they were more widespread.

At the opposite end of the spectrum, San Clemente Island woodland star (*Lithophragma maximum*) is an example of an endemic, perennial herb with a rare and specialized habitat that has become more isolated and scarce over the last 150 years. San Clemente is one of the driest islands, except in the deep, shaded, east-side canyons where trees create moist microclimates. Fog drip is common, the habitat is more mesic, and covered with mosses and lichens. This is all quite different from the vegetation on the rest of the island. The woodland star exists in small, isolated patches in seven of these remote canyons, requiring many hours to reach a single population. The total number of known plants fluctuates between dozens to the low hundreds of plants across all populations each year.

This woodland star exemplifies the challenges facing other island specialists: there are fewer places now that retain the habitat characteristics within which specialists evolved. Microsites are more isolated in the island landscape because the territory in between is inhospitable and places that look like they might be good habitat do not currently support the plant.

The challenges for island botanists include a lack of information about the relationships among poor seed production, isolation, and low genetic diversity within sites and a lack of information on the range of habitat tolerance. It may be that low genetic diversity leads to poor seed set and limited habitat tolerance. Data do suggest that gene flow is limited in the woodland star. However, it is not clear whether populations are more threatened by low genetic diversity or by insufficient pollination and/or habitat isolation.

Paradoxically, some island species like the endangered two-island endemic Hoffman's rock-cress (*Boechera hoffmannii*), have broader habitat tolerance than is apparent from current distributions. This rock-cress has been found growing in a range of vegetation communities wherever there is sufficient shade and fog for seedlings to survive their first dry summer.



Guadalupe Island pine (*Pinus radiata* var. *binata*) was reduced to a few stands and California juniper (*Juniperus californica*) to just a few individuals by more than a century of goat browsing on Guadalupe Island. Their numbers are so low and their habitats are so changed that they are struggling to recover their former dominance. Photo © J.A. Soriano/GEI archive.

Catalina nightshade (*Solanum wallacei*) is found on Santa Catalina and Guadalupe Islands and the nearby mainland, where it sprouts following wildfire. These islands were so denuded that there was not enough vegetation to carry fire, and the nightshade declined to very few island populations. Photo by Julia Parish.





Channel Islands tree poppy (*Dendromecon harfordii*) sprouts readily after fire, and it has seeds that are dispersed by native ants. This is a plant that has suffered the double challenge of lack of fire and displacement of native ants by invasive predators. Photo by Susan Bloom.

For the woodland star, studies to determine causes of poor seed set and ways to increase seed production are needed, along with experiments testing the potential for population growth in similar habitats. Then, botanists can create recovery plans tailored to the specific issues facing this endemic plant and inform recovery options for similar species.

Recovery actions that can help these plants are best targeted to various levels of ecological organization. Examples of recovery work range from manipulations within populations (informed by genetic studies) to actions taken within and across habitats and landscapes. Often, management actions benefit other

species in the local area. Addressing ecosystem-level challenges is more difficult, but we are working to add resilience by cultivating healthy populations and spreading the risk of decline across island environments and across the archipelago.

Here are some of the current recovery actions:

- Adding plants within populations
- Habitat improvement
- Exclosure construction where feral animals are still present
- Pinniped trampling prevention through exclusion fencing and plant population re-location
- Installing fog-capture structures to facilitate seedling and small plant establishment
- Planting groups of flowering plants that are big enough to attract and retain pollinators
- Hand pollination for seed production
- Non-native Argentine ant eradication to increase populations of native seed-dispersing ants
- Eradicating non-native European honey bees and yellow star thistle control to reduce pollen clogging with non-native pollen
- Seed banking to ensure conservation collections exist for rare island natives

Reasons for the lack of spontaneous recovery across the California Islands archipelago are numerous and varied. There are suites of species with similar problems across islands, just as there are similar suites of problems across species. Working together, island botanists are discovering ways to help manage declining species. We are finding that sharing information, techniques, materials, and staff is the most efficient and cost effective way to provide assistance to these most vulnerable island plants across the archipelago.

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RESTORATION AND PROTECTION OF THE ARCHIPELAGO'S FLORA AND HABITATS: A NEW ERA

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Anthropogenic impacts to the unique flora and fauna on the Islands of the Californias are responsible for extinctions and large-scale disruption of ecological processes that have shifted within recent history. Changes in land-use practices have led to the advent of a new era of conservation and protection and a new focus on ecological, habitat, and species restoration across islands. During the last four decades, restoration actions have included removal of introduced vertebrates which has facilitated dramatic recovery of native vegetation and rare plant species on some islands. However, these conservation actions have also led to a release from herbivory, opening up vast habitat to many invasive plants, leaving some areas severely degraded. In these places, native vegetation is not recovering and some species are still threatened with extinction.

In 1959, after the first round of removal of introduced rabbits from Santa Barbara Island, Channel Islands National Monument biologist Lowell Sumner recognized that the conservation future on these islands would be a competitive battle between non-native and native plant species. Looking across a land-

scape which, in that year, was dominated by 85 percent cover of crystalline iceplant (*Mesembryanthemum crystallinum*), one of the most prolific plant invaders throughout the archipelago, he contemplated “Whether the native plants can win back control over the aggressive iceplant constitutes the next chapter of the unfolding ecological history of Santa Barbara Island”.

Indeed, this battle between species is still unfolding today, not only on Santa Barbara Island, but throughout the archipelago. Invasive species are considered the second-greatest threat to biodiversity worldwide, and are the leading cause of species extinctions in island ecosystems (Wilson 1999). Invasive plants are a

Above: On Santa Rosa Island, wattles and fog nets are being used to restore island oak (*Quercus tomentella*) habitat which was impacted by the Air Force. Photo by Michael Kauffmann.

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1. Channel Islands National Park
 2. U.S. Geological Survey, Western Ecological Research Center
 3. Wildlands Conservation Science
 4. Oikonomos Ecosystem Knowledge
 5. Catalina Island Conservancy
 6. Growing Solutions Restoration Education Institute
 7. Soil Ecology and Restoration Group, San Diego State University
 8. U.S. Navy
 9. The Nature Conservancy
 10. Grupo de Ecología y Conservación de Islas, A.C.
 11. Mountains Restoration Trust
 12. Channel Islands Restoration
 13. California Institute of Environmental Studies
 14. US Fish and Wildlife



Degradation of habitat on Santa Catalina Island at the Valley of the Moon due to grazing. Photo by Doug Propst.

significant factor affecting the preservation of native biodiversity and one of the major restoration challenges of this century, along with the conservation of biodiversity and halting the degradation and loss of ecosystem function (D'Antonio and Meyerson 2002).

Islands have experienced more extinctions than any other ecosystem, and globally twice as many island species face imminent risk of extinction (Ricketts et al. 2005). Island taxa are particularly vulnerable to species introductions (Zavaleta et al. 2001); however, islands provide great opportunity for restoring resilient, functioning ecosystems, which is a major goal in the practice of ecological restoration (Perring et al. 2015). More invasive species eradications have occurred on islands than in mainland systems, and islands where invasive species are absent or have been eradicated offer a greater potential for species reintroductions (see Oberbauer this issue, Jones et al. 2016).

Active ecological restoration and preservation are underway on the California Islands. Common goals include restoring ecosystem function, increasing biodiversity, preventing extinction, and facilitating species recovery. Primary drivers of restoration and conservation science include the Endangered Species Act of 1973 (ESA; 16 U.S.C. § 1531 et seq.), Natural Resource Damages Assessment (NRDA; CERCLA, 1980) funds, and well-articulated agency and organizational missions. The urgent need for conservation and restoration of native species and habitats has attracted a wide-range of scientific talent aimed at advancing conservation strategies and restoration techniques. Restoration projects on the islands focus on a broad range of species including both rare and common while other efforts seek to restore entire vegetation communities in the most damaged areas.

The remoteness and isolation of these islands has

created a unique flora and fauna, but such insular traits also represent major challenges for effective restoration. Although approaches and techniques vary, restoration challenges include species recovery, invasive plant eradication and control, and funding—working on islands is logistically challenging and more costly than working on the mainland. Such conservation requires creativity and the ability to do more with less. As any islander knows—you never throw anything away because you never know when you might need it. Island conservation and research projects require creativity and have reused many items including discarded fencing, old fishing nets, decommissioned pier pilings, and even tapped old spring boxes from the ranching era for irrigation.

As a result island conservationists have developed unique strategies for harnessing the power of wind to disperse seeds and capturing fog to water out-plantings. We have excelled at engaging volunteers, drawn on diverse conservation experiences, adapted methods for pig eradication techniques and invented new techniques to eradicate Argentine ants (*Linepithema humile*). What follows are some of the more innovative projects we are pursuing for restoration, research and plant conservation throughout the islands.

HABITAT RESTORATION:

SANTA ROSA AND GUADALUPE ISLANDS CLOUD FOREST PROJECTS

Dense fog is a common in the California Island ecosystems where it provides moisture that sustains vegetation through the summer drought in the Mediterranean-type climate (Rastogi et al. 2015). Fog droplets condense on twigs and leaves, drip to the ground, water plants, and percolate into the water table

where they support stream flow, springs, and seeps. As the islands became denuded by grazers the fog watering cycle was broken and the vegetation dependent on it suffered. The result has been the functional decline of many community dominant plants, including bishop pine (*Pinus muricata*), island oak (*Quercus tomentella*) and Cedros and Guadalupe Islands pines (*Pinus radiata* var. *cedrosensis* and *P. radiata* var. *binata*).

Multi-year restoration projects are now underway on Santa Rosa and Guadalupe Islands to restore upland cloud forests. Both projects capture fog as a source of water for native species plantings. Fog is harvested with mesh screens that mimic a plant's ability to capture fog-drip with leaves and branches, once provided by the vegetation itself. As young plants become established they take over the fog harvesting function thus jump-starting recovery of the fog water cycle for the island.

Active outplanting was also recognized as a necessary restoration component, especially where the presence of herbivores severely impacted the landscape for prolonged periods. For example, on Isla Guadalupe, approximately 40 adult oaks survived impacts from feral goats. Since the removal of goats in 2006, natural recruitment has returned. However, because island oak is slow to recover, more proactive actions were needed. As part of the larger cloud forest reforestation project, 400 oaks were planted in the winter of 2016–17 near the existing pine-oak forest, in the northern part of the island.



Native plant nurseries on the islands are a vital resource for restoration efforts. Photo by David Mazurkiewicz.

SEABIRD HABITAT RESTORATION

Invasive, non-native plant species and island ecosystem degradation have affected seabird nesting habitat quality on many of the California Islands which imposes threats to population growth and recovery (MSRP 2005). Seabirds are important throughout the archipelago and every island and most offshore rocks provide critical breeding and roosting habitat. The islands afford seabirds a safe haven from overwhelming predation pressure and human disturbance. Recent seabird habitat restoration work has been supported by NRDA funding via Montrose Settlements and Luckenbach Restoration Programs* designed to recover losses to seabirds affected by oil and chemical pollution. Currently, there are project efforts on at least 13 of the islands intended to benefit seabirds and restore breeding habitat.

Scorpion Rock, located off the northeast end of Santa Cruz Island (SCRI) in Channel Islands National Park, is an important seabird nesting and roosting location. A legacy of human use and visitation allowed the spread of invasive, non-native plant species on SCRI and adjacent Scorpion Rock. The altered vegetative cover likely contributed to decreased abundance and quality of nesting habitat for burrow-nesting Cassin's Auklet (*Ptychoramphus aleuticus* subsp. *australis*) and the crevice- and shrub-nesting Scripps's Murrelet (*Synthliboramphus scrippsii*). The removal and control of non-native vegetation and outplanting of more than 9,000 native plants during 2008–14 has dramatically changed the landscape of Scorpion Rock. During this period vegetation was converted from over 90% invasive weeds to over 60% native cover.



Volunteers outplanting on Santa Barbara Island. Photo by Andrew Yamagiwa.

* See www.montroserestoration.noaa.gov &

www.wildlife.ca.gov/OSPR/NRDA/Jacob-Luckenbach



Scorpion Rock, on Santa Cruz Island, is an active restoration site. The first photo (left) is pre-restoration in 2007 the second photo (right) is from 2015 after active restoration. The plant in center of first photo is single giant coreopsis (*Leptosyne gigantea*) in a sea of dried iceplant. It has become one of the dominant plants since restoration efforts began. Photos by David Mazurkiewicz.

To benefit seabirds, a variety of additional larger- and smaller-scale efforts to restore perennial shrub and native cover on Santa Barbara (SBI), Anacapa (AI), and Año Nuevo Islands (ANI) are also underway. Removal of non-native invasive vegetation and the restoration of a native perennial coastal sage scrub community is providing enhanced soil structure, improved nesting conditions, cover for burrow- and shrub-nesting seabirds, and new habitat for invertebrates and passerines. Since 2007, more than 45,000 island-grown plants have been outplanted on SBI and 4,000 on AI. On ANI, non-native rabbits, human infrastructure, and sea lion trampling caused nearly complete loss of vegetation on this small island off the coast of central California by the 1990s. Lack of vegetation facilitated erosion and the collapse of fragile nesting burrows of Rhinoceros and Cassin's Auklets. Scientists countered this with native plant restoration, deployment of erosion control fabric (wattles), exclusion of pinnipeds

(sea lions, seals) from core breeding areas through fencing made from harvested eucalyptus (*Eucalyptus* spp.), and innovative erosion-proof ceramic artificial nest sites. These efforts have reduced erosion damage to burrows and allowed Rhinoceros and Cassin's Auklets populations to rebound. Collaborative evaluation of invasive plant control methods and the development of remote-site restoration techniques have benefitted additional habitat restoration across the California Islands.

On Santa Catalina Island (SCAI), where feral animals like mule deer (*Odocoileus hemionus*) and bison (*Bison bison*) are still present, restoration efforts are focusing on the building of exclosures to protect critical habitat and federally listed species. Over 160 acres of feral animal exclosure are maintained to protect the federally listed species Catalina mahogany (*Cercocarpus traskiae*), Santa Cruz Island rock cress (*Sibara filifolia*) and island rush rose (*Crocanthemum greenei*). Additionally, rare chaparral and oak woodland habitats are being restored with a particular interest in obligate seeding species like island ceanothus (*Ceanothus arboreus*) and north-island bush poppy (*Dendromecon harfordii*) whose seed banks may be depleted due to decades of herbivore impacts.

Efforts prioritize restoration in areas where invasive species such as Harding grass (*Phalaris aquatica*) has been removed through intensive treatment. This process renders habitats devoid of vegetative cover but in the relatively moist, alluvial canyon bottoms in which Harding grass grows, native plant recovery occurs rapidly. These areas may also serve as a refuge for rare chaparral species under altered climate scenarios.

On San Clemente Island (SCLI), scientists have taken a low-maintenance approach to oak restoration to maximize our efforts. By sowing thousands of



Skiffing Santa Cruz Island grown plants ashore to Scorpion Rock during restoration process, remote sites require creative solutions. Photo by Karen Flagg.

acorns (as a sprouted seed with radicle) and not installing any irrigation or performing any maintenance, restoration efforts greatly increased the number of plants installed with minimal effort, while also expanding the area accessible to restoration. Since 2006, 3,106 acorns have been sown in clumps of 10-100, with a majority planted on the eastern side of the island where fog and soil conditions seem most hospitable to oaks. As of 2016, 910 of these acorns had emerged, and 506 are still alive. Some seedlings are even thriving in dense, non-native annual grasslands and growing one foot per year.

Coastal wetland and riparian restoration on SCRI is targeting one of the larger wetland ecosystems and riparian corridors in the archipelago. The goal of this project is to restore ecosystem function to 3 acres of filled wetland and 40 acres of associated riparian corridor infested with invasive eucalyptus (*Eucalyptus camaldulensis* and *E. globulus*) trees. Starting in 2011, 10,000 cubic yards of material was removed from the filled coastal wetland at the mouth of Canada del Puerto, the largest watershed on SCRI. Following excavation, 15,000 native wetland plants were planted while the removal of 40 acres of eucalyptus from the riparian corridor along the associated creek is on-going. Native vegetation is responding positively in areas where eucalyptus have been removed. Despite historic drought conditions, the site met the federal standard for wetlands two out of the previous six years. (Power et.al. 2015).

SINGLE SPECIES RECOVERY AND EXTINCTION PREVENTION

One of the most interesting success stories involves the federally and state endangered island bush mallow (*Malacothamnus fasciculatus* and *clementinus*). This species has two distinct varieties endemic to Santa Cruz Island and Santa Catalina Island (vars. *nesioticus* and *catalina*), and a separate species on San Clemente Island (*M. clementinus*). Plants are relatively short-lived, fire-following shrubs with showy flowers pollinated by specialist insects. Bush mallows were reduced to a few individuals on each island and pushed to the brink of extinction during the ranching days. Plants grow readily from cuttings and, during the last decade, botanists have re-established small colonies on each island. On SCRI and SCLI, several wild populations have re-sprouted following fires. Through a combination of nursery cultivation, out-planting, and habitat management, bush mallows are on a trajectory for recovery



Once believed extinct, California dissanthelium (*Poa thomasi*) was rediscovered on Santa Catalina Island 2005 and San Clemente Island in 2010. Photo by Denise Knapp.

and efforts are helping to preserve genetic diversity and attract pollinators to the benefit of other species.

Restorationists at San Nicolas Island started significant native outplanting in 2015 including for the rare southern Channel Island endemic island sagebrush (*Artemisia nesiotica*). As of 2017, the species has recruited successfully from outplantings and now numbers in the 100s of plants. Two other rare taxa, Baja desert-thorn (*Lycium brevipes* var. *brevipes*) and shore morning-glory (*Calystegia soldanella*), were reduced to two natural populations each on SNI, but, through restoration efforts, have been increased to four populations.

Last seen in 1912 and believed extinct, California dissanthelium (*Poa thomasi*) was rediscovered on SCAI in 2005 and on SCLI in 2010. The only known natural population on SCLI occurred in a heavily used military training area. In 2014, biologists on SCLI started a pilot project to test methods for establishing new populations of California dissanthelium. By collecting small amounts of seed that year, and over the following years, ecologists grew out seed for a test of propagation and outplanting methods. By establishing seedlings in four substrates including under Baja desert-thorn scrub (mimicking the two known natural sites), in an open non-native grass dominated site, under island morning glory (*Calystegia macrostegia* subsp. *amplissima*) vines, and in an area that had previously been cleared of freeway iceplant (*Carpobrotus edulis*), survival strategies were tested. Survivorship was



Battling crystalline iceplant on Santa Barbara Island in restoration areas. This invasive species is considered the worst invader across the Archipelago. Photo by Andrew Yamagiwa.

best under Baja desert-thorn, mediocre under freeway iceplant and island morning glory, and worst in annual grasses—but at least some plants survive to reproduce in all four treatments. While results were mixed, a shotgun approach was warranted for further outplanting at a range of sites across the island for another round of planting in 2015.

With new regional targets for planting, the project expanded California dissanthelium distribution to five new sites in 2015 which included a variety of different habitats, slopes, aspects, soil types, and vegetation communities. Now in their second and third years all six project sites are recruiting, expanding in numbers of individuals, and in area. Interestingly, some of the healthiest individuals are now found in habitats that do not closely resemble the remaining natural population, indicating that we have a lot to learn about the limiting factors in restoration and recovery of this rare annual.

In 1989, Santa Catalina Island was endowed with a native plant nursery and seed conservation facility. This resource, in addition to the Wrigley Memorial Botanic Garden (Avalon, California) which has been in operation since 1935, provides avenues for seed conservation in partnership with accredited programs such as Center for Plant Conservation (Escondido, California). Seed banks protected here are considered the first line of defense against extinction of insular endemic species.

In addition, the nursery and botanic garden facilitate active restoration out-planting of prioritized at-risk species (CNPS 2017) including the charismatic Catalina ironwood (*Lyonothamnus floribundus* subsp. *floribundus*). Presently the Catalina Island Conservancy (Avalon, California) has restoration projects underway

for over a dozen rare taxa including Catalina mahogany (*Cercocarpus traskiae*), Northern island nightshade (*Solanum wallacei*), Catalina manzanita (*Arctostaphylos catalinae*), and island oak.

INVASIVE PLANT ERADICATION PROJECTS

Invasive plant species have been identified as one of the greatest threats to the biological resources across the Islands of the Californias. Successful removal of introduced vertebrates across the Archipelago has shown that large, complex projects are feasible. This success has instilled confidence in island managers and mainland partners to tackle more looming threats. Our collaborative working group keeps us informed and motivated not only to control invasives, but also to work towards complete eradication of many invasive species on individual islands, and we are now prioritizing invasive plant species for eradication archipelago wide.

Most islands have been surveyed systematically for a suite of invasive plant species ($n = 12-72$ species). Once mapped, research has informed prioritization of management by island, and plans have been initiated for eradication at the archipelago level. Infestations are treated at least once annually and once all above ground plants have been removed, they are monitored annually for regrowth.

On SCRI, the Channel Islands National Park and The Nature Conservancy have worked cooperatively to treat 218 acres of fennel-infested locations on east SCRI and in a ten foot buffer along all island roads. Ten years after fennel removal at Scorpion Ranch, native plant communities dominate areas that had been infested with fennel. Results at Smugglers Cove



Helicopter strike team weed warriors prepare for eradication on Santa Cruz Island. Photo by Joel Sivertsen.

suggest areas that were seeded after fennel removal show greater success over non-seeded areas where invasive annual grasses continue to flourish. The continued removal of fennel seedlings is required because the species has a long-lasting and formidable seed bank. The results of this work are promising from a collaborative framework and storyline of diligence and consistent treatment. These examples show the heavy financial and labor commitment needed to control fennel on the island.

This is where many of our non-profit partners play a crucial part. Our partners, in essence, fill the role of recruiters who supply island managers with the armies of volunteers we need to address this significant threat. In order to meet key eradication criteria [i.e., (1) detect all targets, (2) remove all targets, (3) outpace reproduction, and (4) commit to completion, we have learned that, in addition to boots on the ground, we can implement projects with about an order of magnitude less time and cost of traditional methods by using small economical helicopters to deploy teams of technicians. We also have learned that diligence is required to decrease environmental degradation.

Because of an aggressive and well-planned effort, we have met criteria for some species over a decade ahead of schedule. With that said, the work ahead is severely underfunded given the scope of the problem, necessitating leveraging the strengths of volunteers and scientists alike through fundraising power, technical expertise, and good pairs of hands. Just as native plant recovery is on-going so is the response of invasive plants. We remain diligent for the love of the California Islands.

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THE FUTURE OF CALIFORNIA ISLANDS CONSERVATION IN A CHANGING WORLD

Denise Knapp¹, Donaxi Borjes-Flores², Peter Dixon³, William Hoyer⁴, John Knapp⁵, Luciana Luna-Mendoza⁶, Kathryn McEachern⁷, Julio Hernández-Montoya⁶, Bryan Munson⁴, Paula Power⁸, y John Randall⁵

The Islands of the Californias are precious gems strung along the coast of western North America—stunningly beautiful, rich in cultural history, and home to plants and animals found nowhere else in the world (Knapp and Randall, Guillems et al., this issue). Managed primarily for biodiversity conservation, they provide an opportunity to demonstrate what is possible with vision and a dedicated, sustained effort. As contained systems, they are also important laboratories for learning and innovation.

What does global change have in store for these gems? Drought, warmer temperatures, precipitation extremes, ocean warming and acidification, and sea level rise (IPCC 2014) are all occurring at accelerated rates. Decreasing fog frequency (Johnstone & Dawson 2010) will hurt plants that rely on this vital moisture source, such as the Bishop pine (*Pinus muricata*) (Carbone et al. 2013). Habitats already rare on the islands—such as dunes, coastal bluff scrub, and coastal marshes—will shrink. It is predicted that up to 66% of California's endemic plant taxa will experience range reductions within a century (Loarie et al. 2008). Invasive species will likely be favored over natives (Sandel and Dangremond 2012). Sensitivity to climate change may be higher on the coast than in inland areas (Ackerly et al. 2015), and animals on the Channel Islands may be even more vulnerable than their coastal mainland counterparts (Bova et al. 2012).

These changes are happening, and while the islands have made remarkable progress (Munson et al., Oberbauer et al., this issue), they haven't completely recovered from the introduced ungulates that overgrazed and browsed them for over a century (McEachern et al., this issue). Fewer, smaller rare plant populations with reduced genetic diversity are hindered in their ability to attract pollinators and reproduce, and are less able to adapt to environmental changes. Our goal has been to reverse these human-caused changes and give plants a fighting chance at survival so that their biodiversity can provide the islands resistance to invasion, resilience to disturbance, and adaptation to future environments.

Thankfully, innovative and inspiring restoration is happening on the California Islands (Mazurkiewicz

et al., this issue). Efforts should continue to be strategic and data-driven, prioritizing the restoration of ecological function. For example, the interconnections of food and pollinator webs should be carefully considered. Ongoing restoration of dense mosaics of diverse habitat will reduce fragmentation and favor native wildlife over invasive species such as Argentine ants and rats. By continuing and strengthening biosecurity measures, we will protect these systems from future invasions. Restoration and reintroduction projects should be used as experiments wherever possible—taking plants out of their presumed range limits, for instance, to learn more about their requirements. Finally, we suggest storing funds in order to respond quickly to wildfires or take advantage of high rainfall years for planting.

Changes, both good and bad, are being felt and observed on California's Islands. As stewards, we can be flexible with our goals and targets and practice adaptive management while using the best available data and modern tools. Techniques such as structured decision making and risk assessment may be used to balance trade-offs and ambiguities. Working together, we can continue to harness our passion for island restoration and find efficiencies by sharing knowledge. Our Botanical Collaborative (Hoyer et al. in review) is being strengthened and archipelago-wide goals formalized. We are working to combine information across climate, geology, and land use gradients, which will help us to understand the limits of rare, endemic, and invasive species' environmental tolerance and show us ways forward.

We may need to act boldly to prevent species collapse in the face of climate change. For instance, a mainland common garden experiment for Torrey pines (*Pinus torreyana*) conducted by U.S. Forest Service botanists on Santa Barbara Botanic Garden property is showing

1. Santa Barbara Botanic Garden

2. Comisión Nacional de Áreas Naturales Protegidas

3. Catalina Island Conservancy

4. U.S. Navy, Naval Facilities Engineering Command Southwest

5. The Nature Conservancy

6. Grupo de Ecología y Conservación de Islas

7. U.S. Geological Survey, Western Ecological Research Center

8. Channel Islands National Park

that hybrids of the Santa Rosa Island and San Diego subspecies are more robust than both mainland and island individuals. The increased genetic diversity of these hybrids may buffer them from pest outbreaks and climate changes. Taxa like the relict island ironwood (*Lyonothamnus floribundus*) may already be declining beyond our control (see Guilliams, this issue); perhaps this evidence will guide us to manage selected high-profile stands for education and inspiration.

In this, the era of big data and advanced technology, we must use such resources to our advantage. Island scientists are actively compiling existing data across the archipelago and collecting the information we will need in the future (Randall et al. in review). We are using and contributing to existing databases, while creating a customized Island Information System that lets us go farther, faster. Let's also (with thought and care) consider bold new approaches such as translocations, biocontrol, and even genome editing to tackle extensive weed populations like crystalline iceplant (*Mesembryanthemum crystallinum*) or fennel (*Foeniculum vulgare*). We are up against a suite of modern forces—let's use modern tools.

Across the island chain, land managers must play to their strengths. For example, although Santa Catalina's greater visibility has made it tougher to remove all the invasive animals, it receives over a million visitors a year. The Catalina Island Conservancy is building a prominent new interpretive center near the island's entrance to educate visitors and enhance their experience. With education, the public will become stewards for the priceless resources of these islands and better understand the threats that they face. Catalina can be the gateway to the archipelago and help us to conserve the island chain as a whole.

To promote the appreciation and conservation of these islands, we all need to get better at telling their stories. We can tell both a human and a botanical story, for example, by re-tracing the steps of early scientists (Junak et al., this issue) as we “re-discover” the islands' plants, animals, and communities.

Let's promote the islands as places of inspiration and hope—with exceptional beauty and uniqueness, and fascinating human and natural history stories.



While the islands have been recovering following the removal of introduced vertebrates, many areas like this Island oak (*Quercus tomentella*) grove on Santa Rosa Island still need a lot of help. Photo by Denise Knapp.

Now more than ever people need meaningful natural experiences to inspire them to conserve and restore special places. Forty years ago, it was hard to imagine just how amazing the recovery of these islands would be. Today, the botanists who saw them in their weakened state are in awe at how resilient native species can be when given a chance to thrive. The islands will continue to offer optimism

in a changing world for what is possible if we work together.

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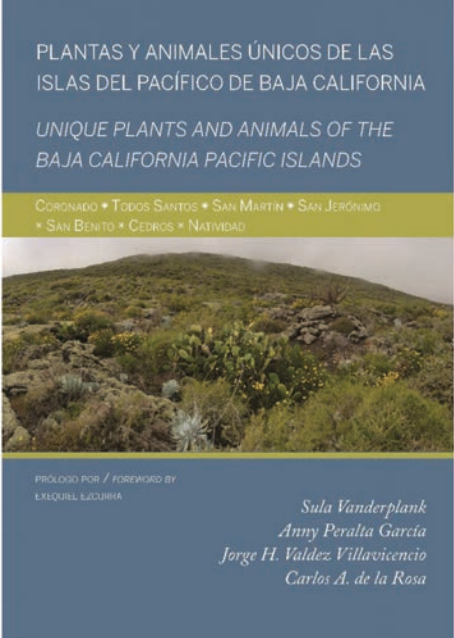
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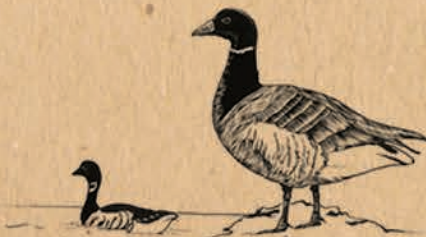
This conservation strategy is responsible for identifying and defining priority conservation sites. It also finds and applies the management tools that best suit their characteristics to ensure that conservation efforts are permanent.

Adaptive Management:

This strategy seeks to ensure that the ecological processes within the natural areas that are already being protected stay healthy. In order to do this, we perform biological and landscape monitoring surveillance programs, infrastructure and restoration activities, and we take care of the visitors that come to the reserves.

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This strategy seeks to achieve and active, conscious and autonomous participation of the community in conservation activities.



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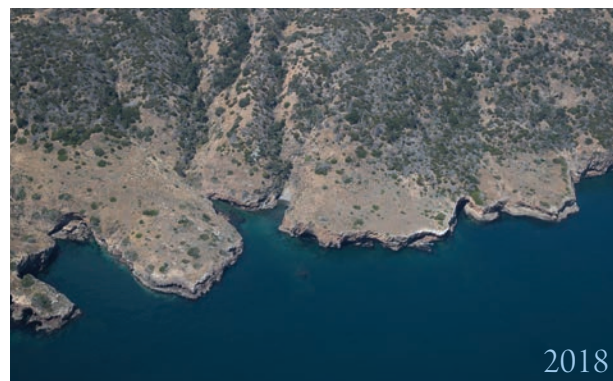
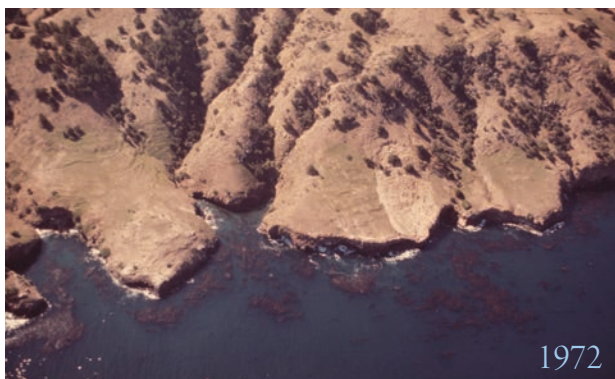
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Dedication

The Santa Barbara Botanic Garden recently lost one of its former leaders and Santa Barbara County's environmental community lost a long-time friend and supporter.



Ralph Philbrick

Sadly, **Ralph Philbrick** (1934-2017) passed away on July 10th.

Ralph worked at the Garden for 23 years, first as Plant Systematist (1964-1973) and then as Director (1974-1987). As Systematist, Ralph organized the first symposium on the biology of the California Islands, expanded the Garden's efforts to document the flora of the Channel Islands, and published a flora for Santa Barbara Island. As Director, he continued his botanical studies on the islands and co-authored annotated checklists for the five islands of Channel Islands National Park and for Todos Santos, San Martin, San Benito, and Natividad islands. He also published several other papers on the plant life of the islands, including the Channel Islands chapter in the first edition of *Terrestrial Vegetation of California*. As a leader, Ralph accomplished a lot, guided the Garden through some lean financial years, and was held in high esteem by his employees.

In 1979, a staff member at the Garden described Ralph's management style in a letter to the Board of Trustees:

"... Ralph is an amazingly competent Director with many attributes that combine sensitivity and wisdom. He is involved with every facet of activity at the Garden and makes the staff feel that what they are doing contributes to the well-being of the Garden. At the same time, he can sort out the trivial from the important and put any issue in proper perspective. If only four words could be used to describe Ralph's interaction with the staff, they would most likely be involvement, concern, support, and competence."

In both his professional and personal life, Ralph will be dearly remembered as a man who, every day, did his absolute best to make the world a healthier, more peaceful, and more beautiful place. He inspired all who knew him!

In his all too brief career **Dr. Cause Hanna** (1982 – 2017) left a legacy of research and discovery that can't be captured in a short passage. It was not just his insatiable thirst for knowledge and understanding of ecological systems that set him apart.



Dr. Cause Hanna

Nor was it his knack for effectively communicating those complexities to students of all ages or his ability to identify questions and problems that could be turned into research or service learning projects, fostering future generations of environmental and conservation stewards. Perhaps it was his unique combination of these characteristics combined with great knowledge, immense passion for the natural world including the Channel Islands, and all-inclusive nature that changed everyone he met.

His warmth, curiosity, and humor were deeply appreciated by his colleagues, collaborators, and students, as well as his boundless energy and enthusiasm for the often grueling work of conservation research, and restoration.

Cause earned his PhD at UC Berkeley where his dissertation revealed the impacts of invasive insects on pollinator communities and the resulting significant decrease in pollinator effectiveness and fruit set in native Hawaiian plant species. As a graduate student, Cause was an influential teacher and mentor to numerous students. He went on to research the impacts of the Argentine ant on Santa Cruz Island native plant and insect assemblages, and was key in the development and initiation of the Argentine ant eradication.

Since 2013, Cause served as CSU Channel Islands' first Director of the Santa Rosa Island Research Station. He taught thousands of students about conservation ecology and field methods, as well as stewardship for and love of the archipelago. His work allowed students to collect data informing future management decisions of the Channel Islands National Park. He facilitated student involvement in service learning and restoration efforts on Santa Rosa Island and initiated a herbarium and DNA barcoding of island bees. Many students pursued careers and advanced degrees in related fields as a result of their experiences and collaborations with Cause.

Cause is survived by his wife Tracy, daughters Solstice and Be Sunshine, an island community, and countless students who will become future island stewards.



From the Editor

Sunrise over Santa Cruz from
the Torrey pine grove

After a childhood enchanted with island literature, aptly including *Island of the Blue Dolphins*, it took nearly 20 years to find myself on a real island. While teaching for the Los Angeles County Outdoor Science School, I ventured to Santa Cruz Island in 1998 with ten other young, eager naturalists. Marooned for the weekend, we gained our first place-based experiences with island biogeography while hiking and kayaking.

On this adventure we witnessed island endemics including island scrub jay (*Aphelocoma insularis*) and island fox (*Urocyon littoralis*). Checking these and other species off our life lists, our appreciation for island time deepened over a sunset staring back at the mainland—our love for biogeography was burgeoning.

Around a campfire under the eucalyptus at Scorpion Canyon we pondered speciation events, biogeographic patterns, and the audacity of invasive species. Falling asleep that evening, I contemplated my study of *Lord of the Flies* in high school and further understood all the mainland offers an island.

In 2017 I returned to the Islands of the Californias—this time to Santa Rosa. The trip was part research to ready myself for this issue but also to become reacquainted with the dynamic island systems. After unpacking and setting camp at the Water Canyon Campground my immediate goal was to reach the cloud forests of Black Mountain. The island oaks did not disappoint, nor did the views across the Pacific.

On my return from the summit I met Channel Island National Park Supervisory Ranger Lulis Cuevas. Having not found *Ljanothamnus* on the hike I asked her where I might find a grove. Eventually, conversation moved toward this issue of *Fremontia*. Her eyes

lit up with excitement—informing me that two of the issue's co-authors were currently on the island. Lulis then introduced me to Kathryn McEachern and Ken Niessen. These two offered a first-hand tour of the restoration work around the island—efforts that are directly addressing issues faced by native flora and fauna. They were also able to share a first-hand perspective on the importance of active management. During their time working here they have witnessed numerous recoveries based on these efforts.

Once home, I enjoyed conference calls and virtual editing sessions with this dynamic team of lead authors as we built this issue. This collection of articles and images is possible only because of the passionate scientists who united in order to share their love for the Islands of the Californias.

John Knapp's dedication and Dan Gluesenkamp's vision for this issue, far before my tenure as editor, was critical in its development. John's connections across the island chain allowed the complete story to emerge. Also, special thanks to Federico Méndez-Sánchez and Alfonso Aguirre-Muñoz for their lead contributions from Baja California and for our Spanish version—a *Fremontia* first! Our own Cris Sarabia helped translate other pages of the issue beyond the articles.

This issue defines a current framework for understanding the islands from the perspective of native vegetation and island phytogeography. It is a great honor and pleasure to share the newest—in a long-storied collection—of island-time publications.

- Michael Kauffmann, fremontia@cnps.org

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Lead Authors

Alfonso Aguirre-Muñoz is an oceanographer with an interdisciplinary Ph.D. in Regional Studies and Sustainable Development. He has forty years of professional trajectory in the conservation and sustainable development of coastal, marine and island ecosystems and was the former Director General of GECI (2002 to 2017).

Matt Guilliams is the Tucker Plant Systematist at the Santa Barbara Botanic Garden. A native Californian, Matt has worked with the plants of the state since 1998. At the Garden he focuses on biodiversity of the Central Coast and Channel Islands, as well as on studies of the Boraginaceae and Montiaceae.

Steve Junak has been exploring the California Islands and studying their plants for almost 50 years. He worked as a botanist at the Santa Barbara Botanic Garden for 37 years, has retired from that job, and is currently a Research Associate there. He co-authored the Flora of Santa Cruz Island (1995), wrote the Flora of San Nicolas Island (2008), and is currently working with several other authors on a flora for Catalina Island.

Denise Knapp has a Ph.D. in Ecology from the University of California, Santa Barbara and an M.A. degree in Geography from the University of California, Los Angeles. She has worked on vegetation, fire ecology, invasive species, rare plant, and habitat restoration projects; her current focus is plant-insect interactions, especially pollinators. She has worked as an ecologist in California, particularly the Channel Islands, for two decades.

John Knapp's love-affair with the California Islands started when, at two years old, his father would leave him to play on Tin Can Beach (now Bolsa Chica) while he went for a run, and John would look across the Catalina Channel at the mountain in the sea wondering what awaited him out there. What he found was great beauty and the need for dramatic conservation intervention, and after working on the islands for the past two decades he now serves as the California Islands Ecologist with The Nature Conservancy. His goal is to develop strategies, methodologies, and tools to more effectively and efficiently address the conservation challenges facing the islands, which is best summarized by Willis Linn Jepson who wrote in 1907, "*In the long run protection must come by the devices and resources of united effort, high intelligence, and careful handling.*"

David Merzurbewicz is a Wildlife Biologist for Channel Islands National Park focused on seabirds and habitat restoration. He has been working on the California Islands for the past decade. The scope of his work within the Park encompasses ecological restoration for seabird nesting habitat and associated plant communities as well as spearheading the Park's Inventory and Monitoring program for seabirds.

Kathryn McEachern is interested in exploring how changes in the environment affect populations of rare and endangered plants. She is a Research Plant Ecologist with the U.S. Geological Survey - Western Ecological Research Center's Channel Islands Field Station, in Ventura, California. She has been studying the distribution, abundance and demography of rare plants on the northern Channel Islands for nearly 20 years, providing research to inform and test restoration and recovery actions.

Bryan Munson is the Botany program manager for Naval Base Coronado, which includes San Clemente Island and 7 properties in San Diego County. Bryan has worked in environmental compliance for the Navy for 10 years. Bryan graduated from the University of Wisconsin-Madison with a B.S. in Biology and a minor in Environmental Studies.

Tom Oberbauer has had a lifelong interest in islands and has had the opportunity to visit most of the California and Baja California Pacific Coast Islands as well as many in the Sea of Cortez. He has written a number of articles describing the botany of the islands including for *Fremontia*.

Federico Méndez-Sánchez is an oceanographer with a MSc in Environmental Management from The University of Auckland, New Zealand. He also has twelve years of experience working on conservation, restoration, and sustainable development of the islands and has been the Director General of GECI since March 2017.

John Randall is a Lead Scientist for The Nature Conservancy's California Chapter. He supervises a team of four other scientists working to conserve and manage protected areas and corridors with the aim of linking them into a statewide network. His own work is currently focused on the conservation and management of the biodiversity of the Islands of the Californias, and on contributing to an urban conservation program for Greater Los Angeles by assessing the distribution of biodiversity and opportunities for enhancing it across the region.