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Islands of the Californias

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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.*"

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

David Mazurkiewicz[1], Josh Adams[2], Morgan Ball[3], Ryan Carle[4], Peter Dixon[5], Karen Flagg[6], Emma Havstad[7], Emily Howe[3], Bill Hoyer[8], John Knapp[9], Kathryn McEachern[2], Luciana Luna-Mendoza[10], Bryan Munson[8], Ken Niessen[11], Ken Owen[12], Julia Parish[5], Paula Power[1], Andrew Yamagiwa[13], and Annie Little[14]

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 landscape 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.

1. Channel Islands National Park
2. U.S. Geological Survey, Western Ecological Research Center
3. Wildlands Conservation Science
4. Oikonos 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.

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

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 scrippsi*). 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.

*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 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.

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

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 (*Cercrocarpus 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

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. *nesiotucus* 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 thomasii*) 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 thomasii*) 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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