Cypress forest on Guadalupe Island showing signs of goat herbivory. The islets Toro and Zapato are in the far distance. All photographs courtesy of Island Conservation unless otherwise noted.

THE RESTORATION OF GUADALUPE ISLAND

by Bradford Keitt, Steve Junak, Luciana Luna Mendoza, and Alfonso Aguirre

"*Guadalupe is remarkable for endemism in the flora and fauna; but it is a naturalist's paradise despoiled by feral goats, housecats, and mice. [The island] is a Mexican national treasure in dire need of protection*" (Moran 1996).

Guadalupe Island rises like a rampart from the wind-whipped sea off the Pacific coast of the Baja California Peninsula. As the westernmost territory in Mexico, the 26,000 hectare island is a lonely outpost for a small military garrison and a community of about 70 fishermen and their families. The island is home to over 30 plant taxa that are found nowhere else in the world. It also supports several southern California ecosystems that are now rare or threatened on the continent, including an extensive lichen flora and important remnants of unique coastal scrub and island chaparral communities.

Guadalupe stirs a love-hate relationship in those that have come to know its sere, rugged landscape. Botanist Reid Moran, whose 40 years of work on Guadalupe brought attention to its unique flora, called it his "very favorite island," but he mused that "at too close a range it has sometimes seemed a hot, ugly, weedy, insuperable rock pile that I have almost wondered, at least fleetingly, why anyone in his right mind would subject himself to climbing it" (Moran 1998).

A primitive dirt road now makes traversing the island easier than it was for most of Dr. Moran's career, but after three hours of bouncing across the island in our own cloud of dust and exhaust, we've also wondered what lures us back year after year. Yet, just as the barren beauty of Guadalupe and the excitement of finding rare and exotic plants seduced Dr. Moran, we too are captivated by the island's ecosystem. For that reason, we have committed ourselves to protecting and restoring the remaining pockets of its unique flora and fauna with the hope that the island can eventually recover some of its original biodiversity.

Thankfully, the political climate in Mexico now exists to help this dream become reality. Over the past decade Mexico has become a world leader in the conservation of island ecosystems, protecting more than 25 islands by removing damaging in-

troduced mammals, both predators and herbivores. With these successes in hand, the Mexican environmental ministry (SEMARNAT), the Grupo de Ecología y Conservación de Islas, and Island Conservation are collaborating with several Mexican and US groups[1] on an ambitious plan to restore Guadalupe, one of the largest and most biologically rich islands in the country.

In this article we offer a glimpse of Guadalupe Island before the introduction of the non-native plants and animals that have radically altered the island's ecosystems, and a brief tale of what has happened to those ecosystems over the past 120 years. We describe efforts initiated in 2001 to exclude goats from some of the most sensitive areas of the island, and the early, promising results of those efforts. And based on results from other islands, we look ahead to what might happen to Guadalupe's vegetation and endemic birds once the goat removal effort, which began in December 2004, is completed.

EARLY DESCRIPTIONS OF THE ISLAND'S VEGETATION

Early descriptions of Guadalupe Island are few, but they paint a picture of extensive shrublands, large juniper forests, and impressive cypress, oak, pine, and palm forests. The lush far-northern end of the island was once blanketed with endemic pines (*Pinus radiata* var. *binata*), island oaks (*Quercus tomentella*), and endemic Guadalupe palms (the common southern California landscaping tree *Brahea edulis*). Shrubs at the north end included *Ceanothus* and *Ribes*, and endemic taxa such as the remarkable *Hesperalcea palmeri*. Moving southwards, pine forests blended into cypress forest dominated by the endemic *Cupressus guadalupensis* ssp. *guadalupensis*. It is thought that this forest included associated shrubs like *Ceanothus crassifolius* and an undescribed endemic *Arctostaphylos* taxon.

Palm trees on the far north end of Guadalupe Island. This area is among the hardest hit by goats. In May 2005 Luciana Luna Mendoza found the first recorded palm seedlings on the island since goats were introduced.

Spreading south and downslope from these forests was an extensive coastal scrub and chaparral ecoregion, similar to the coast of southern California, yet with enough endemics to make it unique. Species like the endemic *Senecio palmeri*, a striking shrub with white foliage, *Sphaeralcea palmeri*, and *Lotus argophyllus* ssp. *ornithopus*, plus more widespread species like *Dichelostemma capitatum* and *Calystegia macrostegia* ssp. *macrostegia* filled the landscape (all descriptions based on Moran 1996). Because the vast majority of these plants are closely associated with the islands off California, Guadalupe is considered a southern extension of the California Floristic Province.

Unfortunately, the island today

Top right: *Senecio palmeri* seedling. • Right: *Senecio palmeri* in flower, safely ensconced atop a cliff looking down 3,000 feet to the ocean. This species is called "white sage" by some, but belongs in the groundsel genus, and is a member of the sunflower family.

[1] Santa Barbara Botanic Garden, The Nature Conservancy, Conservation International, Secretaria Marina, CICESE, Universidad Autonoma de Baja California, Seacology.

Pine exclosure fences with *Ceanothus* and *Calystegia* inside.

is very different from that described by the handful of naturalists who visited it before introduced goats and cats caused widespread devastation. Between 1885 and 1905 visitors documented the destruction of the *Ceanothus*, *Juniperus*, and many of the endemic shrub species (Moran 1996). Over the ensuing 100 years the island has become largely devoid of vegetation across extensive areas. Several endemic plant species have apparently gone extinct, while numerous natives have disappeared from the island. Many other species have become restricted to a few small populations clinging to sheer cliffs and other areas inaccessible to goats. This habitat destruction, combined with predation by introduced cats, also led to the extinction of six endemic bird species, including the Guadalupe caracara, the Guadalupe kinglet, and the Guadalupe storm-petrel (Jehl and Everett 1985, Keitt et al. in press).

A *Ceanothus* plant inside and a dead pine outside an exclosure. This is the first *Ceanothus* reported on the island in over 100 years.

This kind of destruction has become a familiar story played out on islands everywhere—introduced species wreaking havoc on fragile insular ecosystems that have evolved in the absence of terrestrial predators and large herbivores (Coblentz 1978). Goats are especially devastating and are considered "the single most destructive herbivore" of island ecosystems. Because they can survive on almost no water and will eat virtually anything, including bark and roots, goats can kill not only grasses and shrubs, but also adult trees. Their ability to literally strip the landscape bare eventually leads to soil and substrate destruction.

Fortunately, over the past several decades, techniques have been developed to remove goats from islands. At present, goats have been successfully removed from more than 100 islands worldwide in efforts to protect biodiversity and restore island ecosystems (Campbell et al. 2004). The results of these removals have been dramatic and positive even on the most devastated islands.

RESTORATION EFFORTS ON GUADALUPE

The first steps in the restoration effort on the island were to inventory existing plant species and build a series of fences (exclosures) to exclude goats from sensitive areas. In June 2001, Island Conservation, Grupo de Ecología y Conservación de Islas, Santa Barbara Botanic Garden, and the Instituto Nacional de Ecología sent a team to survey the island and mark locations for fences (Junak et al. in press). A rugged group of ranchers from Sonora then overcame incredible logistical obstacles to transport 2 km's worth of fencing materials to remote parts of the island and build 12 fenced exclosures. This was an amazing feat made even more heroic considering that there is no dock at Guadalupe, and everything had to be hand loaded into small open boats to transport it from a Mexican Navy ship to the island. Once on the island, the majority of the gear had to be carried by horses to sites many miles from any road. The main goals of this effort were to see what species grew up in the absence of goat herbivory and try to protect some critically endangered species long enough to enable them to reproduce.

Plant response inside the exclosures was rapid and positive. In January 2002, after only one growing season, 47 seedlings of the endemic pine had sprouted inside one

of the exclosures built around nine adult pine trees. It is estimated there are 220 adult pine trees on the island (Rogers et al. 2003), so this one growing season produced a greater than 20% increase in the number of pines on the island. By June 2003, the number of seedlings inside two of the exclosures was up to 231 and by April 2005, about 1,700 young pines had been counted.

Perhaps the most amazing discovery inside the exclosures was that of a small *Ceanothus*. Another member of this genus, *C. perplexans*, was collected on the island by early botanical visitors (D. Wilken, pers. comm., 2005) but has not been seen there since the late 1800s. Early examination of this *Ceanothus* seedling indicates that this is a new species for the island, closely resembling *C. arboreus*. However, the leaves on this plant are different enough to suggest that this could possibly be an undescribed endemic subspecies. Between May 2004 and April 2005, four additional juveniles of this *Ceanothus* have been discovered around the southernmost pines on the island.

We have also made exciting discoveries outside of the exclosures. In June 2001 we found *Calamintha* (*Satureja*) *palmeri* in small patches around the north end of the island. This mint family member was first described in 1876 and had not been seen since 1885, leading Moran (1996) to consider it "undoubtedly extinct." Also in June 2001 *Nicotiana attenuata*, a native species last seen in 1898 and considered extinct on the island, was found under the cypress trees at the high north end of the island and protected with a fenced exclosure.

The striking "white sage," *Senecio palmeri*, is a Guadalupe endemic that once covered large areas of the island but has not been seen on the island since 1974, and even then was known from only a few individuals in inaccessible cliff areas. To our great delight, in April 2004, we discovered a healthy population of more than 50 *Senecio palmeri* individuals, many in flower, on cliffs along the west side of the island. Giant coreopsis (*Coreopsis gigantea*), common on the offshore islets of Guadalupe but never reported on the main island, was discovered in spring 2005 at a remote beach area at the south end of the island. Likely a favorite food of goats, this species

A field of island poppies (*Eschscholzia ramosa*). Inset: Closeup of *Eschscholzia palmeri*, which is endemic to Guadalupe Island. Photograph by R. Henry.

Above: Laysan albatross on Islote Zapato amidst giant coreopsis (*Coreopsis gigantea*). Common on the offshore islets, Luciana Luna Mendoza discovered the first specimen of *Coreopsis gigantea* ever recorded on the main island. Probably once abundant, this species was rapidly wiped out as a favorite food of the goats. • Right: Laysan albatross family on Islote Negro with the succulent *Cistanthe guadalupensis* in the foreground. Photographs by R. Henry.

may have been very common across the south end of the island but disappeared before botanists ever reached the island.

Amazingly, in good years some native taxa can still dominate even in areas accessible to goats. Following heavy winter rains, the spring of 2003 saw whole mountainsides blanketed with blooming island poppies (*Eschscholzia ramosa*), and fields blue with the flowering stalks of blue dicks (*Dichelostemma capitatum*).

Discoveries such as these are helping establish momentum towards restoring Guadalupe Island. After an extended planning period, goat eradication efforts began in summer 2004. Presently goat populations are so low that they are having little detectable impact over most of the island. The few remaining goats are confined to steep inaccessible cliffs, and it will undoubtedly take some time before the island is completely free of goats. In the meantime, the island is already recovering dramatically; plants (both native and non-native) are growing up and providing much needed protection against erosion across large parts of the island. Annuals are surviving long enough to go to seed, and perennial and shrub species are spreading out into areas formerly overrun with goats.

Restoring vegetation will have far-reaching impacts on Guadalupe Island's ecosystem. An example is the change in precipitation due to destruction of the island's forests. At 26,000 hectares, Guadalupe is slightly larger than Santa Cruz Island off southern California, but is considerably drier except near the top of its 1,300 meter peak, where the nearly constant northwest winds drive clouds up and over the ridge. Previously, the extensive cypress and pine forest caught the fog and increased precipitation. As the goats have devastated the forests there has been much less water capture, and only one main spring now remains on the island.

Luciana Luna Mendoza and Clokey's nightshade (*Solanum clokeyi*) inside an exclosure in the cypress forest. This *Solanum* has peculiar clonal growth habits compared with other nightshades on the Channel Islands, and may be a unique taxon.

Pine seedlings growing inside a fenced exclosure. Over 1,700 seedlings have been counted. These are perhaps the first seedlings to reach this size since goats were first introduced to the island.

Although it is impossible to know exactly what will happen to the vegetation on Guadalupe Island when goats are removed, the data from our exclosures and the rapid changes we are seeing outside the exclosures now that goat numbers are reduced indicate that the benefits to native plants will be dramatic. Another place we can turn to learn about the potential future for Guadalupe's plants is the Channel Islands off Southern California—the islands most floristically similar to Guadalupe. On San Clemente Island, where goats were eradicated in 1992, the initial response was a flush of non-native grasses. However, over time native species began prospering and in some areas they now dominate the landscape.

Although we may not be able to predict exactly what will happen to the island's vegetation, we do know that removing goats from Guadalupe Island is already having dramatic results and will be more effective than any other action to prevent the extinction of the majority of the island's

GUADALUPE ISLAND BIOSPHERE RESERVE

In order to protect Guadalupe Island forever, Island Conservation and the Grupo de Ecología y Conservación de Islas partnered with the Mexican federal government (SEMARNAT and CONANP), the Mexican Navy (SEMAR), and the local fishing cooperative to develop a proposal to create a federally protected area that includes Guadalupe Island and the surrounding marine region. In April 2005 Mexican President Vicente Fox signed into law the decree, officially creating the Guadalupe Island Biosphere Reserve. This means the conservation of Guadalupe Island will be forever monitored under the watchful eye of the Mexican Natural Protected Areas system. To learn more about the decree, visit *www.islandconservation.org*.

HOW CAN YOU HELP?

You can support the conservation work on Guadalupe and the other islands off the Baja California Peninsula by making a tax deductible donation to Island Conservation. Island Conservation is an action-oriented organization dedicated to the protection of island life. Together with our partner organizations Grupo de Ecología y Conservación de Islas in Mexico and Island Conservation Canada, we have eradicated damaging invasive animals from 27 islands in western North America. While Guadalupe Island is our most important project to date, the results described here are similar to those we have found on some of the other 27 islands we have worked on. For example, on the San Benito Islands, the endemic live-forever, *Dudleya linearis*, appeared to be extinct in the wild due to overgrazing by invasive European rabbits. Once the rabbits were eradicated, the *Dudleya* came back from the seed bank and, along with the other native plants, is now flourishing. Please send tax deductible donations to: Island Conservation, 100 Shaffer Road, Center for Ocean Health, Santa Cruz, CA 95060. Or visit our website to donate online: *www.islandconservation.org*.

endemic plant species and, in turn, the loss of the remaining endemic birds that depend on those plants. While the damage to Guadalupe's ecosystem is significant, the observations of rare and presumed extinct plants over the past four years demonstrate that many pieces of the island's unique biotic puzzle still exist. It is now a question of whether these pieces can again be connected. Inside the fenced exclosures, where pine seedlings are growing up out of the shade of their dead and fallen neighbors, recovery of the native vegetation is well underway. On the rest of the island, we are already seeing the beginnings of what we hope will be a process of recovery that will repeat itself across the entire island.

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REFERENCES

Campbell, K., C.J. Donlan, F. Cruz, and V. Carrion. 2004. Eradication of feral goats *Capra hircus* from Pinta Island, Galápagos, Ecuador. *Oryx* 38:328–333.

Coblentz, B.E. 1978. The effects of feral goats (*Capra hircus*) on island ecosystems. *Biological Conservation* 13:279-285.

Jehl, J.R. and W.T. Everett. 1985. History and status of the avifauna of Isla Guadalupe, Mexico. *Transactions of the San Diego Society of Natural History* 20:313-336.

Junak, S., B. Keitt, L.L. Mendoza, A. Aguirre, B. Tershy, and D. Croll. In press. Recent conservation efforts and notes on the current status of the flora of Guadalupe Island, Baja California, Mexico. In: Santos del Prado, G.K, and E. Peters (Eds). *Taller Sobre la Restauración y Conservación de Isla Guadalupe: Memorias.* Instituto Nacional de Ecología. México, D.F.

Keitt, B., R.W. Henry, A. Aguirre, C. Garcia, L.L. Mendoza, M.A. Hermosillo, B. Tershy, and D. Croll. In press. Impacts of introduced cats (*Felis catus*) on the Guadalupe Island ecosystem. In: Santos del Prado, G.K, and E. Peters (Eds). *Taller Sobre la Restauración y Conservación de Isla Guadalupe: Memorias*. Instituto Nacional de Ecología. México, D.F.

Moran, R. 1996. *The Flora of Guadalupe Island, Mexico*. California Academy of Sciences, San Francisco, CA.

Moran, R. 1998. Guadalupe Island and its flora. *Fremontia* 26:3-12.

Rogers, D., J. Vargas-Hernández, A. Matheson, and J. Guerra-Santos. 2003. Conserving the pines of Guadalupe and Cedros Islands, México: An international collaboration. In: Romero, A. and S. West, (Eds). *Environmental Issues in Latin America*. University of Wisconsin Press, Madison, WI.

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