Restoring Hawaii's Dry Forests

Research on Kona slope shows promise for native ecosystem recovery

BY WILLIAM ALLEN

A half-dozen black feral goats looked up with a start as Robert Cabin emerged from the stand of trees. Wild and wary, they had been scrounging for food in the rough lava field on the Kona slope of the island of Hawaii.

"There's the enemy right there," said Cabin (pronounced CAY-bin), a plant ecologist with the US Forest Service's Institute of Pacific Islands Forestry, in Hilo. Almost before he got the words out, the goats turned and darted over a ridge and out of view.

Goats, pigs, and other feral ungulates, or hooved animals, are "the enemy" on the Big Island and elsewhere in Hawaii because these alien (nonnative) species wreak havoc on forests and other ecosystems, eating native plants and digging up soil. Ungulates are a major reason Hawaii is the extinction capital of the United States. With less than 1 percent of the US land mass, Hawaii is home to more than 30 percent of the nation's endangered and rare species. More than 1000 native Hawaiian species are known to be extinct.

The particular ecosystem that concerns Cabin is the tropical dry forest. The dry forests of Hawaii receive about 20 inches of rain a year, while rain forests can get about 10 times as much. On the Hawaiian Islands, feral ungulates, cattle ranching, alien grasses, and other biological insults have eliminated 90 percent of the state's original dry forests. By comparison, about 40 percent of Hawaii's rain forests are gone.

Robert Cabin, US Forest Service plant ecologist, examines ilima (Sida fallax) *at the Kaupulehu preserve on the Kona slope of Hawaii. This and other native species have begun to take hold in the preserve since Cabin and his colleagues removed nonnative fountain grass. Photo: Robert Cabin.*

But here at a region called Kaupulehu, Cabin and fellow biologists and conservationists have begun an important demonstration project for reclaiming Hawaii's degraded dry forests. The demonstration site is protected from ungulates by a fence. In just a few years of research at the site, the biologists have begun to assemble much-needed information about how degraded forests respond to fencing out the enemy and about what other steps may be necessary for restoring the forests.

"We're standing among all kinds of species right on the edge of extinction," Cabin said in June as he led a journalist through the upper part of the site. The upper part, called Kaupulehu mauka, is separated from the lower section by the main highway running upslope from the resort area of Kailua-Kona. The scene is sobering. Kaupulehu mauka, a mere six-acre fenced area, is one of the few remnants of the hundreds of thousands of acres of tropical dry forest that once blanketed the lowland leeward slopes of all the Hawaiian Islands. Many of these areas are slowly degrading, victims of alien animals and plants and the rogue fires that come with them.

Yet in just 3 years of weed whacking, spraying with herbicide, and other toil on these sun-baked slopes, Cabin and his colleagues have seen signs that the forest—with a little help—can restore itself. At the study site, native tree seedlings, shrubs, and vines are rising anew out of the shallow soil and rough lava amid dead, gray clumps of the invasive African bunch grass known as fountain grass (*Pennisetum setaceum*). "I'm continually amazed at how many natives are

Native vines like the awikiwiki (Canavalia hawaiiensis) *have made a strong comeback since nonnative fountain grass has been removed from the experimental plots. Photo: Robert Cabin.*

popping up here and there, regenerating on their own," Cabin said.

A devastated ecosystem

The devastation of dry forests is a common story everywhere in the tropics. They have succumbed to a modern-day crescendo of extinction that began with the original human settlement and grew with Western contact, large-scale ranching, and a rising tide of development. In Hawaii's case, habitat degradation by alien ungulates was—and still is—the crowning blow.

Dry forest is one of the Hawaiian Islands' most culturally important and critically endangered habitats. Native Hawaiians use plants from the forest for everything from medicines to building materials. Throughout the tropics, dry forest regions often were the first to be settled and their resources the first to be consumed. That was largely because these areas were the most hospitable in terms of climate and disease and offered fertile soil and accessible resources.

Hawaii's native species, which evolved amid the oceanic isolation of the mid-Pacific islands, didn't need to adapt to a wide range of natural enemies, as species on larger landmasses must do. Thus, they were particularly vulnerable to disturbance by late-arriving alien species. Dry forest species were among the hardest hit, mainly because the forests were so accessible as habitat. "What's left today are these tiny little fragments of dry forest, and we're standing in one of the best in the state," Cabin said. "It's just this little bread crumb of what was."

Behind him, down the parched slope to the North Kona beach resorts nearly 2000 feet below, spread an ecological desert, a barren carpet of black lava and sandy-colored alien grass dotted with single trees, many of them nonnative. Despite what today seems like an austere environment—hot and dry—North Kona, like the lowland dry side of all the Hawaiian islands, was once among the most species-rich areas in the state.

To try to reverse the all but completed trend of dry-forest destruction, a group of scientists, conservationists, and volunteers formed the North Kona Dry Forest Working Group in 1993. The group is an informal partnership of state and federal agencies, nongovernmental organizations, botanical gardens, and native Hawaiian and other local residents. Lisa Hadway, formerly a researcher at the National Tropical Botanical Garden (NTBG), on Kauai, is coordinator.

The working group is confronting one of the fundamental challenges of conservation biology: restoring a native ecosystem without quite understanding how it functions, much less the precise details of what species and ecological linkages it contained before degradation began. Researchers know little about Hawaii's dry forests, especially about how the ecosystem operates across the Kona landscape's patchwork of different lava flows.

This challenge typifies the so-called Nero dilemma of conservation biology. Conservation biology project leaders can choose to make immediate tactical decisions about a conservation problem before they know all of the problem's complex dimensions and range of solutions, or they can wait until all the data are in—that is, like Nero, they can fiddle while Rome burns. But the North Kona working group believes it has the tools to stop fiddling and start fighting the fire. Through research, education, and demonstration, they believe, dozens of endangered and rare species, mainly plants, can be recovered once the overall structure of the forest is restored. Kaupulehu still supports small populations of the endangered plants kauila (*Colubrina oppositifolia*), uhiuhi (*Caesalpinia kavaiensis*), aiea (*Nothocestrum breviflorum*), kokio (*Kokia drynarioides*), and hala pepe (*Pleomele hawaiiensis*).

"This project is a wonderful example of integration of scientific experimentation and on-the-ground management," says Marie Bruegmann, a biologist with the US Fish and Wildlife Service (FWS) in Honolulu and one of the working group members. "The work that Bob Cabin and Lisa Hadway are doing with research grant funding gives us a scientific basis for making management decisions. While members of the group don't always agree on what should be done or how, we work through these issues and continue to make progress."

The group's work includes "outplanting" hundreds of individuals of federally endangered dry forest species—that is, transplanting nursery-raised individuals to protected areas. The work is funded by the National Science Foundation, State of Hawaii, FWS, NTBG, and other sources. In July, FWS added $72,000 to boost the effort, hoping to provide habitat for the endangered Blackburn's sphinx moth (*Manduca blackburni*), the state's largest native insect.

Fences and fires

The spot from which the goats fled was at the uppermost edge of Kaupulehu mauka, just beyond the fence. From this location, the meaning of an ungulate-excluding fence for native species in Hawaii was clear: On one side were at least some signs of native plant life; on the opposite side, seemingly nothing.

The site was chosen by the working group largely because it had been fenced 40 years earlier by the Territory of Hawaii, protecting it from damage by feral ungulates. "It's not entirely clear why they fenced it," Cabin said. "Somebody just took it upon themselves to do it. Now this is one of the only dry forest pieces that's been fenced for any length of time in the state."

The fence also saved Kaupulehu mauka from cattle grazing, bulldozing, paving, and other forms of clearing that destroyed dry forest elsewhere. But it was luck that kept the site from succumbing to fire. In the past few years, dozens of fires have raged across the North Kona slopes, taking with them many of the last few fragments of dry forest. Fountain grass, an extremely flammable and invasive alien species, is the primary culprit in Hawaii's relatively new history of fire, a history that has been devastating to dry forest remnants.

Researchers believe that fires were rare in the past, and that most were probably ignited by lava, not lightning. Without the grass-layer fuel of today, those fires that did occur were probably quite localized. Native plant species therefore did not need to adapt to fire, so today they don't recover from it easily, if at all. Even if the plants do come back, they must contend with goats, fountain grass, and other invasive alien species. In short, a fire today generally spells the end of a native plant population.

"A really good forest down there burned a couple years ago last fall," Cabin said, pointing down the slope and to the north. "There was a huge fire on this whole side of the island. It jumped the highway in several places and burned a lot of the last pieces left." Kaupulehu mauka was spared because it borders a lava flow dating from 1801 that serves as a natural firebreak.

Lisa Hadway (left), North Kona Dryland Forest Working Group coordinator, collaborates with Susan Cordell, US Forest Service plant physiological ecologist. Photo: Robert Cabin.

Kaupulehu mauka was rife with fountain grass until 1996, when Cabin and his colleagues began a campaign to wrest it out. "That and fire breaks are a big part of what we do now," he said. "It's just to keep this area from burning. When it hasn't burned for a while and there's been rain, the fountain grass can be neck high. And it's just as dry as tinder. So when the winds pick up, it's just a tremendous tinder box."

Overcoming rodents and grass

The research arm of the working group began its study of regeneration at the Kaupulehu mauka preserve in 1995. The study, the results of which were published in *Conservation Biology* in April 2000, was conducted by Cabin, Hadway, Stephen Weller and Ann Sakai of the University of California–Irvine, David Lorence and Tim Flynn of NTBG, and Darren Sandquist of Stanford University.

The biologists began by comparing regeneration of canopy trees in the preserve with that in an adjacent, unfenced area that had been grazed continuously. They found the unfenced area all but devoid of trees and shrubs. The preserve had many older trees of several native species, but a census found almost no native canopy tree seedlings in the study plots of the protected site—this after more than 40 years of potential recovery time.

Cabin and his colleagues suspected that native tree regeneration had been kept in check largely by small alien animals and fountain grass. Three species of nonnative rodents thrived on the site: the mouse (*Mus musculus*), black rat (*Rattus rattus*), and Polynesian rat (*Rattus exulans*). And fountain grass covered the uneven surface of Kaupulehu's lava almost completely at waist-high level.

The researchers proposed that these invasive alien species played a major role in suppressing canopy tree regeneration—the rodents decimating the natural rain of seeds in the plot and the grass smothering any seedlings that might have successfully run the rodent gauntlet and sprouted.

To test these ideas, they placed bait traps with rodenticide throughout the six-acre site. They also painstakingly weed-whacked all the fountain grass, sprayed each remaining clump six separate times with a grass-specific herbicide to kill any newly emerging grass, and pulled out as many clumps as possible. They recorded subsequent developments within the reserve and in the adjacent unprotected, untreated area.

By 1996, the grass was reduced to only 10 percent of the pretreatment cover. Detailed rodent population data

Experimental plots at Kaupulehu, on the Kona slope. Within this fenced area, the North Kona Dry Forest Working Group is trying to learn how best to restore sections of Hawaii's native dry forests. Covered plots are testing the effect of shade on seedling growth. Photo: Robert Cabin.

were not collected, but the researchers observed a general decline in activity by rats and mice, resulting partly from the rodenticide and partly from drought, they believe.

By 1997, canopy tree seedlings had taken a dramatic hold in the preserve. For example, the number of seedlings of lama (*Diospyros sandwicensis*), whose ebony wood is so hard that native Hawaiians once used it for house rafters, jumped from zero in 1996 to 838 a year later in the site's 53 study plots.

The main conclusion of the study is that the dry forest needs a helping hand in overcoming not only damage done by ungulates but also the choking effects of fountain grass and, possibly, damage from seed-consuming rodents. "Removing ungulates is a necessary and critical first step, but it is not sufficient in itself," Cabin said. "Putting up a fence and walking away won't cut it. You've got to do more." Indeed, spraying and clump pulling continued, and by mid-2000 the grass covered only 4 percent of the site.

The regeneration heartened working group members and local resident volunteers, who, along with school groups, began to flock to the site to help plant seedlings and pull fountain grass on weekend work parties. "We had a lot of trees that people who had lived here all their lives had never seen regenerate," Cabin said. "We thought, 'Hey, this is it. You fence it, you get rid of the fountain grass, you poison the rats, and the system recovers.' We got all excited."

But rain had been plentiful in 1997, and when a severe drought hit the next year, regeneration slowed dramatically. The researchers realized that with the original forest and its lower layer of shrubs and herbaceous plants long gone, the site had lost its "microclimate protection," as Cabin put it. In other words, the preserve was still extremely vulnerable to periodic regimes of hot, dry weather, and when it comes to restoration, "shade matters," Cabin said.

Table 1. Federally endangered dry forest species to be outplanted in the Kaupulehu preserve.

Scientific name	Hawaiian name	Abundance on island of Hawaii	Wild individuals left in the state[a]
Abutilon menziesii	Kooloaula	extinct	450
Bonamia menziesii	*no known name*	very rare	*200*
Caesalpinia kavaiensis	Uhiuhi	very rare	42
Colubrina oppositifolia	Kauila	rare	280
Hibiscadelphus hualalaiensis[b]	Hau kuahiwi	extinct	only in cultivation
Hibiscus brackenridgei	Mao hau hele	rare	70
Kokia drynarioides[b]	Kokio	very rare	3
Nothocestrum breviflorum[b]	Aiea	rare	100
Pleomele hawaiiensis[b]	Hala pepe	rare	300

Source: Hawaii Rare Plant Restoration Group.

[a]These estimates continually change as new populations are discovered and old ones destroyed.
[b]Indicates species is found only on the island of Hawaii.

"We're realizing now that it's more complicated than we ever thought, and we've got to do more, depending on the weather," he said. The biologists have begun a series of experiments comparing regeneration in plots with and without drip-line irrigation.

Meanwhile, they are monitoring invasion by other nonnative plants, which take advantage of the new conditions as much as the native plants do. In the study published in April, the researchers found 16 nonnative plants new to the preserve. "One of the species that's really come in heavy in some places is this guy," said Cabin, walking over to a milkweed plant and pulling it up. Milkweed was brought to Hawaii by an aficionado of monarch butterflies, which rely on milkweed as a host plant. "You'll see monarchs flittering all around here, laying their eggs," Cabin said. "The plant looks pretty innocent here, but there are places up the road where it's just 'milkweed forest,' where it's 12-feet-high solid milkweed."

For about 2 years, the biologists studied the invasion of milkweed, thistle, and other alien plants at the site to document how they competed with native species. "On the one hand, it would be really fascinating to just step back and see the natives and the alien species kind of fight it out, now that we've gotten rid of fountain grass," Cabin said. "But from a restoration and political point of view, this forest is too valuable to do that." So the working group now removes nonnative plants as frequently as possible.

Searching for new methods

Below the highway, in the lower part of Kaupulehu, the working group in 1995 began work at a second site, a 70-acre dry forest patch known as Kaupulehu makai.

The focus at this site is larger-scale restoration demonstration and experiments. Group members want to show that dry forest can be protected from fire and restored using economical methods. Row after row of test plots spread across the site, around which a large fence and firebreaks have been constructed. Among other experimental variations, some plots have been irrigated, some covered with shade cloth, some outplanted with native tree seedlings, and some directly seeded.

US Forest Service technicians Don Goo (left) and Alan Urakami have worked closely with Cabin and others on the restoration project. Photo: Robert Cabin.

"We want to come up with coarser, more efficient, bigger-scale projects," Cabin said. The researchers hope that such projects will help the working group persuade landowners to restore the native dry forests on their land. At least one local rancher has shown interest in the group's activities. But members acknowledge that building relationships with local landowners will be difficult, largely because of the history of polarization between many ranchers and environmentalists.

The working group has organized field trips to Kaupulehu for schools and local residents. Interest has grown, but the project must still overcome a widely held attitude that restoring the system is hopeless. That's why demonstration is so important.

Despite learning much, the researchers admit they have a long way to go. Basic questions they are studying include the role of soil organisms and the physiology of key tree species, to better understand the ecological factors involved in regeneration. On a more practical research level, they have studied whether spraying herbicide from helicopters can kill fountain grass on a large scale (it can't) and whether the controversial approach of turning over the fountain grass–choked landscape with a bulldozer might give native plants an advantage.

Beyond these questions of how to restore the Hawaiian dry forest is perhaps the most vexing question of all: What exactly was the Hawaiian dry forest ecosystem? If the biologists can't answer this question, how can they be sure that, if left alone, the system will regenerate into what it was before? "Because nothing is left of any size, we don't know what the model is to restore to, and that's a big problem, both biologically and philosophically," Cabin said. "Should you just do what works? Should you try to restore in some image of what you think was here?"

He bent down and pulled at another clump of dead fountain grass as vehicles whizzed past on the highway a hundred meters or so above him. "You couldn't create a perfect replica of what was here if you wanted to," he said. "The system has changed. The soil is all fountain grass litter. The dispersal agents in this system—the birds—are gone. Rats are here to stay. For me, as a pragmatist, I say forget about trying to get back what was here. We've had extinctions right and left, we've got new species that are here to stay. Let's do what works." The important point, say working group members, is that the dry forest can come back. ❑

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