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Restoration of Native Hawaiian Dryland Forest at Auwahi, Maui

Figure 1. Dryland forests in Hawai'i harbor many species found nowhere else in the world. **A.** *Maui 'amakihi* (*Hemignathus virens wilsoni*) on *'ohia lehua* (*Metrosideros polymorpha*, photo © J. Jeffrey); **B.** *wiliwili* (*Erythrina sandwicensis*, photo by J. Jacobi); **C.** the endangered Blackburn's sphinx moth (*Manduca blackburni*, photo by B. Harrison Gagné).

Background

The powerful volcanoes that formed the high islands of the Hawaiian archipelago block northeasterly tradewinds, creating wet, windward rain forests and much drier, leeward forests. Dryland forests in Hawai'i receive only about 20 inches of rain a year. However, the trees in these forests intercept fog and increase ground moisture levels, thereby enabling these seemingly inhospitable habitats to support a diverse assemblage of plants and animals.

Dryland forests of the Hawaiian Islands, like those worldwide, have been heavily impacted by humans both directly and indirectly. Less than 10% of Hawai'i's original dryland forest habitat remains. These forests have been severely impacted by urban development, ranching and agriculture, and invasive species. In particular, browsing animals and alien grasses have caused significant damage. Feral ungulates, including goats, sheep, cattle, and pigs, consume sensitive plants. Alien grasses have become dominant in the understory in many dryland habitats. In addition, these introduced grasses are fire-adapted and have increased the incidence of wildfire in these ecosystems. Native Hawaiian plants did not evolve with frequent fires or mammalian herbivores and typically do not survive well under these pressures.

An Endangered Ecosystem on Maui

On the east side of the Hawaiian Island of Maui, the dormant, but not yet extinct, Haleakalā volcano rises over 10,000 feet above sea level and that height, combined with the island's size and age, created a large region of diverse dryland forest on its southern flank. Many biologists have considered these leeward Haleakalā forests to be the richest of Hawaiian terrestrial ecosystems. Unfortunately, the combined impacts of habitat destruction, ungulates, invasive plants, and wildland fires have reduced dryland forest to 5% of its original extent on Maui.

An especially biologically diverse remnant of this forest type on leeward Haleakalā volcano is found in the Auwahi district, privately owned by 'Ulupalakua Ranch. At Auwahi, much of the original native

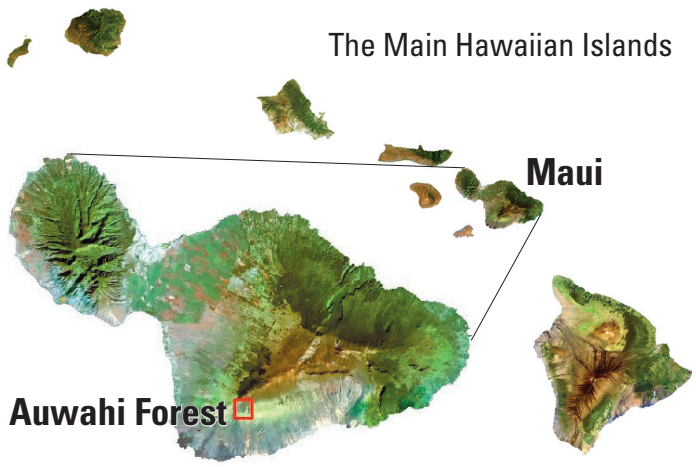


Figure 2. Maui is the second youngest and second largest island of the Hawaiian archipelago, positioned west of Hawai'i island. Auwahi dryland forest is in the southern portion of east Maui island. Indicated in red, the study site is located along the southwest rift zone of Haleakalā volcano. (Landsat images courtesy of NASA.)

shrub and fern understory has been replaced by alien kikuyu grass (*Pennisetum clandestinum*). This African grass forms a matted layer up to two feet thick that prevents the regeneration of native plants. Having lost many of the processes that keep a forest alive, Auwahi has become more like a museum than a forest. Just as in a museum, Auwahi is a place to observe isolated specimens of rare plant species, rather than a functioning forest. Although the ancient trees in this forest produce viable seed, few seedlings have become established in the last century.

The forest at Auwahi was well known to ancient Hawaiians because it harbored many useful plants. Of the 50 types of native trees at Auwahi, 19 were used for medicine, 13 for tool making, 13 for canoe building, and 13 for house building. Some plants had dual uses; species found at Auwahi also provided materials for making weapons, fishing implements and fish poisons, cordage and firewood, sticky substances for trapping birds for feather work, recreation, food, dyes and perfumes, and religious and cultural items.

Restoration Techniques

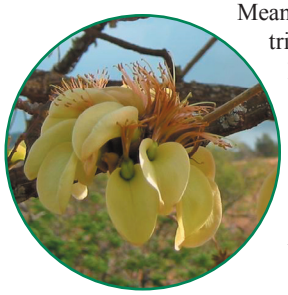
In 1997, a partnership among visionary landowners, governmental resource managers and scientists was formed to explore methods for restoring this unique ecosystem before it was lost. Scientists from the USGS Pacific Island Ecosystems Research Center serve as scientific advisors and technical consultants to resource managers on the most efficient ways to achieve these goals.

Prior to the experimental restoration of Auwahi forest, efforts to conserve dryland forests in Hawai‘i were focused primarily on the exclusion of ungulates and the removal of invasive plant species. Although these activities are important, they are not sufficient to re-establish self-sustaining native forests. In contrast, an important goal at Auwahi is to restore natural forest processes, such as seed dispersal, seed germination, and seedling regeneration. In recent decades, invasive plants and animals have destroyed those forest microhabitats that would allow natural seedling regeneration (cool, moist sites shaded by native shrubs and trees) at the site. The Auwahi restoration project encourages unassisted reproduction of long-quiescent forest species, once relegated as victims of a slow but inevitable extinction process.

Our approach to restoration includes three main elements: 1) high quality forest tracts are fenced to exclude ungulates, 2) volunteer and part-time laborers work to eliminate the kikuyu grass and other invasive species using both herbicides and hand-pulling, and 3) native tree, shrub, vine and grass species that were elements of the original forest community are outplanted during monthly volunteer trips.

The first project undertaken at Auwahi was the construction of a four-hectare ungulate exclosure completed in 1997 (Figure 3). This exclosure has served as a prototype for subsequent restoration efforts. Within this exclosure, ungulates were eliminated, kikuyu grass mats were killed, and a program was initiated to augment numerous native plant species by broadcasting seeds and outplanting nursery-raised plants (Figure 4).

Seeds collected from wild plants, particularly from rare and endangered species, are germinated and propagated at two nurseries. Every month, seedlings are outplanted by 20 to 40 dedicated volunteers (Figure 5). To date, over 300 community members have participated in these efforts and new people participate each month. As volunteers involve their friends and families, our volunteer community grows. Meaningful work gets accomplished on these trips, and perhaps even more importantly, Maui community members are exposed to the plight of native species and the positive role restoration can have in conservation. The impact of the real life environmental education being gained during these trips may be as significant as the actual restoration work being performed.



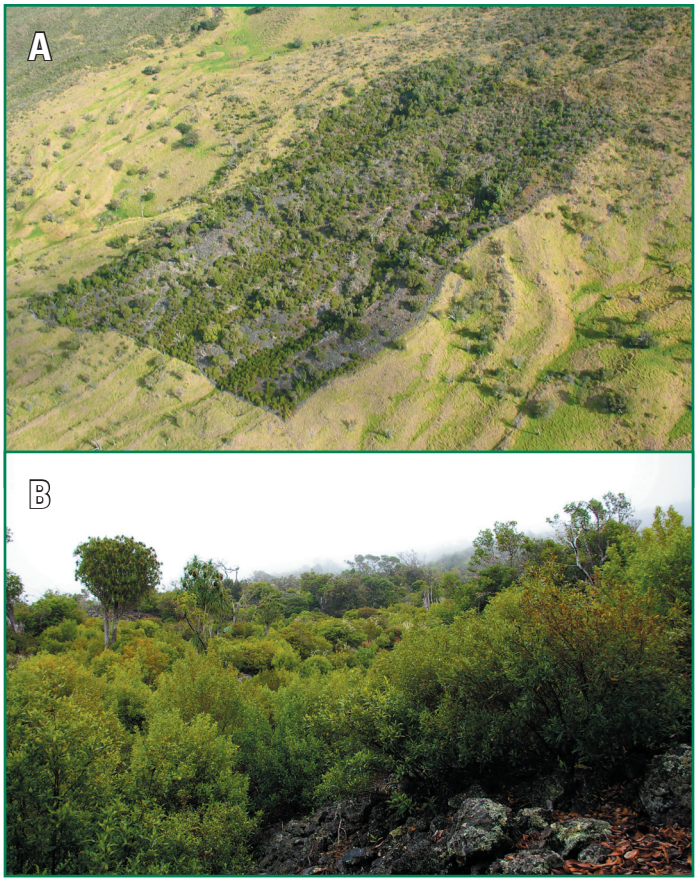


Figure 3. A. Aerial image of 4 ha dryland forest exclosure at 1200m elevation at a site called Pu‘u-ouli in Auwahi. Outplanting of native shrubs and trees began here in 2000 and has proceeded to the point where non-native grasses have been naturally excluded (Photo by A. Palomino). **B.** Native shrubs and trees are recovering inside the Auwahi exclosure. Protection from ungulates and establishment of favorable microhabitats inside the exclosure has encouraged natural unassisted reproduction of over 20 native species that mostly do not reproduce outside the exclosure. Some have not reproduced for many decades.

Scientific Name	Status	Wild Individuals on Maui	Outplanted at Auwahi	Population Increase
Alectryon macrococcus var. *auwahiensis*	E	16	4	25%
Bidens micrantha kalealaha	E	2000	200	10%
Melicope adscendens	E	30	2	7%
Zanthoxylum hawaiiense	E	6	50	833%
Santalum freycinetianum var. *lanaiense*	E	200	51	26%
Ochrosia haleakalae	C	250	123	49%
Nothocestrum latifolium	R	400	193	48%
Panicum tenuifolium	S	350	95	27%
Pleomele auwahiensis	S	1000	522	52%
Xylosma hawaiiense	S	600	158	26%

E = endangered; C = candidate for protected status; R = rare; S = apparently secure

Figure 4. In the five years following completion of the four-hectare exclosure in 1997, dedicated volunteers have outplanted almost 1400 plants inside the exclosure where they are protected from browsing ungulates. These activities have significantly increased the populations of many of these species.

Figure 5. A. Volunteers weeding and planting native seedlings in an Auwahi gulch, Fall 2000. **B.** By Fall 2004, native shrubs were the dominant vegetation component in the gulch.

Figure 6. The non-native tree bocconia is an ever-present challenge to dryland restoration because it produces millions of seeds that are dispersed by many introduced birds and that form a persistent seed bank. (Photos by F & K Starr)

Native Species Increase in Managed Area

Unassisted natural establishment of seedlings and saplings of native shrub-tree species, such as *ʻaʻaliʻi* (*Dodonaea viscosa*), *ʻulei* (*Osteomeles anthyllidifolia*), and *pilo* (*Coprosma foliosa*) is now common inside the exclosure. The increasing cover of these native shrub-tree species will likely make the site less susceptible to invasion by non-native plant species and promote recruitment of native forest species. The creation of shaded microhabitats under these native shrubs has also enabled the regeneration of numerous rare and endangered species.

After a single herbicide application, kikuyu grass in treated plots within the exclosure declined from 70% to less than 5% cover. The lack of subsequent kikuyu grass seedling establishment provides evidence of what ranchers believe, that local kikuyu grass does not produce seed. Although efforts to control kikuyu grass have been successful, one threat to the long-term conservation of Auwahi and similar forests is the spread of aggressive and shade-tolerant, non-native tree-shrub species, especially bocconia (*Bocconia frutescens*, Figure 6). Left uncontrolled, bocconia would likely become the dominant species at the site.

The exclosure has provided a refugium for five endangered plant species, including: *aʻe* (*Zanthoxylum hawaiiense*, Figure 7A), two species of *alani* (*Melicope knudsenii*, seen in Figure 7B, and *M. adscendens*), *mahoe* (A*lectryon macrococcus* var. *auwahiensis*), *ʻiliahi* (*Santalum freycinetianum* var. *lanaiense*), and the endangered Blackburn's sphinx moth (*Manduca blackburni*).

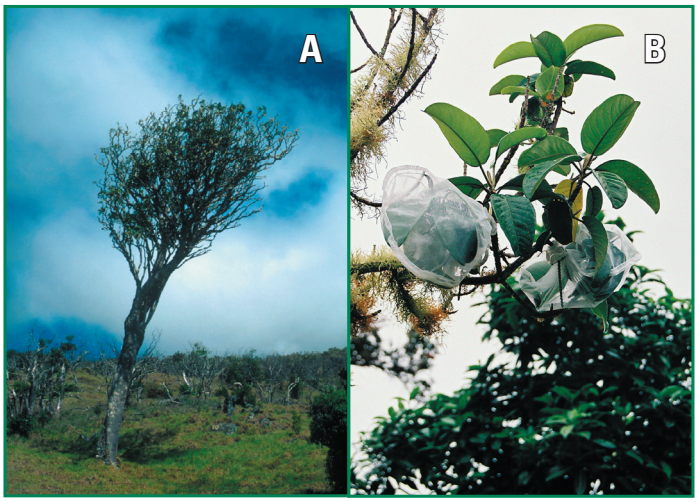


Figure 7. A. Less than a half dozen mature individuals of the rare and ethnobotanically important *aʻe* tree exist on Maui, most in the Auwahi district. Since 2001, in an attempt to rescue the nearly extinct Maui genotype, over fifty seedlings have been grown and outplanted in pollinating proximity of each other. **B.** There is a single surviving mature individual of *alani* (*Melicope knudsenii*) in the Auwahi district. This previously common endemic species, known only from Maui and Kaua'i, is now limited to this one wild individual and one in cultivation at the D.T. Fleming Arboretum at Pu'u Mahoe. Developing fruits are bagged to prevent near total loss of seeds caused by seed predation by the larvae of an endemic moth species. In 2005, eight seedlings were outplanted surrounding the last adult tree and are now growing vigorously.

Lessons for the Future

We predict that native shrubs and trees will increasingly dominate the exclosure over the next decade, re-creating shaded understory sites probably similar to those of the original forest stands. Only time will tell whether the return of favorable microsites will spur the spontaneous reproduction of a broader spectrum of native dryland forest tree species, many of which have failed to reproduce naturally for decades, or whether some other perturbation will interfere.

Dryland forest on Maui constitutes a small but significant part of our nation's natural heritage. Until recently, this ecosystem was believed to be impossible to restore and destined for extinction. With multi-agency cooperation, critical information and technology has been generated that promises to shift the trajectory of this ecosystem toward recovery and long-term conservation.

Both the restoration technology and the public-private partnership developed at Auwahi should serve as models for cost-effective, landscape-level restoration of leeward forest ecosystems across the Hawaiian archipelago. It is the hope of USGS scientists that Auwahi will serve as an important demonstration project for the restoration of ungulate- and fire-degraded ecosystems elsewhere in the Pacific Basin.

Volunteers have been a key component of the restoration of the Auwahi dryland forest.

Auwahi Dryland Forest Restoration Partnership

The community-based restoration of diverse tracts of dryland forest at Auwahi has been a surprising success thanks to the collaborative efforts of a visionary landowner at ʻUlupalakua Ranch, state and federal agencies, and non-governmental organizations. These include:

Federal agencies:

USGS Pacific Island Ecosystems Research Center
USDA Natural Resources Conservation Service
Haleakalā National Park
US Fish and Wildlife Service

State and county agencies:

State of Hawai'i Division of Forestry and Wildlife
County of Maui Water Department

Non-governmental organizations:

Community Work Day Program
D.T. Fleming Arboretum
Friends of Haleakalā National Park
Hana High School
Hoʻolawa Farms
Living Indigenous Forest Ecosystems
Lyon Arboretum
Maui Community College
Maui Nui Botanical Garden
Na Pua Noʻeau
Native Hawaiian Plant Society
Rene Sylva

Private landowners:

ʻUlupalakua Ranch

Figure 8. *Ochrosia haleakalae* seedling (*above*) and flower (*below left*; photos by F & K Starr).

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Recommended Reading

Abbott, I.A. 1992. *La'au Hawai'i: Traditional Hawaiian Uses of Plants*. Bishop Museum Press, Honolulu, Hawaii, 163 pp.

Allen, W. 2000. Restoring Hawaii's dry forests: research on Kona slope shows promise for native ecosystem recovery. *Bioscience* 50(12): 1037–1041.

Cabin, R.J. et al. 2004. Restoration of tropical dry forests in Hawaii: Can scientific research, habitat restoration and educational outreach happily coexist within a small private preserve? *Proceedings of the 16th International Conference of the Society for Ecological Restoration*, August 24–26, Victoria, Canada.

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