

Fencing creates safety barriers for restoration projects in Hawai'i. Without fencing and intensive management of feral mammals and nonnative plants, restoration efforts would not be possible. Hawai'i's long evolutionary isolation created unique species having few defense mechanisms. Today, its modern position as the commercial hub of the Pacific makes native species especially susceptible to destruction by alien species. Many nonnative plant species occupy modified forests after feral mammals have eliminated native species. Establishment of nonnative plants is rapid in exposed mineral soils and feral mammals and birds aid their dispersal. The construction of ungulate-proof fences and the elimination of feral mammals create recovery areas for both native habitats and rare and endangered species.

KEY WORDS

threatened and endangered species, alien species

NOMENCLATURE

(plant and animal names) ITIS (2002);
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Using fences to exclude nonnative feral mammals is essential for protecting Hawai'i's native vegetation and restoring degraded vegetation communities. Building fences is difficult, expensive, dirty work that often goes without the recognition it deserves. Most growers of rare, threatened, or endangered plants understand that their propagation work would be for naught without dedicated fencing crews.

‘ŌLA‘A-KĪLAUEA PARTNERSHIP LANDS, HAWAI‘I

The ‘Ōla‘a-Kīlauea Partnership on the island of Hawai‘i is a cooperative land management effort for approximately 104 000 ha (260 000 ac) of state, federal, and private land. The goal is to link important native ecosystems and create a large, contiguous area for cooperative management. Instrumental is the construction of fences that link existing smaller management areas coupled with the removal of feral pig (*Sus scrofa* L. [Suidae]) populations within fenced management units. Following fencing, partnership staff monitor subsequent forest recovery. Kūlani Correctional Facility inmates have helped complete fencing for 4 units protecting a total of 4000 ha (9900 ac). Most recently, inmates have started construction on a 16-km (10-mi) boundary fence to add an additional 2000 ha (4000 ac) to this large protected area (Rubenstein 2002).

National Park Service crews have successfully removed feral pigs from hundreds of hectares of NPS and partnership lands. Park staff regularly hunt pigs with dogs

New Zealand style stainless steel fencing protects the Kanepu‘u Nature Conservancy Preserve on Lāna‘i.

Photo by Brian Valley



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IS KEY TO NATIVE PLANT RESTORATION IN HAWAI‘I

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but also with trapping and snaring in some areas. These efforts require that staff regularly inspect and maintain fencing. Monitoring vegetation recovery and pig ingress in fenced areas will help determine effectiveness of removal methods. Deputized public pig hunting is allowed in some areas of the project area to further reduce pig populations. Additional smaller fenced enclosures are constructed to protect newly discovered rare plant populations and other sensitive habitats. The partnership is planning for several fenced units including more than 12 800 ha (32 000 ac). This project is critical to protect lands from another serious ungulate pest: the mouflon sheep (*Ovis aries musimom* Pallas [Bovidae]). Mouflon sheep were introduced as a game animal on the island of Hawai'i and have recently been seen in the project area, including Hawai'i Volcanoes National Park (Tunison 2002).

Both the National Park Service and the 'Ōla'a-Kilauea Partnership have an intensive nonnative plant control program that occurs concurrently with pig control and fencing both in fenced and unfenced areas. The program includes mapping, development of control strategies, use of herbicides or manual removal, and monitoring the effectiveness of control measures. Alternative techniques for nonnative plant control may be used in the future as these are developed. The initial focus of mapping and control efforts was for a variety of exotic species, including yellow himalayan raspberry (*Rubus ellipticus* Sm. [Rosaceae]) and banana poka (*Passiflora mollissima* (Kunth) Bailey [Passifloraceae]). More than 25 nonnative plant species are now being mapped for control efforts.

More efficient predator control measures are being developed for protecting large areas of forest bird habitat. Small predators, such as rats (*Rattus rattus* L. [Muridae]), mongoose (*Herpestes javanicus* E. Geoffroy Saint-Hilaire [Herpestidae]), and cats (*Felis sylvestris* L. [Felidae]), prey both on ground and tree-nesting birds. They also consume large quantities of insect prey and vegetation, including seeds, seedlings, and new growth on plants.

HALEAKALĀ NATIONAL PARK, MAUI

The management goal at Haleakalā National Park is to fence the entire park and remove feral predators and ungulates from within its boundaries. The fencing project is now within 8 km (5 mi) of completion, enclosing 8000 ha (19 800 ac). Initially, fencing enclosures were prioritized to protect individual plants such as alani (*Melicope ovalis* (St. John) T.G. Hartley & B.C. Stone [Rutaceae]) and other small populations that were highly endangered. Habitat fragments containing assemblages of native species were also fenced until the entire project could be completed. One of the results of the internal fencing efforts was the recovery of the haha (wetforest cyanea, *Cyanea hamatiflora* ssp. *hamatiflora* Rock [Campanulaceae]). Recently, a single, naturally dispersed plant appeared within a 0.8-ha (2-ac)

enclosure and this species has colonized in other areas within the fencing unit (Anderson 2002; Welton 2002).

Today, removal of all pigs, goats (*Capra hircus* L. [Bovidae]), and virtually all axis deer (*Axis axis* Erxleben [Cervidae]) has been completed. Goats were the largest problem, heavily impacting bird and plant species and creating erosion problems (Figure 1). In some areas, grazing reduced vegetation to bare mineral soil and bedrock. By 1989, all goats had been successfully removed (Rodrigues 2002). Haleakalā silversword (*Argyroxiphium sandwicense* ssp. *macrocephalum* [Asteraceae]) is a species that has shown a dramatic comeback following goat removal.

In 1969, the Hawaiian Rainforest District was added to park lands, along with its healthy population of feral pigs. The pigs proved to be the most difficult feral animal to eradicate and caused substantial damage to understory growth in rainforest habitat. Native tree ferns (hāpu'u, *Cibotium* spp. Kaulfuss [Dicksoniaceae]) were originally the dominant sub-canopy species at elevations up to 1500 m (4950 ft), but were rapidly depleted by pig predation. Loss of mature tree ferns had a ripple effect as other rare species linked to the tree ferns became scarce. However, by the mid-1990s, all pigs were removed. Fencing has also substantially slowed the rate of nonnative plant invasion and resulted in noticeable recovery of the rainforest understory.

Feral predators such as rats, cats, and mongooses are live trapped to protect nesting Hawaiian Dark-rumped Petrels (*Pterodroma phaeopygia sandwichensis* Salvin [Procellariidae]). Nearly the entire known population, about 500 breeding pairs, of this endangered bird breeds in or near the park's volcanic crater. Continued removal of feral ungulates, nonnative plants, and predators is leading to the recovery of native ecosystems and endangered species within the park. This, in conjunction with the propagation and outplanting of both rare and common plant species, is central to overall management plans on Maui.

More recent feral animal introductions are now exhibiting problems for resource managers on Maui. Axis deer were introduced in 1959 as a game animal and their numbers have steadily increased, especially in recent years on leeward Haleakalā. Degradation was particularly severe during the 4 y of El Nino drought (1998 through 2001) when some vine and shrub species declined in cover by 80% to 90%. Deer browsing and girdling of young saplings has had catastrophic effects, with high mortality of some rare and other native plant species of the Pu'u-o-kali lava flows. As a result, construction of deer-proof fencing was required to protect these unique remnant dryland forests (Medeiros 2002).

KANEPU'U NATURE CONSERVANCY PRESERVE, LĀNA'I

Types and effective height of fencing are continually evaluated throughout Hawai'i to deal with different climatic conditions and the feral animals present on each island. Axis deer are cur-

rently the largest problem on Lānaʻi (Valley 2002). The Kanepuʻu Nature Conservancy Preserve on the island of Lānaʻi comprises 7 fenced management units, including earlier internal fences that protect individual plants or small populations from ungulates (Figure 2). Lānaʻi is subjected to strong trade winds, increasing the rate of deterioration of the fence coating in large areas of the preserve. Only a few areas protected by vegetation have escaped major deterioration. TNC Preserve manager Brian Valley and staff have installed stainless steel fencing used extensively in New Zealand, which in spite of its high initial cost, has proved to be an effective and successful long-term investment. Initially, 2 units of the preserve were fenced with stainless steel including a 80-ha (200-ac) unit with the greatest species diversity and another unit located on the windiest portion of the island.

SUMMARY

Controlling and eliminating nonnative pests and containing their spread are essential to successful restoration in Hawaiian habitats. Fencing has been successful and is used as a long-range management tool for large tracts of native ecosystems and links restoration projects and vital recovery areas for rare and endangered species. Constant maintenance and monitoring are needed in conjunction with fencing efforts. Because Hawaiian native species have not evolved with ungulates, nor do they have protection strategies to deal with predation or grazing, resource managers have to be ever vigilant against the incursion of new nonnative species.

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Figure 1. Goats caused serious defoliation problems within Haleakalā National Park on Maui.



Figure 2. The benefits of protecting native ecosystems from nonnative ungulates is dramatic.

Photos by Jack Jeffrey Photography