SUMMARY OF VEGETATION ALTERATION IN THE HAWAIIAN ISLANDS

Pre-European Contact Changes

By the time of Captain James Cook's arrival in the Hawaiian Islands in 1778, the original vegetation of the lowlands had been greatly altered by more than 1,000 years of Hawaiian occupation. Agricultural practices of the Hawaiians were the major cause of environmental change in the Islands. Kirch (1982) expressed the opinion that any lowland area receiving 500 mm (20 in.) or more of annual rainfall would reveal archaeological evidence of Hawaiian agricultural use if examined. In nearly every valley with a permanent stream, the natural vegetation was replaced with irrigated taro (*Colocasia esculenta*) and other plants introduced by Hawaiians. The development of large dryland field systems on the island of Hawai'i (and East Maui) completely cleared the original dry and mesic vegetation over large tracts of the lower leeward slopes. Newman (1972) estimated that as much as 260 km² (100 mi²) of the island of Hawai'i (amounting to 2% of the land area) was "churned up" during preparation of field systems.

Shifting cultivation, using slash and burn techniques, was carried out at least to 460 m (1,500 ft) elevation on windward slopes and in areas near sites of irrigation agriculture. Plants introduced by the Hawaiians largely replaced native plants in succession on fallow and abandoned fields. Dryland cultivation greatly altered the vegetation cover of the islands of Ni'ihau, Kaho'olawe, and Lana'i long before the arrival of Europeans.

Even in lowland areas not actually cultivated, natural vegetation was degraded through the use of fire to encourage thatching grasses (Kirch 1982), firewood gathering, and removal of timber for construction purposes. The forest zone above cultivated areas was used for wild plant products, canoe logs, and for collecting feathers and was invaded to some extent by plants of Polynesian introduction. Only above 760 m (2,500 ft) elevation was the original vegetation essentially untouched by Hawaiians (Kirch 1982). Lowland areas below this upper limit of Polynesian influence where native vegetation has survived to the present and escaped modification are found on rough substrates, steep terrain, or remote coasts of difficult access.

In recent years, evidence for the destruction of lowland vegetation has come from analysis of fossil bird bones and land snails. Olson and James (1982) identified 40 previously unknown extinct species of birds from fossil bone deposits at a number of sites (primarily lowland) on five Hawaiian Islands; this doubled the number of endemic land bird species known from Hawai'i. Additional work on fossilized bird remains from a cave on Maui tripled the number of bird species known to have occurred on that island (James et al. 1987). Radiocarbon dates on the Maui fossils and both radiocarbon dates and stratigraphic analysis at the previously discovered sites indicated that many of these birds had become extinct since Polynesian occupation of the Islands. Olson and James (1982) also pointed out that the currently understood fossil record is probably incomplete and the "original bird diversity" of the Islands may have been even greater. On O'ahu, deposits of endemic land snails indicate changes in the snail fauna.
during the Polynesian period, with some endemic taxa decreasing and others, more adapted to disturbance, increasing (Kirch 1983). Both Olson and James (1982) and Kirch (1983) suggested that the primary reason for the extinction of native animals and change in faunal composition was the destruction of lowland forest habitats, particularly those of the dry leeward regions. (Predation by humans and introduced rats also had a role in the demise of native birds, especially flightless and ground-nesting species.)

Although the plant communities in much of the Hawaiian lowlands were disturbed, it is clear, from early botanical collections and the many native plants that were regularly used in the Hawaiian culture, that some plants rare or non-existent in the lowlands today were relatively common in Hawai'i before European contact. St. John (1976) found more than a dozen species that are now extinct among the plants collected in Kona by David Nelson in 1779. The disruption of montane vegetation and the almost complete loss of native plant species in the coastal and lowland zones that characterize present-day Hawai'i were only accomplished through modern land-use practices and the disturbances caused by alien plants and animals in the last 200 years.

**Post-European Contact Changes**

The alteration of natural vegetation in the Hawaiian Islands has progressed steadily upslope since 1778. Perhaps the most serious and persistent early impact of western culture was the introduction of large grazing and browsing mammals, which quickly established large feral populations and began to open up and destroy upland forests and high-elevation systems. Also significant in the early post-European contact period, particularly on O'ahu and near lowland population centers, was the wholesale exploitation of lowland forests for sandalwood (Santalum spp.) and firewood. By the middle of the 19th century, land clearing for large-scale commercial agriculture and koa (Acacia koa) logging had begun to transform much of the remaining natural vegetation cover at low and middle elevations into one-crop plantations, primarily sugar cane (Saccharum officinarum). Unlike the shifting cultivation that characterized the Hawaiians' agricultural use of the upland slopes, modern agriculture completely and permanently removed all native plant cover. The last few decades of the 19th century and the early 20th century saw the conversion of vast tracts of upland forests into cattle ranches and the spread of alien grasses, often leaving very little or no unmodified forest sandwiched between plantations and ranchlands. Land clearing and conversion of natural habitats to agricultural and urban uses have been identified as major causes of extinction of endemic Hawaiian plants and animals (Simon 1987); perhaps 10% of the Hawaiian flora has become extinct and another 40-50% is threatened with extinction (Wagner et al. 1985; Vitousek et al. 1987). Extinction among Hawaiian animals has been even more dramatic; two-thirds of the native bird species, more than 50% of the endemic land snails and a large but unknown percentage of Hawaiian insect species are already extinct (Howarth et al. 1988).

The intentional and accidental introduction of alien plants accelerated at the beginning of the 20th century and resulted in the loss or degradation of most of the remaining natural vegetation of the lowlands and a significant proportion of upland habitats, particularly since the mid-20th century emphasis on multiple use of public forests for feral game animals. By 1980, an estimated 60,730 ha (150,000 a) of Conservation-zoned forest land had been invaded by seriously disruptive alien plants (Hawaii State Department of Land and Natural Resources 1980). Few natural systems are totally immune to the invasion of alien plants, but upper-elevation forests with difficult terrain and
no or low populations of feral animals have fared the best. In their analysis of the distribution of six important alien plants in the uplands of Hawai'i Island, Jacobi and Warshauer (in press) found that those ecosystems with the least disturbance from animals or humans were “the most resistant to colonization by noxious introduced plants.”

Particularly in dry and mesic vegetation, the widespread invasion and establishment of alien grasses have resulted in a great increase in the size and frequency of fires, which are typically deleterious to native plants. It is likely that some of Hawai'i's alien plant problems are intractable, and many areas currently supporting diverse native vegetation will be overwhelmed as invaders intensify and expand their ranges. This scenario is made even more likely if steps are not taken to control feral animals and prevent fires in important natural areas; those that are nearly intact, have high biological diversity, and contain many rare species.

Mid-20th century attempts to establish a commercial forestry industry in Hawai'i resulted in the loss of native forests and other plant and animal communities on public lands and, perhaps of more far-reaching impact, the introduction of alien plants. In recent years new industrial uses for remote, little-disturbed sites have come to threaten areas previously protected from development by their unsuitability for agriculture or distance from population centers. The trend for expansion of commercial activities and urbanization into remaining native ecosystems in the uplands and undeveloped lowlands will doubtless continue as Hawai'i's population grows and the visitor industry continues to flourish.

After more than a millennia of human occupation, few remnants of natural vegetation may still be found in the coastal and lowland zones of Hawai'i, still the sites of most human occupation and activity. What does remain is often degraded and simplified by alien organisms and continuing destructive land practices. Thus, the few lowland sites still containing a diversity of native organisms are especially precious to those who would preserve examples of the original Hawai'i. More than 75% of the recognized types of plant communities remaining in the coastal and lowland zones are considered to be rare. Although examples of most of these do occur on either State or Federal land, more than 30 of 95 coastal and lowland plant communities are not represented in areas designated for protection (The Nature Conservancy of Hawaii 1987).

The montane and subalpine zones have fared somewhat better than the lowlands, in part because of factors of time and distance. Today, however, with modern developments in technology and access, and continuing problems with the spread and intensification of alien organisms, almost no area is completely free of the possibility of human manipulation. Despite the large areas in these zones still covered by native vegetation, more than 80% of montane communities and all of those in the subalpine zone are considered rare, because of past disturbance and present vulnerability (The Nature Conservancy of Hawaii 1987).

Gagné (1988) estimated that less than 10% of the land on Kaua'i, O'ahu, Maui, and Hawai'i continued to support undisturbed native forest. Of the four Islands he reviewed, heavily urbanized O'ahu showed the lowest percentage of forest cover even when forests disturbed or replaced by nonnative plants were considered. Others have noted the paucity of native vegetation on O'ahu. Mueller-Dombois (1973) observed that the native lowland forests of O'ahu had been replaced by alien species except for one area of dry and mesic forest in the northern Wai'anae Range. Even the wet ‘ōhi‘a (Metrosideros spp.) forests of the Ko'olau Summit area are declining in cover,
resulting in drier conditions and depletion of understory species (Obata 1985b). A recent map shows ʻōhiʻa/hāpuʻu (Metrosideros polymorpha/Cibotium spp.) forest covering the upper reaches of the Koʻolau Mountains on Oʻahu, (Little and Skolmen 1989), but little undisturbed vegetation actually remains there.

Other main Hawaiian Islands (excluding Niʻihau, Kahoʻolawe, and Lānaʻi) have fared somewhat better than Oʻahu and still have significant amounts of native vegetation. The central portion of Kauaʻi, amounting to perhaps one-third of the island, still supports native wet forests (Little and Skolmen 1989); the combined categories of relatively undisturbed forests and those disturbed to some degree were estimated by Gagné (1988) to cover 40% of Kauaʻi. The Nature Conservancy of Hawaii (1987) identified and listed a number of intact or nearly intact native communities on the island of Kauaʻi, including wet forests, bogs, and rare types of dry and mesic forests.

Molokaʻi, despite its relatively small size and the loss of most of its dry lowland vegetation, still contains a significant amount of nearly "pristine" wet ʻōhiʻa forest at upper elevations (Little and Skolmen 1989), as well as important bog communities. The Nature Conservancy Preserves and State Natural Area Reserves contain examples of many of the remaining natural communities on Molokaʻi (The Nature Conservancy of Hawaii 1987); these areas have legal protection and are (or will soon be) managed for their natural values.

Maui, the second-largest of the Hawaiian Islands, currently supports large stands of native wet forest (mostly ʻōhiʻa) at upper elevations on both its eastern and western sections (Little and Skolmen 1989). East Maui also contains important subalpine and alpine communities (The Nature Conservancy of Hawaii 1987), but large areas of former dry and mesic forests of leeward Haleakalā have been severely degraded (Medeiros et al. 1986; Little and Skolmen 1989). Maui vegetation benefits greatly from the protection afforded to National Parks and State Natural Area Reserves, which contain many of the known natural plant communities of the Island (The Nature Conservancy of Hawaii 1987).

The question of how much relatively undisturbed natural vegetation remains is best understood for the island of Hawaiʻi, where vegetation data from the U.S. Fish and Wildlife Service Forest Bird Survey have been analyzed and vegetation types mapped by Jacobi (in press b). Jacobi and Scott (1985) reported large expanses (more than 100,000 ha or 247,000 a) of wet ʻōhiʻa forest on Hawaiʻi Island (above 500 m or 1,640 ft elevation) that were dominated by native plants and not severely invaded by alien plants. In contrast, they found that most native dry and mesic vegetation types of the montane and subalpine zones contained significant cover of alien plant species, and in some cases were completely dominated by nonnative plants. The best-preserved dry and mesic communities were those dominated by ʻōhiʻa with other native trees and shrubs; more than 50,000 ha (123,500 a) of these vegetation types contained few alien plants. A large area of dry and mesic ʻōhiʻa shrublands, including pioneer communities on lava flows, also remained intact; this amounted to more than 35,000 ha (86,450 a) (Jacobi and Scott 1985).

Although much of the natural vegetation and associated animal species of the Hawaiian Islands has been lost, the surviving biota display great resilience, and what remains is of great biological significance (Howarth et al. 1988). Management of remaining natural areas in Hawaiʻi is possible, albeit expensive, and an added benefit is that knowledge gained in managing highly invaded island ecosystems will ultimately prove useful for conservation of continental systems (Loope et al. 1988). Even those
ecosystems that have been damaged or degraded by alien organisms and past land use may have the "capacity for significant recovery" if the agents of disturbance are controlled (Jacobi and Scott 1985).

Considerable area still covered by native vegetation, particularly in high-rainfall regions, owes its continued existence to the early 20th century establishment of forest reserves and watersheds. Many important natural communities are still found in forest reserves, which currently receive little protective management. However, former parts of many forest reserves are now included in the State Natural Area Reserves System, which was established in 1970 to preserve native plants and animals and important geological features. Currently the System includes 18 reserves on five Islands, encompassing more than 43,840 ha (108,288 a). Management plans for these areas have been developed and include fencing and ungulate and alien plant control. One State Wilderness Preserve (Alaka‘i) and several sanctuaries also protect important plants, animals, or communities.

Other agencies and organizations that protect natural areas in Hawai‘i include the National Park Service, U.S. Fish and Wildlife Service, and The Nature Conservancy of Hawaii. Altogether, these areas designated for protection total more than 197,000 ha (486,620 a) (Holt 1989). Although not all known natural communities and assemblages of species are contained within these legally protected areas, The Nature Conservancy has identified lands that support the unprotected types, and there is hope that these lands will also receive protection in the near future (The Nature Conservancy of Hawaii 1987). The recent development of protected areas managed for their natural values is a positive and extremely important step toward saving the best of what remains of Hawai‘i's natural legacy.