VEGETATION ZONES OF THE HAWAIIAN ISLANDS

Each vegetation zone supports its own rare plant species and unique native plant communities. About 75% of the Hawaiian native plant communities are in danger of being lost to human "progress."

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The Hawaiian Islands, despite their relatively small land mass, support a great diversity of plant **communities**. More than 175 different natural plant communities have been recognized by botanists during recent attempts to classify Hawaiian vegetation (The Nature Conservancy of Hawaii 1987). This large number of distinct **native** communities, almost all of them unique to the Hawaiian Islands, has developed because of the great variation in elevation, rainfall, substrate, topography, and exposure that occurs even over short distances in Hawai'i. For the purposes of generalization, plant communities may be grouped together into several major vegetation zones delineated by elevation and moisture regime: coastal, lowland **rain forest**, **montane** rain forest, **subalpine**, **alpine**, and dry leeward.

ENVIRONMENTAL FACTORS INFLUENCING VEGETATION

Climate

The location of vegetation zones is controlled in part by the Hawaiian climate. A very important element in the climate of the Hawaiian Islands is the prevalence of the northeasterly **trade winds**, which bring moisture-laden air to the windward slopes of the Islands. With increasing elevation, air temperature decreases. Because cold air is less capable of holding moisture, water precipitates out as rain on the northeast-facing slopes of the Islands. The wettest regions are the summits and upper slopes of islands, such as Kaua'i, O'ahu, and Moloka'i, and a windward band between 2,000 and 5,000 ft (600-1,500 m) elevation on the **high islands** of Maui and Hawai'i. These two larger islands have a **temperature inversion layer** between 5,000 and 7,000 ft (1,500-2,100 m) elevation, where a mass of air slightly warmer than that below prevents lower air masses from moving higher. Because more rain falls below the temperature discontinuity, the upper elevations of Maui and Hawai'i are very dry, often receiving less than 20 in. (500 mm) of precipitation annually. Leeward mountain slopes and low areas to the southwest of tall mountains are dry because they are in "rain shadows;" the windward slopes of the mountains (or summits of the lower islands) intercept the moist air, and water precipitates out as rainfall. This **orographic** effect also explains why the **low islands** of Ni'ihau and Kaho'olawe are dry; these islands are in rain shadows formed by Kaua'i and East Maui.

An exception to the wet windward and dry leeward climatic pattern is the Kona Coast of the island of Hawai'i, which has a narrow band of wet and **mesic** (moderately wet) vegetation on the leeward slopes of Hualalai and Mauna Loa volcanoes. The Island is so massive that a distinct wind circulation pattern that involves onshore and offshore breezes is produced independent of the trade winds.

Substrate

Almost all of the substrates upon which vegetation grows in the Hawaiian Islands are volcanic in origin: either unweathered lava, ash, and cinder, or soils derived from volcanic materials. Exceptions are white **sand** beaches, consolidated sand dunes, and elevated **reefs**, which are composed of material derived from the remains of **corals** and other marine organisms (see Street, this volume).

The age of the substrate is important in determining what type of plant community will be found in an area. Young substrates, such as recent lava flows, generally support simple communities which become more complex with time, in a process known as primary **succession.** In wet regions on the active volcanoes of Hawai'i, the development of mature rain forests may require as little as 400 years (Atkinson 1970). Vegetation development on lava flows in dry leeward regions proceeds much more slowly, and in some cases forest communities may never develop. The most diverse and species-rich communities are often found on old substrates.

The textures and origins of substrates are also important in determining which plants will grow in an area. Succession and community development generally proceed more rapidly on rough, clinkery **aa** than on smooth **pahoehoe** (see Heliker, this volume), which provides fewer suitable sites for plant establishment. In both wet and dry regions, forests are more likely to become established quickly on aa or soils derived from aa. Specific tree **species** may also have particular requirements. While *'ohi'a* (*Metrosideros polymorpha*) may be found on almost any type of substrate (except sandy beaches), *koa* (*Acacia koa*) achieves community dominance only on relatively deep soils, and *mamane* (*Sophora chrysophylla*) is most abundant on loose cinder or ash soils.

VEGETATION ZONES OF HAWAI'I

The following discussion of vegetation zones (sometimes also called **ecological zones**) will begin with the coastal zone, move upslope on the windward side of an island to the summit, then progress down the leeward-facing slopes.

Coastal Zone

The coastal zone is a narrow band of variable extent that encircles each of the islands and includes landforms and substrates (such as beaches, dunes, and terraces) created through processes occurring only at the shore. Coastal vegetation is strongly influenced by the proximity of the ocean, and many plants found there are able to withstand salt spray, **saline** soils, hot, sunny conditions, and strong winds. Most of the vegetation of Hawai'i's coasts has been disturbed and even replaced by introduced trees and shrubs. Trees commonly associated with Hawaiian coastlines, such as coconut palms (*Cocos*

nucifera), *kamani* (*Calophyllum inophyllum*), and *milo* (*Thespesia populnea*), were actually introduced by the Hawaiians (Nagata 1985). In more recent times, **alien** trees such as ironwood (*Casuarina* spp.) have been planted in coastal areas, and many weedy shrub and grass species have become established along disturbed coasts.

Where native coastal vegetation still exists, it is composed mainly of **indigenous** plants, native to Hawai'i as well as other parts of the Pacific. The fact that coastal vegetation contains proportionally fewer **endemic** plant species than other Hawaiian vegetation zones is explained in part by the relative ease with which the **propagules** of many coastal plants are dispersed by ocean currents and migrating **shorebirds.** This lack of isolation and ready flow of propagules inhibits the process of **speciation** and results in the coastal vegetation of Hawai'i sharing many plant species with other Pacific islands.

The composition of native coastal vegetation varies with substrate, climate, exposure and salinity. Plant communities on sandy beaches differ from those of rocky shores or cliffs, but both substrate types often support the shrub *naupaka-kahakai* (*Scaevola sericea*). In all coastal substrates, there is variation in the composition of plant communities based on proximity to the water's edge and the salt spray zone, with more salt-tolerant species found in exposed areas close to the shore. On sandy beaches, vegetation may be very well developed and contain numerous native species in addition to naupaka. Most commonly seen are vines such as beach morning glory or *pohuehue* (*Ipomoea pes-caprae*), the related blue-flowered *pa'u o Hi'iaka* (*Jacquemontia ovata*), and the yellow-flowered *nanea* (*Vigna marina*); succulent plants such as *'akulikuli* (*Sesuvium portulacastrum*) and the silvery *hinahina* (*Heliotropium anomalum*); beach dropseed grass (*Sporobolus virginicus*); and shrubs, particularly *'ilima* (*Sida fallax*), *nehe* (*Lipochaeta* spp.), and *naio* (*Myoporum sandwicense*), a species with a wide distribution in other vegetation zones. Many **strand** species are regrettably quite rare on the main Hawaiian islands; among these are the beautiful red-flowered, **leguminous**, shrubby *'ohai* (*Sesbania tomentosa*), the viny *popolo* (*Solanum nelsonii*), which is related to the potato, and a beach-adapted sandalwood or *'iliahi* (*Santalum ellipticum*).

Vegetation of **basaltic** shores, cliffs, **talus** slopes, and coral substrates is also frequently dominated by naupaka, often with the addition of other shrubs like *'akoko* (*Chamaesyce celastroides*), *maia-pilo* (*Capparis sandwichiana*), *ko'oko'olau* (*Bidens* spp.), and 'ilima, as well as native grasses and **sedges** (grass-like plants in the **family** Cyperaceae). Coastal shrub communities dominated by native plants other than naupaka still occur as remnants on some leeward shores; examples are **relict** communities of naio and Hawaiian cotton or *ma'o* (*Gossypium tomentosa*). These and other coastal shrublands have been largely replaced by thickets of the alien *kiawe* or mesquite (*Prosopis pallida*).

Coastal forests of native trees are today restricted to wet windward shores. On some undeveloped windward coasts of the larger Hawaiian Islands, native forests dominated by *hala* (*Pandanus tectorius*) may still be seen. The **understory** of these forests is often composed primarily of plants of Polynesian introduction such as *ti* (*Cordyline fruticosa*). Windward coastal forests of *hau* (*Hibiscus tiliaceus*) also occur, particularly near streams and other sources of fresh water; hau forests have often developed in areas formerly cultivated by Hawaiians. In a very few isolated and rocky

windward areas, low-statured 'ohi'a and *lama* (*Diospyros sandwicensis*) forests grow down to the sea shore. Native *loulu* palms (*Pritchardia* spp.) may have been a more important component of coastal forests in pre-human Hawai'i; today these palms are abundant in the coastal zone only on offshore islands and very steep cliffs.

Lowland Rain Forest

On windward (northeastern) slopes above the coastal zone, a very wet lowland rain forest formerly occurred up to an elevation of 2,500-3,000 ft (750-900 m) on the larger Hawaiian Islands (excepting Ni'ihau and Kaho'olawe). Annual rainfall in this zone usually exceeds 100 in. (2,500 mm) and may be as great as 300 in. (7,500 mm). Today little of this vegetation type remains, because most of this zone has been developed for agriculture, a conversion which began with the colonization of Hawai'i by Polynesians approximately 1,500 years ago (Kirch 1985). Even where lowland wet forests have not been used for farming or logging, most have been invaded to some degree by alien plants such as strawberry guava (*Psidium cattleianum*), Koster's curse (*Clidemia hirta*), and many others. The State Tree of Hawai'i, *kukui* (*Aleurites moluccana*), perhaps the most common tree of windward valley floors and lower slopes, is a Polynesian introduction.

Most remaining native lowland rain forests are dominated by 'ohi'a, although other native tree species such as lama, *'ohi'a-ha* (*Syzygium* spp.), hala, and *'ohe* (*Tetraplasandra* spp.) are co-dominants in some areas. In a few lowland valleys with well-developed soils, koa is the dominant **canopy** tree. Lowland koa forests formerly occurred in many windward valleys of Maui, Moloka'i, O'ahu, and Kaua'i, as well as in a band on the lower windward slopes of the island of Hawai'i. Little remains of these lowland koa forests because of logging in the 1800s, cattle (*Bos taurus*) grazing, and conversion to agriculture.

Typically, lowland rain forests have at least two tree layers: the upper one, the canopy, composed of 'ohi'a alone or mixed with co-dominant tree species, and an understory layer of lower-statured tree species. Native trees which are often components of the diverse understory include *'olapa* (*Cheirodendron* spp.), *hame* (*Antidesma platyphyllum*), tree **ferns** (*Cibotium* spp.), and a number of species in the coffee family, particularly *kopiko* (*Psychotria* spp.), *pilo* (*Coprosma* spp.), *manono* (*Gouldia* spp.), and *'ahakea* (*Bobea* spp.). Native shrubs are also important here. Examples are *'akia* (*Wikstroemia* spp.), *naupaka-kuahiwi* (*Scaevola* spp.), *mamaki* (*Pipturus albidus*), and the weak-stemmed *Cyrtandra*, a large group of plants related to African violets, which have fleshy leaves and white flowers. Lowland rain forests are also the **habitat** of **lianas** and vines, such as the *'ie'ie* (*Freycinetia arborea*), a climbing relative of the hala, and *nuku'i'iwi* (*Strongylodon ruber*), a member of the pea family notable for its showy clusters of scarlet flowers.

Where these forests are undisturbed, the ground is usually covered with native **mosses**, sedges, and a great diversity of ferns. On steep slopes and in more open lowland wet forests, the matted fern *uluhe* (*Dicranopteris linearis*) and its relatives may form a dense cover beneath the tree layer.

A distinct type of wet forest occurs on peaks and ridges of the older Islands where wind-borne clouds frequently collect. This kind of forest occurs on both windward and leeward upper slopes of islands such as O'ahu and Moloka'i. These cloud forests support a rich assemblage of native trees and shrubs, which are usually stunted and often sculpted by the prevailing winds.

The trunks and branches of woody plants here are typically covered by **epiphytes** such as **bryophytes, lichens**, and ferns. This type of vegetation is a haven for moisture-loving plants such as native orchids, violets, and members of the lobelia family whose species bear strikingly beautiful curved flowers, probably adapted for pollination by native long-billed **birds**. In a remarkable example of **evolution**, six distinct endemic **genera** have developed in Hawai'i from ancestral *Lobelia: Brighamia* (which has straight, uncurved flowers), *Clermontia*, *Cyanea*, *Delissea*, *Rollandia*, and *Trematolobelia*.

Montane Rain Forest

A very wet and cool forested region is found on the summits of Kaua'i, the Wai'anae Range of O'ahu, and eastern Moloka'i, as well as on the windward slopes of the high islands of Maui and Hawai'i, where the rain forest extends well above 5,500 ft (1,650 m) elevation. The dominant tree species of montane rain forests is most often 'ohi'a, but a distinct type of forest in which tall koa trees emerge above the 'ohi'a canopy also exists in areas with deep soil above an elevation of 3,000-4,000 ft (900-1,200 m). Montane rain forests are the refuge of many species of native **insects** and birds, including a number of extremely rare species Federally **listed** as **Endangered**.

Like its lowland equivalent, the montane rain forest is distinctly multilayered. Below the canopy of 'ohi'a or koa and 'ohi'a, there is a layer of lower-statured native trees in which no one species is dominant. Many of the lowland rain forest species extend into the montane zone. Commonly seen tree species are *kawa'u* or Hawaiian holly (*Ilex anomala*), 'olapa, pilo, manono, *alani* (*Pelea* spp.), *kolea* (*Myrsine* spp.), and olomea (*Perrottetia sandwicensis*). Epiphytic mosses, **liverworts**, ferns, and the silver-leaved lily *pa'iniu* (*Astelia* spp.) are often abundant on the trunks and branches of large trees. Many trees also get their start as epiphytes in larger trees or on fallen logs. In many montane rain forests, particularly on the island of Hawai'i, another layer, composed almost entirely of tree ferns, is found below the secondary trees. Below the dense tree fern cover are usually found scattered shrubs of *kanawao* (*Broussaisia arguta*), *'ohelo-kau-la'au* (*Vaccinium calycinum*), *kamakahala* (*Labordia* spp.), *pukiawe* (*Styphelia tameiameiae*), *Cyrtandra* spp., and less frequently lobelioids such as *Cyanea* and *Clermontia*. In areas undisturbed by **feral** pigs (*Sus scrofa*), native ferns (particularly *Dryopteris* and *Athyrium*) are frequently the most abundant plants in the ground cover, along with sedges (*Carex alligata*, *Uncinia uncinata*), vines of the mint family (*Stenogyne*, *Phyllostegia*), and numerous species of **herbaceous** *'ala'ala-wai-nui* (*Peperomia*).

Bogs

Bogs are a special type of community that occur in some of the wettest regions of the montane zone; the rainfall in some areas supporting bogs is greater than 400 in. (10,000 mm) per year. They develop in poorly drained flat or gently sloping areas with impervious clay or ironstone substrates (see Street, this volume), where water from heavy rainfall and stream flow tends to collect. The water-saturated soils of bogs are characteristically acidic and nitrogen poor. Hawaiian bogs are relatively small and are usually surrounded by more typical rain forest vegetation. The vegetation of open bogs is characterized by mosses and hummock-forming endemic sedges and grasses, particularly *Oreobolus furcatus*, *Carex* spp., *Machaerina* spp., *Rhynchospora* spp., and small-leaved, creeping members of the grass genera *Panicum* and

Dichanthelium. Woody plants such as pilo (*Coprosma ochracea*), *'ohelo* (*Vaccinium* spp.), and *na'ena'e* (*Dubautia* spp.) may also be prominent in bogs, but they are short-statured and often dwarfed; bog-adapted varieties of 'ohi'a may flower and fruit when only four inches tall.

A number of Hawaiian plant species are especially adapted for life in bogs, such as the insectivorous sundew (*Drosera anglica*), endemic violets (*Viola* spp.), and the diminutive **club-moss** *lepelepe-a-moa* (*Selaginella deflexa*). Many bog plants display a growth form with rosettes of fleshy leaves, sometimes arranged low to the ground; examples are *lau-kahi* (*Plantago* spp.), geraniums (*Geranium humile*), the daisy-like *Lagenophora viridis*, and greenswords and bog-adapted silverswords (*Argyroxiphium caliginis*, *A. grayanum*.)

Bogs are relatively small and uncommon in Hawai'i and are the only habitat for many endemic and specialized Hawaiian plant species. They are exceptionally vulnerable to destructive rooting and trampling by feral pigs because of soft, easily dug soils and the succulent plants they contain. Fencing and active management may be needed to preserve them.

Montane Mesic Forests and Parkland

At the upper reaches of the montane forest zone near the temperature inversion layer, as well as in areas of transition between windward and leeward slopes, the forests are mesic or moist rather than extremely wet. In general, mesic forests receive less rainfall than rain forests (often 75 in. (1,900 mm) per year or less) but do not suffer actual moisture shortages. Mesic forests lack the dense tree fern layer and abundant epiphytes so prominent in rain forests. However, where they occur on old substrates, they may be particularly species-rich and are the habitat of many rare plant and bird species.

One type of vegetation formerly common in the area of transition from montane wet forest to subalpine communities is a parkland or open woodland of koa. Where protected, this parkland consists of relatively low-growing, spreading koa trees in a matrix of native shrubs and **bunchgrasses**. Most of this upper elevation koa community has been used for cattle ranches, resulting in the prevention of koa reproduction and the replacement of native species by alien grasses.

Subalpine Zone

Only on the younger islands of Maui and Hawai'i do the volcanoes reach a height allowing the development of subalpine vegetation. This high-elevation zone (above 6,000-6,500 ft or 1,800-2,000 m) occurs on both the windward and leeward slopes of Haleakala, Mauna Kea, Mauna Loa, and Hualalai and is essentially a band encircling the tall mountains. Plants that grow here are adapted to dry conditions and periodic cold temperatures. Rainfall ranges from approximately 20-50 in. (500-1,300 mm) per year, and the mean monthly temperature is less than 50°F (10°C). The composition of plant communities varies with substrate age and elevation. Older substrates support open forests of shrubby mamane, a leguminous species with brilliant yellow flowers, often mixed with naio or bastard sandalwood, a widespread species which occurs in many communities from the coast to the subalpine zone. Native bunchgrasses and shrubs grow here, notably species of na'ena'e, which are a group of plants in the sunflower family related to the silverswords (*Argyroxiphium* spp.), and *'aheahea* (*Chenopodium oahuense*), said to be the largest, woodiest plant of its genus in the world (Carlquist 1980). Mamane

forests on both Maui and Hawai'i have been seriously impacted by feral goats (*Capra hircus*), sheep (*Ovis aries*), and mouflon (*O. musimon*), but in recent years Federal and State agencies have attempted to reduce or eradicate **populations** of these destructive animals on lands that they control (see Stone, Non-Native Land Vertebrates, this volume).

On younger, rockier substrates the major tree of the subalpine zone is the 'ohi'a, a species remarkable for its ability to grow in almost every ecological zone of Hawai'i, from the shoreline to the high mountain treeline. Subalpine communities in rocky areas are usually characterized by a dense cover of hardy, small-leaved native shrubs, particularly pukiawe, 'ohelo (*Vaccinium reticulatum*), *'a'ali'i* (*Dodonaea viscosa*), and geraniums (*Geranium cuneatum* and others).

Subalpine shrub communities extend well above the treeline to above 10,000 ft (3,000 m), but with increasing elevation, shrubs become sparser and lower to the ground and eventually disappear. The unique Hawaiian silverswords or *'ahinahina* are denizens of the upper subalpine region; their silver color is associated with reflective hairs, an adaptation to extremes of temperature and exposure to strong sunlight. Formerly one of the commonest plants of the zone, silverswords have been particularly affected by feral animals. Although relatively secure on Haleakala, the subspecies peculiar to Mauna Kea is now restricted to a very limited area and is considered Endangered.

Alpine Zone

The summits of Mauna Loa and Mauna Kea reach an altitude of nearly 14,000 ft (4,250 m). Summit areas receive almost no rainfall and experience great daily variation in temperature, which often drops below freezing at night. Under such harsh conditions, only hardy lichens, mosses, and scattered grasses can survive. However, even areas that appear barren and devoid of vegetation may support a community of native **invertebrates**, such as the recently discovered wekiu bug (*Nysius wekiuicola*) of Mauna Kea, which survives on insects blown to the summit from lower elevations by strong winds.

Dry Leeward Zone

The leeward slopes of all the Hawaiian Islands are much drier than the windward slopes (excepting the previously-discussed band of leeward rain forest of the Kona coast of Hawai'i) and originally supported a variety of native dry and mesic forests and shrublands. The dry leeward zone typically receives less than 50 in. (1,300 mm) of rainfall annually, and regions at the lower elevational limits of the zone get even less precipitation, sometimes as low as 10 in. (250 mm) per year. On the large islands of Maui and Hawai'i, the communities of the dry leeward zone start below the subalpine zone, while on Kaua'i, O'ahu, and Moloka'i, the region of dry and mesic communities occurs below the rain forests of the summits and upper mountain slopes. All or most of the low islands of Ni'ihau, Kaho'olawe, and Lana'i fall into the dry leeward zone. Of all the zones, dry leeward vegetation has perhaps been the most seriously impacted and fragmented by fire, feral goats, cattle grazing, and alien grass invasion. Few examples of dry forest remain relatively intact.

Dry and mesic forests of upper leeward slopes (especially on Maui and Hawai'i) are more difficult to characterize than are windward rain forests, which are typically dominated by only one or two tree species over large tracts of land. Some leeward forests are composed predominantly of lama, 'ohi'a,

koa, *koaia* (*Acacia koaia*), *olopua* (*Nestegis sandwicensis*), *'ala'a* (*Pouteria sandwicensis*), or tree *'akoko* (*Chamaesyce olowaluana*); more often, dry and mesic forests contain a variety of important tree species, and sometimes no clear dominant plant exists. Other smaller-statured trees commonly encountered in many dry forests are *alahe'e* (*Canthium odoratum*), *kauila* (*Alphitonia ponderosa*), *holei* (*Ochrosia* spp.), *hao* (*Rauvolfia sandwicensis*), sandalwood (*Santalum* spp.), and *kulu'i* (*Nototrichium sandwicense*).

Dry forests are usually open with a less layered structure than rain forests. Tree ferns are essentially absent, but native shrubs such as pukiawe, 'a'ali'i, ko'oko'olau, na'ena'e, 'ilima, 'akoko, and others may be common. In contrast to rain forests, epiphytes, terrestrial herbs, and ferns are usually not abundant. Vines and lianas are also relatively uncommon, although *huehue* (*Cocculus trilobus*) and *'awikiwiki* (*Canavalia* spp.) are notable exceptions.

Some of the rarest trees of Hawai'i occur in this zone. Some dry forest trees, such as members of the endemic genera *Hibiscadelphus* and *Kokia*, are nearly extinct in the wild. Others, such as the huge-trunked *mehamehame* (*Flueggea neowawraea*) and the double-fruited *mahoe* (*Alectryon macrococcum*), may still be encountered frequently in some areas but are rarely able to successfully reproduce. A number of plants restricted to the dry leeward zone are officially listed Endangered species; among these are vines and shrubs (*Haplostachys haplostachya, Lipochaeta venosa, Stenogyne angustifolia*), as well as trees such as *uhiuhi* (*Caesalpinia kavaiensis*), *na'u* (*Gardenia brighamii*), and a sandalwood (*Santalum freycinetianum* var. *lanaiense*) (see Stemmermann, this volume). Many other dry forest trees are among the hundreds of Hawaiian **Candidates** for the Federal list of Endangered taxa. Examples are kauila (*Colubrina oppositifolia*), *'aiea* (*Nothocestrum breviflorum, N. latifolium*), *a'e* (*Zanthoxylum semiarticulatum, Z. dipetalum*, and others), and *halapepe* (*Pleomele hawaiiensis*), an unusual tree-like member of the lily family.

At lower elevations on leeward slopes, forests are drier, less diverse in species composition, and appear more open and savanna-like. *Wiliwili* (*Erythrina sandwicensis*) and lama are frequently the dominants in these open forests; in a few areas *'ohe makai* (*Reynoldsia sandwicensis*) is a codominant tree species. Both wiliwili and 'ohe makai are **deciduous** trees that drop their leaves and remain bare for part of the year. Other leeward lowland areas have few or no trees and are dominated by shrub species such as 'a'ali'i or 'akia.

Almost none of the lowland dry forest remains undisturbed. Much was burned and cleared by Hawaiians in the pre-contact period (Kirch 1985; see also Stone, Hawai'i's Wetlands . . . ; Burrows, this volume); other forests and shrublands have been replaced in historical times by alien trees such as kiawe, or have been invaded by alien grasses that are often fire adapted (see Smith, Non-Native Plants, this volume). The extensive lowland grasslands seen today in this zone are relatively recent and largely anthropogenic (man-made).

CONCLUSION

Much of Hawai'i's natural vegetation has been removed, reduced, or degraded, especially in the coastal, lowland, and dry leeward zones, where human use has been concentrated for centuries. The remnant vegetation of the

dry leeward zone contains many of Hawai'i's rarest plants (see Stemmermann, this volume), but each vegetation zone supports its own rare plant species and unique communities. Vulnerable coastal strand and upland bog communities are extremely limited in number and area, and they deserve immediate protection (the strand from people and the bogs from pigs). Rain forest areas are especially rich in native plant species, and not many examples are left. Montane rain forests and the subalpine and alpine vegetation in Hawai'i have been less modified than other vegetation zones because of more extreme temperature and precipitation regimes, remoteness, and comparatively low value to humans. However, current threats from feral **ungulates** and many alien plant species are extremely serious. Even though much montane 'ohi'a rain forest remains in Hawai'i, effective conservation of this type of vegetation may require the protection of very large tracts of land because of the dynamic natural processes of 'ohi'a dieback (see Gerrish, this volume). The upper elevation zones also contain rare and declining species of Hawaiian birds, many already at remnant levels (see Stone, Native Birds, this volume; Giffin, this volume).

About 75% of the 175 native plant communities in Hawai'i are in danger of being lost to human "progress." Some of these communities were never very common. Yet fragmentation and reduction in numbers of examples of each community type have decreased **biological diversity** and jeopardized survival of species and communities alike. Plants and animals cannot long survive when their populations fall below **minimum viable population** sizes, and as each species is lost, diversity and stability decrease. Invasions of alien plants and animals further pave the pathway to extinction and community degradation. That many examples of intricate biological communities, ostensibly little affected by humans, still exist in each vegetation zone today is more a matter of circumstances than of conservation. Public awareness about how little is left and action to preserve our irreplaceable natural heritage must increase dramatically if we are to ensure the continued existence of many unique Hawaiian organisms and communities.

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