

THE NATIVE COASTAL PLANTS OF O'AHU, HAWAI'I

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INTRODUCTION

The most vulnerable elements in the coastline vegetation are the endemic strand elements, which are narrow in range...and the endemic elements of the native dry forests, which may have extended to the coast in the leeward areas.... (Richmond & Mueller-Dombois 1972).

The demise of the Hawaiian endemic flora has been a concern for many decades. Degener (1932 et seq.), Egler (1947), and Richmond and Mueller-Dombois (1972) have documented the gradual loss of native plants on O'ahu due to the impacts of agriculture, development, and introduced plants. In recent years, with increased interest in Hawaiiana, the native Hawaiian environment, and coastal zone management, there has been increasing concern for native coastal plants. This is shown by several recent publications written for general audiences on this subject: Arrigoni (1977, 1978), Merlin (1977), and Tabata (1979). Also, a 20-minute slide/tape program "Nā Mea Ulu Ma Kahakai o Hawai'i" was produced by Kimura and Nagata (1979).

For O'ahu, particularly, there is now new information on the status of native coastal plants: Richmond and Mueller-Dombois (1972) on O'ahu coastline ecosystems; Fosberg and Herbst (1975) on rare and endangered plants; Herbst (1976), EIS Corp. (1977), and Miura and Sato (1978) on the Barber's Point Deep-Draft Harbor site; Stemmermann (1977) on Hawaiian sandalwoods (Santalum spp.); Degener and Degener (1978) on the 'ōhai (Sesbania spp.); Elliott and Hall (1978) on the Kahuku area; Char and Balakrishnan (1979) on the 'Ewa Plains flora; Gardner (1979) on nehē (Lipochaeta spp.); and Kimura and Nagata (1980) on endangered coastal environments. These works provide considerable new information on the taxonomy and distribution of O'ahu's native coastal flora, particularly those considered threatened or endangered.

Objectives

The objectives of this paper are: (1) to generally describe coastal environments associated with native coastal plants; (2) to survey the status of O'ahu's native coastal flora, especially the threatened and endangered plants; (3) to provide examples of

management concerns; and (4) to offer recommendations for consideration. A bibliography of pertinent literature is provided. A plant checklist originally prepared for publication in the proceedings will be available separately (Tabata, in prep.).

VALUES OF NATIVE COASTAL PLANTS

The study of Hawai'i's native coastal flora is important to science as it would help to improve our understanding of the Hawaiian environment and would show us how native plants adapt to varying conditions at the shoreline, including exposure to heat, intense sunlight, drought, salt spray, blowing sand, and onshore winds. The study of native plants may also benefit man; medicinal uses and genetic characteristics having economic value (e.g., resistance to disease) are associated with certain native plants. The study of the native coastal flora is also important for educational purposes. Areas such as Ka'ena and Kaloko ("Alan Davis Beach" or "Queen's Beach") provide many opportunities for field trips and studies for students as well adults. On such occasions, studies dealing with other subjects relating to the coastline can easily be integrated into the curriculum: climatology, geology, marine algology, nearshore oceanography, social studies, the study of tidepools, and Hawaiiana. Some coastal plants such as naupaka-kahakai (Scaevola taccada (Gaertn.) Roxb.) and 'aki'aki (Sporobolus virginicus (L.) Kunth) are not only a part of the beach landscape, but also provide some protection against storm waves by helping to bind sand dunes. As sea level appears to be rising slowly at 5.6 inches per century, dune systems may be particularly important for protecting inland areas.

There is also some recent interest in using native coastal plants such as hinahina-ku-kahakai (Heliotropium anomalum H. & A.) and 'ohai for ornamental and lei-making purposes. As for economic value, some coastal plants such as the ālula (Brighamia citrina var. napaliensis St. John, a lobelia relative from Nā Pali, Kaua'i) are being cultivated and sold commercially as house plants. Other native coastal plants, notably the naupaka-kahakai, provide a setting for beach recreation. Commonly seen on many windward coasts with sand dunes are scores of picnickers, campers, and sunbathers among the clumps of naupaka (Scaevola).

There are many recreators who value such areas for joy-riding and "dune-busting." However, off-road recreational vehicle (ORV) use is often detrimental to coastline environments, particularly naupaka on sand dunes. At places like Ka'ena, Kahuku, and Kaloko, ORVs (e.g., motorbikes, dune buggies, and jeeps) are commonly driven on the sand dunes and nearby areas.

COASTAL ENVIRONMENTS ON O'AHU

This paper is limited to the strand and dry coastal lowland flora of O'ahu and their associated environments. Coastal wetlands and areas along embayments (e.g., Pearl Harbor and Kāne'ohe Bay) were specifically not considered. The dominant flora generally associated with the latter types of areas include: hau (Hibiscus tiliaceus L.), mangrove (Rhizophora), and bulrush (Scirpus).

A few native plants occasionally encountered in isolated wet areas within the strand or dry coastal lowlands were considered for field trip reference purposes: the water hyssop, Bacopa monniera (L.) Wettst.--Ka'a'awa Beach; the marsh cypress, Cyperus javanicus Houtt.--Mokulē'ia, near Camp Erdman; and Marsilea villosa Kaulf., an endemic fern--Koko Head.

Strand Environment

Strand plants directly influenced by the sea are the primary focus of this paper. The harsh strand environment is characterized by salt spray, constant wind, low rainfall, intense sunlight, high evaporation, high temperatures, and shifting sands. Strand plants have a variety of special adaptations to cope with these conditions, including small, succulent, often hairy leaves; succulent stems; prostrate habit; thick cuticles; and rosette leaves. The vegetation zone influenced by the ocean varies in width. On windward coasts unprotected from waves and salt spray (e.g., Ka'ena), the strand vegetation may extend far inland. On the other hand, along sheltered embayments (e.g., Kāne'ohe), there may be little or no strand vegetation (AECOS 1979).

Richmond and Mueller-Dombois (1972), in attempting to relate vegetation patterns to environmental factors (i.e., climate, physiography, exposure to wind and spray, substratum, and ground water), recognized 13 ecosystem classes, of which four could be considered strand-related environments:

- Scaevola on dunes (e.g., Paumalū, Kahuku, Makapu'u, Ka'ena, and Mokulē'ia);
- Scaevola on raised reef (Hau'ula);
- Scaevola on rocky basalt (Kaloko);
- Scaevola on talus and alluvium (Camp Erdman).

Five other ecosystem classes, principally associated with leeward O'ahu shores, had relatively narrow strand vegetation zones due primarily to the invasion of introduced lowland plants such as swollen fingergrass (Chloris), koa-haole (Leucaena), and kiawe (Prosopis):

- Chloris-Sida (swollen fingergrass-'ilima) on talus (e.g., south of Ka'ena);
- Chloris-Prosopis on dune and clay flat (Barber's Point);
- Prosopis on talus and alluvium (Kahe, Mā'ili);
- Prosopis on tuffaceous headland (Palea Point);
- Prosopis on dunes (Nānākuli, 'Ōhikilolo).

The distribution of strand vegetation on O'ahu, then, appears to be largely affected by exposure to wind and salt spray. One recent report (AECOS 1979) observed that most strand plants are found in the maritime zone not because they need salt or some other characteristic but because they are better adapted to compete with faster-growing lowland plants. A useful guide to classifying terrestrial environments, especially near the sea, is provided in the AECOS report. The guide helps classify strand/lowland vegetation at or near sea level on the basis of: (1) degree of wind and salt spray exposure evidenced by the proximity of trees to the seaward vegetation line; and (2) substratum types, ranging from basalt rock to dunes. This classification scheme would be useful for identifying sensitive habitat types for management purposes.

Coastal Lowland Environments

For the purposes of this paper, dry lowland flora found in coastal areas were included. Many native lowland flora can be found today at Ka'ena, Makapu'u, Koko Head, Diamond Head, and Kalaeloa (Barber's Point). Some are found fairly close to the sea and are easily accessible from the coast (e.g., naio or Myoporum sandwicense Gray, at Kaloko). Others described in this paper are perhaps marginal coastal plants as they are found at the edge of the transitional zone between the strand and dry forest vegetation, often on talus slopes, cliffs, and ledges near the sea (Kimura & Nagata 1980). Nevertheless, they are also exposed to some of the conditions faced by strand plants, though perhaps to a lesser degree. For the dedicated, intrepid hiker, these transitional coastal plants are also accessible from the coast.

Climatically, the coastal lowland flora described in this paper are mostly in the "summer drought" zone adapted by Char and Balakrishnan (1979) from Kartawinata and Mueller-Dombois (1972) and from Richmond and Mueller-Dombois (1972). Figure 1 illustrates the location of the three major climatic zones of O'ahu and major coastal sites having significant native coastal flora.

In terms of typical vegetation, several habitat types described by Fosberg (1961) are associated with coastal lowland flora:

- Kākonakona-'ilima seasonally dry scrub-grassland
drier areas on coastal flats or lower slopes, mostly
leeward; typical plants include wiliwili (Erythrina),
ma'o (Gossypium), nehe (Lipochaeta), kākonakona (Panicum
torridum Gaud.), and 'ilima;
- Pili grassland
coastal flats and foothills in drier parts of O'ahu;
typical plants include pili (Heteropogon contortus (L.)
Beauv. ex R. & S.) and a variety of introduced plants
(e.g., kolū (Acacia farnesiana (L.) Willd.), lantana
(Lantana camara L.), koa-haole, prickly pear (Opuntia),
kiawe, and Christmas berry (Schinus terebinthifolius
Raddi));
- Eragrostis variabilis grassland
from coral sand on beaches to moderately wet forest,
and lower drier sites of main islands; typical plants
include variable lovegrass or 'emo-loa (Eragrostis
variabilis (Gaud.) Hbd), sedge (Fimbristylis), and nehe
(Lipochaeta integrifolia (Nutt.) Gray).

Representative coastal areas on O'ahu with these types of habitats include the Koko Head to Makapu'u area, Diamond Head, and the Ka'ena to Mokulē'ia area.

THE NATIVE COASTAL FLORA OF O'AHU

It is truly difficult to reconstruct the native flora which once pervaded the dry coastal areas of O'ahu. Accounts are generally sketchy and collection data are not always adequate. However, from the few available accounts--notably, Hillebrand (1888), Rock (1913), MacCaughey (1918), Degener (1932 et seq.), and Egler (1947)--a general picture can be drawn of the typical flora of the strand and coastal lowlands. In addition, for specific plant groups, monographs and other papers provide some insight regarding the distribution of coastal plants on O'ahu: Rock (1916), Skottsberg (1927), and Stemmermann (1977) on sandalwoods (Santalum spp.); Sherff (1935) and Gardner (1979) on nehe (Lipochaeta spp.); Sherff (1936) on 'akoko (Euphorbia spp.); and Degener and Degener (1978) on the 'ōhai (Sesbania spp.).

An interesting account of the former native vegetation of the coralline 'Ewa Plains is presented by Char and Balakrishnan (1979: 59-60). It is difficult to imagine that plants which are rare today, especially many lowland plants, once stood where kiawe and other introduced plants now predominate. It is quite apparent that what remains today of native coastal plants is a mere remnant.

Indigenous Coastal Plants

Among the native coastal flora, a number are indigenous and relatively common in certain localities. Familiar members of the indigenous strand flora include:

Alena (Boerhavia diffusa L.)
(Indig. Tropics)

Fimbristylis pycnocephala Hbd.
(Indig. H.I. to Solomon Is., Laysan I.)
a coastal sedge;

Hinahina-ku-kahakai (Heliotropium anomalum)
(Indig. Pacific Is.)

Nena (Heliotropium curassavicum L.)
(Indig. H.I., America)

Pōhuehue (Ipomoea brasiliensis (L.) Sweet)
(Indig. Pantropic)
also called beach morning glory;

'Ōhelo-kai (Lycium sandwicense Gray)
(Indig. H.I., Polynesia)

'Ihi (Portulaca lutea Soland. ex Forst f.)
(Indig. H.I., Pacific Is.)

Naupaka-kahakai (Scaevola taccada
var. sericea (Vahl) St. John)
(Indig. H.I., tropical Pacific and Indian Oceans)

'Ākulikuli (Sesuvium portulacastrum (L.) L.)
(Indig. Tropics)

'Ilima (Sida fallax Walp.)
(Indig. H.I., Pacific Is., China)

'Aki'aki (Sporobolus virginicus)
(Indig. Pantropic)

Nohu (Tribulus cistoides L.)
(Indig. trop. cosmop.)

Nanea (Vigna marina (Burm.) Merr.)
(Indig. H.I., Tropics)
also called beach pea;

Pohinahina (Vitex ovata Thunb.)
(Indig. H.I., Asia, Pacific Is.)

Some of these indigenous plants are locally uncommon due to pressures from intense recreational activity. For example, many dune systems with naupaka-kahakai and pōhuehue have been heavily damaged or obliterated by coastal development, trampling, and vehicular traffic.

Endemic Coastal Plants

Many of the Hawaiian endemic coastal plants found on O'ahu are relatively abundant. The endemic strand representatives include:

- Kauna'oa (Cuscuta sandwichiana Choisy)
(End. H.I.)
an orange vine-like parasite in the morning-glory family; locally common in areas such as Ka'ena and Kaloko;
- 'Akoko (Euphorbia degeneri Sherff)
(End. Kaua'i, O'ahu, Moloka'i, Maui, Hawai'i)
a typical strand plant found on arid sand dunes, rocky or clay soils, near the sea; it has been reported from Kailua and Waimānalo, as well as many other locales on O'ahu (Hillebrand 1888; Degener 1932 et seq.);
- Pā'ū-o-Hi'i-aka (Jacquemontia sandwicensis Gray)
(End. H.I.)
another member of the morning-glory family, with pale white to blue, bell-shaped flowers; commonly found on dry plains and rocky slopes, especially near the sea;
- Hawaiian nama (Nama sandwicensis Gray)
(End. H.I.)
a perennial herb with bluish flowers, found chiefly on coastal dunes and sandy areas; once reported from Kahuku and Waikīkī (Hillebrand 1888); it is quite common seasonally at Kaloko;
- 'Ihi (Portulaca cyanosperma Egler)
(End. Kaua'i, Lehua, O'ahu, Hawai'i)
a reddish prostrate herb fairly common on Koko Head, especially on the slopes around Hanauma Bay.

Other endemic coastal plants, more common on coastal plains and slopes, include:

- Naio (Myoporum sandwicense)
(End. Kaua'i, Ni'ihau, O'ahu, Moloka'i, Lāna'i, Maui)
partial to leeward areas in shallow or rocky soils; it grows as a shrub near sea level and as a tree at higher elevations;

Kākonakona (*Panicum torridum*)

(End. O'ahu to Hawai'i, and Leeward Is.)

an annual panicgrass quite common in areas such as Ka'ena and Koko Head;

Kūpala (*Sicyos microcarpus* Mann)

(End. O'ahu, Kaua'i)

locally common vine member of the gourd family found during rainy seasons at places such as Kalaeloa, Ka'ena, and Kea'au.

Threatened and Endangered Coastal Plants

A number of coastal plants found on O'ahu are candidates for threatened or endangered species designation. The following summarizes their current status.

Marsilea villosa is a small fern endemic to the Hawaiian Islands. Each leaf has four leaflets (like a four-leaf clover). Marsilea can be found growing carpet-like in wet depressions subject to occasional drying. Forbes observed that it was becoming rare around 1920. Between 1925 and 1933, Marsilea was observed at Nānākuli, Makapu'u, and Luaualei (Degener 1932 et seq.). Marsilea has also been reported from Mōkapu Peninsula and Diamond Head crater (Corn, pers. comm. 1980). A population was photographed at Barber's Point beneath kiawe in 1932 (Char & Balakrishnan 1979) but has not been seen there lately. A fairly large population is still found in 'Ihi'ihilauākea, a depression on Koko Head.

Pololei (*Ophioglossum concinnum* Brack.) is a single-bladed fern endemic to O'ahu, Moloka'i, Lana'i, Maui, and Hawai'i. It was last collected on O'ahu at Sisal, a town near 'Ewa, by Forbes and Cooke in 1912.

Eragrostis paupera Jedw. is an annual grass endemic to O'ahu and related to E. variabilis, the more common variable lovegrass. Like the pololei, it was last seen on O'ahu at Barber's Point, 'Ewa, by Egler and Oliviera in 1937. Fosberg and Herbst (1975) think this species is probably extinct.

Panicum carteri Hosaka, an annual panicgrass endemic to O'ahu, was thought to be extinct (Fosberg & Herbst 1975) but has been reported recently from Mokoli'i (Chinaman's Hat); it is being nominated for endangered status. A relative, Faurie's panicgrass (P. fauriei Hitch.), is endemic to O'ahu, Moloka'i, and Lana'i; this species has been reported from Koko Head and Popoi'a Island. Species reported from Koko Head as P. fauriei by Fosberg (1961) is probably P. nubigenum Kunth, a more common species reported from O'ahu, Moloka'i, Lana'i, and Hawai'i (Herbst, pers. comm. 1980).

Achyranthes splendens var. rotundata Hbd. (Amaranthaceae) is considered by many botanists to be truly endangered. Endemic to O'ahu, it has been reported from Wai'anae and Ka'ena (Hillebrand 1888) as well as from Barber's Point (Herbst 1976; EIS Corp. 1977; Char & Balakrishnan 1979). It is a bushy shrub two to four feet tall with broadly rounded, thick silvery leaves; flower spikes are six to 12 inches long. A few individuals have been seen on the talus slopes of Ka'ena; however, today, the main population is limited to the Barber's Point area.

Another genus in the Amaranth family, Nototrichium, is represented in the coastal flora of O'ahu by four endemic taxa. These may be considered marginal coastal plants as they are associated more with lower elevation vegetation such as on the tops of talus slopes; they are at the fringe of the coastal zone. Kulu'i or Kaala nototrichium (Nototrichium humile Hbd. var. humile) was collected by Hillebrand at Ka'ena (Degener 1932 et seq.) and noted by Rock (1913); it was not reported in a recent survey of Ka'ena (Hawaii, Division of State Parks 1978). Nototrichium humile var. subrhomboideum Sherff was noted on the windward talus slopes in the coastal zone. Nototrichium viride var. subtruncatum Sherff, collected in 1950 from sea level to 1200 feet between Mokule'ia and Kawaihāpai (Degener 1932 et seq.), has not been seen lately. Finally, kulu'i or Hawaiian nototrichium (N. sandwichense (Gray in Mann) Hbd. var. sandwichense) has been observed on the talus slopes of Manini Gulch at Ka'ena; it is endemic to Kaua'i, O'ahu, Moloka'i, Lāna'i, Maui, and Hawai'i.

Maiapilo (Capparis sandwichiana DC. var. sandwichiana) is endemic to the north shores of O'ahu between Ka'ena and Makapu'u. Its white flowers are nocturnal and fragrant. Although rare, it has been observed at Ka'ena Point, and on Popoi'a and Kekepa islands off windward O'ahu. It may also have been observed at Hau'ula 50 to 70 m (164-230 ft) inland (Richmond & Mueller-Dombois 1972). Another variety, zoharyi Deg. & Deg., is not considered rare or endangered but is thought to be depleted (Fosberg & Herbst 1975). It is found on Midway and other main islands, such as at Keāhole Point, Hawai'i; on O'ahu, var. zoharyi is found today only at Barber's Point and Kahe Point Beach Park.

The genus Schiedea is represented by four taxa, all endemic to O'ahu. Mā'oli'oli (S. globosa Mann var. globosa) is restricted to the spray-swept cliffs between Koko Head and Waimānalo (Degener 1932 et seq.). It prefers crevices in arid cliffs and ledges such as at Makapu'u Head. It was also reported on the rim of Kahauloa Crater (Koko Head Firing Range) (Egler 1947). Schiedea globosa var. graminifolia Deg. & Sherff in Sherff, a perhaps marginal coastal plant, has been reported from the cliffs and crevices southwest of Waimānalo Landing (Degener 1932 et seq.). Two other species of Schiedea are also marginal coastal plants but are included as they are found fairly close to the sea. Schiedea adamantis St. John is found today only on the rim of Diamond Head. Schiedea kealiae Caum & Hosaka inhabits the dry exposed cliffs along the Keālia Trail near Kawaihāpai in the Ka'ena area (Degener 1932 et seq.).

Four taxa of nehe (Lipochaeta integrifolia) recognized by Sherff (1935) have been reported from O'ahu coasts:

- var. integrifolia
(End. Kure, Laysan, Kaua'i, O'ahu, Maui)
- var. gracilis Sherff
(End. H.I.)
- var. major Sherff
(End. O'ahu)
- var. megacephala Deg. & Sherff in Sherff
(End. O'ahu)

The latter three taxa were once recommended for endangered species status (USDI 1976). A fifth taxon, var. argentea Sherff, is endemic to Maui. Generally found in exposed wind-swept areas, prostrate over rocks, nehe grows near sea level to 20 to 30 m (60-90 ft) elevation. This species is distinguished by its thick succulent leaves and mat-forming habit (Gardner 1979). The four O'ahu taxa, recently consolidated into L. integrifolia by Gardner, have been reported from places such as Makapu'u, Hanauma, Ka'ena, and Popoi'a Island. Specimens have been collected in the past from: Waimānalo, Lā'ie Point, Pearl Harbor, Diamond Head (Sherff 1935); and Kailua (Hillebrand 1888). If Gardner's taxonomy is accepted, the species may not be as endangered as previously thought.

Of six coastal varieties of Lipochaeta lobata (Gaud.) DC., all were nominated at one time for endangered status except var. denticulata (Wawra) Sherff; five are endemic to O'ahu, while one is also endemic to Kaua'i (Sherff 1935). All six have been grouped into L. lobata var. lobata by Gardner (1979). According to Gardner, L. lobata var. lobata is common at Ka'ena Point and from Koko Head to Makapu'u Point in low coastal dune areas to a few hundred feet elevation on scrubby, open hillsides. Specimens of L. lobata var. lobata were noted by Gardner from Nānākuli, Diamond Head crater, near Hawai'i Kai Golf Course, and Ka'ena. Other specimens have been collected from the dry, grassy eastern slopes of Kuli'ou'ou Valley and Lualualei near the beach (Degener 1932 et seq.), as well as from the Wailupe and Niu areas (Sherff 1935). Again, if Gardner's taxonomy is accepted, L. lobata var. lobata may be more common than thought earlier. Another nehe, L. remyi Gray, is considered a marginal coastal plant as it is found at 200 m (600 ft) elevation above the talus slopes at Manini Gulch, Ka'ena; it is endemic to O'ahu.

Cuscuta sandwichiana var. kailuana Yuncker, a variety of the more common kauna'oa, was once found on O'ahu as well as on Moloka'i and Hawai'i. Degener (1932 et seq.) reported it from the beach at Kailua-Kona, Hawai'i, in addition to Mo'omomi, Moloka'i, and Ka'ena Point, O'ahu. It has not been reported in recent years on O'ahu.

'Ānaunau (Lepidium o-waihiense C. & S.) (mustard family, Cruciferae) is endemic to the Northwestern Hawaiian Islands, Kaua'i, O'ahu, Moloka'i, Lāna'i, and Maui. Today, it is reportedly found at Lā'ie Point and in the Makapu'u area of O'ahu and is common in the Northwestern Hawaiian Islands.

Sicyos laysanensis St. John is endemic to Laysan and O'ahu, and was once observed at Barber's Point, 'Ewa, and Damon Tract. This plant was not mentioned in the 'Ewa Plains study (Char & Balakrishnan 1979). It was once recommended for threatened species status.

Five taxa in the genus Euphorbia ('akoko) have been reported from O'ahu coasts. All are endemic to O'ahu except E. degeneri Sherff; E. degeneri is not considered endangered at this time. Euphorbia celastroides var. kaenana Sherff is restricted to Ka'ena on the rocky slopes near the point. Euphorbia skottsbergii var. kalaeloana Sherff was thought to be extinct (Fosberg & Herbst 1975) but was rediscovered recently during botanical surveys for the Barber's Point Deep Draft Harbor (Herbst 1976). This particular 'akoko is a perennial erect shrub up to 2 m (6 ft) tall and is found now mostly among the kiawe at Barber's Point. Euphorbia skottsbergii Sherff var. skottsbergii is endemic to the 'Ewa Plains area and thought to be extinct. Forbes and Skottsberg collected this plant on the 'Ewa coral plains between 1916 and 1922 (Sherff 1936). It was last collected by Degener on the arid fossil reef between Barber's Point and Pearl Harbor in 1932. Euphorbia multiformis var. tomentella Boiss. in A. DC. is not well known. Plants of this species are normally found upland; however, it was reported along the sea-shore in Kailua and elsewhere by Hillebrand (1888). Fosberg and Herbst (1975) list this plant as extinct.

'Āwiwi (Centaurium sebaeoides (Griseb.) Druce) (Gentianaceae) is considered rare but, where found, gregarious. It is endemic to Kaua'i, O'ahu, Moloka'i, and Maui. 'Āwiwi grows within reach of salt air on dry coastal plains and in sand-filled crevices of raised fossil reefs. It has been reported by Degener from Lā'ie Point, Hale'iwa, and Mokulē'ia (Degener 1932 et seq.). It is still found in the pastureland below Manini Gulch at Ka'ena and on the steep slopes above Hālonā Blowhole. This species has not been officially nominated for endangered status but is identified as rare and depleted (Fosberg & Herbst 1975).

Scaevola coriacea Nutt. is a prostrate shrub with trailing branches, pale green leaves, whitish erect flowers, and black fruits (Char & Balakrishnan 1979). Hillebrand found it at Ka'ena Point on lava near the shore; it has not been seen there since 1922 (Degener 1932 et seq.). Rock found S. coriacea at Barber's Point in 1919 (Degener 1932 et seq.); it was not found in the 'Ewa Plains botanical survey (Char & Balakrishnan 1979). Once thought to be found on the arid lowlands of all the main Hawaiian Islands, S. coriacea is now restricted to the lithified dunes of Wai'ehu, Maui; a few individuals have been found recently at Kaupō, Maui.

'Ōhai (Sesbania tomentosa H. & A. var. tomentosa) (pea family, Leguminosae) is an attractive shrub with large reddish flowers. Hillebrand (1888) reported it along the Wai'anae seashore on O'ahu. Degener noted it was known only from Jacquemontia-Heliotropium covered limestone and clays between the railroad tracks from Ka'ena Point to Kawaihāpai. He also noted that Neal collected it at Mōkapu Peninsula in 1934 (Degener 1932 et seq.). On O'ahu, this plant is now restricted to Ka'ena, amid sand dunes and coastal flats on the windward side; it is also found on Nihoa and Necker islands.

Another member of the pea family, the Oahu vigna (Vigna o-wahuensis Vogel), is endemic to Kaua'i, O'ahu, and Moloka'i. Degener, in 1934, considered it almost extinct. He found it at Waimānalo climbing over low shrubs and grasses in limestone deposits just below the cliffs (Degener 1932 et seq.). The Oahu vigna has also been observed on Mokulua Island off Lanikai.

Ma'o (Gossypium sandwicense Parl.), relative of the hibiscus, grows on arid, rocky, or clay plains not far from the sea, usually in leeward areas. On O'ahu, it is still fairly common near Koko Head and between Hono'uli'uli and Mākua on the leeward coast (Degener 1932 et seq.). Ma'o is endemic to the main Hawaiian Islands.

Myoporum sandwicense var. stellatum Webster (naio) is a rare variety restricted to the 'Ewa coral plains between the mouth of Pearl Harbor and Barber's Point. Degener (1932 et seq.) noted that due to construction and other works of man, M. sandwicense var. stellatum was on the verge of extinction. Recently, it was recommended that this naio be placed on the federal list of endangered species (Char & Balakrishnan 1979).

Hedyotis littoralis (Hbd.) Fosb. (coffee family, Rubiaceae) is known from Kaua'i, O'ahu, Moloka'i, Maui, and Hawai'i (St. John 1973). There have been no recent observations or collections from O'ahu. Its typical habitat is the cliffs of Ke'anae, Maui.

Of the two varieties of coastal sandalwood ('ili-ahi-a-lo'e), Santalum ellipticum var. littorale (Hbd.) Skottsb. is considered endangered. This plant is a pale green shrub found along arid coasts among rocks and in adobe soil, and occasionally inland in drier areas (Degener 1932 et seq.). It is endemic to Laysan and O'ahu, although it is reportedly extinct on Laysan. The plant is found now at Ka'ena, Moku'auia (Goat Island), Diamond Head, and Makapu'u (near Sea Life Park). It was also formerly reported from Kailua and Wai'anae (Rock 1916).

CURRENT STATUS OF THREATENED AND ENDANGERED SPECIES

The original list of proposed endangered species expired in November 1979; a revised list of active candidates for threatened or endangered status has subsequently been republished in December 1980 (USDI 1980). Of the endemic coastal plants described above, some are being considered for official endangered species status (D. Herbst, pers. comm. 1981). The 1980 list includes the following coastal taxa:

Ophioglossum concinnum
Eragrostis paupera
Panicum fauriei
Nototrichium humile
N. viride var. subtruncatum
Capparis sandwichiana var. sandwichiana
Lipochaeta lobata var. leptophylla Deg. & Sherff in Sherff
Sicyos laysanensis
Euphorbia celastroides var. kaenana
E. skottsbergii var. skottsbergii (probably extinct)
Sesbania tomentosa var. tomentosa
Vigna o-wahuensis
Hedyotis littoralis

Two other candidates are now being proposed for endangered status: Euphorbia skottsbergii var. kalaeloana and Panicum carteri. Information is being compiled for future listing on Achyranthes splendens var. rotundata, Bidens cuneata Sherff, Scaevola coriacea, and Schiedea adamantis. A status report is being prepared for Santalum ellipticum var. littorale. Future study is planned for Marsilea villosa, a high-priority candidate.

THREATS TO NATIVE COASTAL PLANTS

There are few areas along O'ahu shores which have not been disturbed by grazing, agriculture, residential development, parks, military installations, golf courses, or coastal roads. The areas, which are relatively undeveloped such as at Ka'ena, Kahuku, Kaloko, and Barber's Point, support a significant native coastal flora with associated habitats, all of which are threatened to varying degrees.

Coastal development has permanently displaced native flora along substantial sections of O'ahu. In windward areas (e.g., Kailua-Lanikai, Waimānalo), residential development has probably displaced sizeable naupaka ecosystems. Beach park developments, such as at Sandy Beach, have replaced strand vegetation on dunes and rocky outcroppings with Bermuda grass (Cynodon dactylon (L.) Pers.) lawns and banyan trees. Golf courses like the one at Kahuku have probably displaced considerable strand vegetation on coastal dunes. Along the Wai'anae coast and between Ka'ena and Hale'iwa, coastal roads, and even railroads, were built on dunes

and probably led to the loss of many native strand plants. The presence of military installations such as at Mōkapu Peninsula has contributed to changes in the native shoreline vegetation.

Other undeveloped areas along the coasts have also been affected. Additional stresses placed on native coastal vegetation include grazing, erosion, and invasion by introduced lowland species.

Recreational Pressure

Today, in addition to increasing coastal development, especially for resorts, condominiums, and industrial purposes, recreational pressures pose a serious threat to certain types of habitats. The relatively few uncrowded sandy beaches accessible to the public and free of major development are found farther from heavily urbanized areas such as Honolulu and Kailua-Kāne'ohe, resulting in generally less disturbed environments than the more heavily used beach parks. Unfortunately, the dominant ecosystem associated with many of those rural areas--naupaka on dunes--is also popular for shoreline recreation.

The sheer impact of large numbers of people can be devastating. Parking, camping, and trampling on dunes over a long period of time can cause erosion, blow-outs, and dune movement. One study (Vogt 1979) found that fewer than 10,000 people walking over sand dunes in a single season could eliminate dune plants and cause sand erosion. At popular beach parks (e.g., Makapu'u), the effects of heavy recreational use (e.g., completely eroded dunes) are readily apparent. Nearby Sandy Beach also shows long-term effects of vehicular and pedestrian traffic, including parking.

Off-road Recreational Vehicles (ORVs)

The effects of people can hardly compare with the impacts of off-road recreational vehicles such as jeeps, 4-wheel drives, motorbikes, and dune buggies. Ironically, ORVers appear to share with bikers and other non-motorized recreationists a desire to get away from the urban life and confining jobs, into the wilderness and open space (U. S. CEQ 1979). Unfortunately, the ORVers create substantial impacts on fragile habitats (e.g., dunes). One study (NEMAS 1980) concluded that there is no carrying capacity for vehicular traffic on coastal ecosystems. Even low-level impacts can result in severe environmental degradation. In many test areas, it was found that the first few vehicle passes did the most damage. Another five-year experimental study conducted at Cape Cod National Seashore between 1974 and 1977 examined the impacts of 4-wheel drive vehicles on beaches, dunes, salt marshes, and tidal flats (Godfrey et al. 1978). This study concluded that the driftlines and developing dunes were the most susceptible to ORV damage. A few ORV passes could break up the concentrated organic deposit from beachdrift and destroy regenerating plants just below the sand surface.

Similar ORV damage appears to be occurring at the seaward edge of dune ecosystems. For example, at Makapu'u, Sandy Beach, and Kaloko, where pōhuehue, or the beach morning glory, and naupaka-kahakai should be common, the vegetation line appears to have been moved inland by ORV traffic on the beach itself. ORV tracks and vegetation damage can be observed at the vegetation line.

Coastal lowlands are also vulnerable to ORV damage although the substrate may be more durable than dunes. ORV traffic in some areas (e.g., Ka'ena) has resulted in a vast network of tracks and eroded areas.

Invasion of Introduced Flora

Finally, invasion of disturbed habitats by introduced plants is a great concern. Introductions of aggressive plants (e.g., koa-haole, Pluchea, and kiawe) have led to their dominance in many coastal areas. Richmond and Mueller-Dombois (1972) noted that "...with disturbance, dryland floristic elements, notably Prosopis and Chloris (finger grass), have displaced the typical strand flora to a very narrow zone along the coastline, although a few species may persist under Prosopis with low cover." They also observed that the "undergrowth of Prosopis ecosystems is dominated by introduced drought-resistant grasses and shrubs. However, in Scaevola ecosystems, except under extremely disturbed conditions the native strand flora have persisted (emphasis added)." Preventing the disturbance of their habitats, then, is crucial to protecting native strand plants. For example, a study by Takemoto (1977) of vegetation changes at Ka'ena Point between 1966 and 1977 concluded that:

1. Jeeps and other motor vehicles caused more unvegetated open areas in the 11-year period;
2. Naupaka cover was significantly reduced;
3. Much of the loss included native herbs and vines between naupaka clumps and at the edges of the clumps;
4. The plants most vulnerable to vehicle damage included alena, 'akoko, hinahina-ku-kahakai, and 'ilima;
5. Koa-haole invasion had begun mostly on the leeward side of the naupaka clumps; the koa-haole's deeper root system was thought to be more resistant to damage.

SPECIAL CONCERNS

Although there are reportedly pockets of native coastal flora along O'ahu's coastline (e.g., Makahoa Point, Hau'ula, Lā'ie Point, Pahumoa ["Pounders"], and some offshore islands), there are few significant areas remaining. Three areas urgently need protection: Ka'ena Point, Kalaeloa (Barber's Point), and 'Ihi'ihilauākea on Koko Head. Other areas having considerable native coastal flora include Kaloko ("Alan Davis" or "Queen's Beach") and Makapu'u Beach Park. Certain areas, although rather rich with native coastal plants, need management less urgently due to less accessibility and human pressures. Those areas include the Makapu'u spray-swept cliffs and upper talus slopes of the Ka'ena area.

Ka'ena

Recent concern for the rare and endangered flora at Ka'ena has been partly responsible for proposals for a state park and natural area reserve there. Kimura and Nagata (1980) describe the variety of native coastal plants found at Ka'ena, as well as the different habitats ranging from sand dunes to talus slopes. Among a number of endangered plants in the area at least three are of special interest:

<u>Euphorbia celastroides</u> var. <u>kaenana</u>	'Akoko
<u>Lipochaeta lobata</u> var. <u>lobata</u>	Nehe
<u>Sesbania tomentosa</u> var. <u>tomentosa</u>	'Ōhai

The 'akoko at Ka'ena is locally common on the slopes between rock outcroppings. As this 'akoko is restricted to Ka'ena, it deserves special attention. During a May 1980 field survey, a number of damaged plants were observed on the lower slopes near the dirt road. People collecting rocks for stone walls may be rolling the rocks over the plants.

Lipochaeta lobata var. lobata may also be endemic to Ka'ena, according to Sherff (1935). However, Gardner (1979) believes this nehe is the same as other L. lobata varieties found along other O'ahu coastlines. In either case, the Ka'ena nehe is unusual because of its deeply-lobed leaves. Fortunately, it appears relatively safe from human impacts as it grows mostly on slopes protected by rock outcroppings; however, some plants along the road are threatened by introduced weeds.

The 'Ōhai at Ka'ena is probably the most threatened of the three plants as it is found mostly on the coastal flats potentially in the path of ORVs, especially near the point. A May 1980 field survey located over 100 individual plants distributed between the point and the Mokulē'ia end of the paved road; 86 were at the point in exposed areas near the dunes where ORVs are regularly driven. Immovable boulders strategically placed in the vicinity may help to protect this population of 'Ōhai.

In addition to the rare and endangered plants at Ka'ena, the naupaka on dune ecosystems also deserve attention. ORVs have decimated the dunes in recent years, adding to the damage incurred by vehicles and human trampling over many decades since the turn of the century. Increasing ORV use has accelerated destruction of the Ka'ena dunes and has altered the landscape considerably as well as the flora. ORV use should generally be controlled in the area.

Kalaeloa (Barber's Point)

Richmond and Mueller-Dombois (1972) noted that the endemic flora of the native dry forest, which may have extended to the coast in leeward areas, is one of the most vulnerable elements of O'ahu's coastline vegetation. The 'Ewa fossil reef plains are the most extensive of its kind in the Hawaiian Islands and represent a unique ecosystem. Kimura and Nagata (1980), and Char and Balakrishnan (1979) both describe the area in terms of climate, geology, environments, and flora. The beach flora at Barber's Point is not exceptional, especially due to substantial disturbances by development, trampling, ORVs, and invasion of exotic plants. However, a number of rare and endangered plants, located slightly inland from the beach, are of special interest:

<u>Achyranthes splendens</u> var. <u>rotundata</u>	
<u>Capparis sandwichiana</u> var. <u>zoharyi</u>	Maiapilo
* <u>Eragrostis paupera</u> Jedw.	An endemic grass
<u>Euphorbia skottsbergii</u> var. <u>kalaeloana</u>	'Akoko
* <u>E. skottsbergii</u> var. <u>skottsbergii</u>	'Akoko
<u>Gossypium sandwicense</u>	Ma'o
<u>Marsilea villosa</u>	An endemic fern
<u>Myoporum sandwicense</u> var. <u>stellatum</u>	Naio
<u>OphioGLOSSUM concinnum</u>	Pololei, an endemic fern
* <u>Scaevola coriacea</u>	Naupaka

Three of the plants, indicated by an asterisk (*), are no longer thought to be found in the area; two of them, Eragrostis paupera and Euphorbia skottsbergii var. skottsbergii, are endemic to Barber's Point.

Marsilea villosa and pololei, both described earlier, have not been observed in this area since 1932 and 1912, respectively, but may have been overlooked in field surveys due to their seasonal growth (Char & Balakrishnan 1979). Ma'o is thought by several botanists to be less endangered than initially recommended; it is locally common in dry leeward coastal areas such as the Wai'anae coast. Maiapilo or native caper, is not considered endangered, unlike var. sandwichiana found at Ka'ena. However, it is rather rare on O'ahu except in this general vicinity where approximately 140 plants are found.

This leaves three plants still found at Barber's Point of special interest. Euphorbia skottsbergii var. kalaeloana, needs attention urgently as it is found mostly in the back-up area for the proposed Barber's Point Deep Draft Harbor. Of the approximately 4400 plants located, 2450 are in the immediate project area. Another 1300 is found where the West Beach resort has been proposed, and approximately 100 were destroyed when a parcel next to the Chevron Oil Refinery was bulldozed in 1979. Assuming that all of the proposed developments proceed, the best management options are to find a suitable habitat and successfully propagate the plant for transplanting, as recommended by Char and Balakrishnan (1979).

The other two plants of concern are the Achyranthes and Myoporum (naio). The Achyranthes is endemic to O'ahu and though a few individuals have been seen at Ka'ena, it is found mostly in the Barber's Point area. There are two main colonies at Barber's Point. Approximately 600 plants are located among the Pluchea and kiawe between the cement and fertilizer plant buildings; another 500 are near the lighthouse; and about 115 less vigorous plants are under kiawe in the Malakole Military Reservation.

Finally, as described earlier, the Myoporum is a variety found only at Barber's Point. Most of the plants are found generally in the same areas as the Achyranthes. A kiawe community adjacent to the Barber's Point Beach Park harbored some of the aforementioned Achyranthes, maiapilo, and naio. However, a roadside clearing and the development of a parking lot for an adjacent lu'au operation destroyed an unknown number of these plants within the last two years. A sanctuary has been proposed to preserve examples of plants native to the unique 'Ewa plains area (Char & Balakrishnan 1979).

'Ihi'ihilauākea

A third area in need of special protection is 'Ihi'ihilauākea, a wet depression above Hanauma Bay. It is the habitat for the small endemic fern Marsilea villosa which has been nominated for endangered species status. Aside from the Barber's Point population, whose status is uncertain, this may be the last major population on O'ahu. However, within the last two years, motorbikes have found their way into this area and have begun to damage the habitat. Today, tire ruts, tire scars, and campfire sites mark the presence of recreationalists. In some of the disturbed areas, particularly in tire ruts, weeds such as cocklebur (Xanthium) are beginning to appear while other weeds and various grasses are beginning to encroach upon the habitat margins. Measures should be taken soon to bar vehicular entry and to control trampling; campfires should also be restricted to prevent fires during the dry season. Invading weeds such as the cocklebur may need to be removed periodically.

Kaloko and Makapu'u Beach Park

Kaloko ("Alan Davis" or "Queen's Beach"), which is owned by the Bishop Estate and has been proposed for resort development, is a prime field trip site for the study of native coastal plants as well as for other ocean-related subjects. A diverse number of native strand plants can be found at Kaloko including alena, kauna'oa, 'akoko, Fimbristylis, hinahina-ku-kahakai, nena, pōhuehue, pā'ū-o-Hi'i-aka, nehe, 'ōhelo-kai, nama, naupaka-kahakai, 'ilima, 'aki'aki, and nohu. Ma'o and naio are also found nearby. Few places on O'ahu are so close to Honolulu schools and offer a safe field trip environment with such a diversity.

The 1980 State Legislature appropriated \$1 million for park-land acquisition at Queen's Beach; the appropriation lapses in June 1982. Past appropriations to the State totalling \$2.1 million between 1975 and 1977 for land acquisition lapsed through June 30, 1980. Additional appropriations to the City and County of Honolulu have similarly lapsed. The current appropriation should be used to purchase selected portions of Bishop Estate lands as soon as possible before the Queen's Beach resort development proceeds. The area could be managed as an official coastal field trip site for the primary and secondary schools on O'ahu.

Makapu'u Beach Park is already publicly owned and also has some potential as a field trip site due to its excellent tide pools and interesting geology and coastal flora. The dune areas are severely damaged by ORVs and heavy recreational pressures; however, a number of common strand plants still persist, including 'akoko, hinahina-ku-kahakai, nena, 'ili-ahi-a-lo'e, naupaka-kahakai, and nohu. If ORVs and other vehicles are restricted from the dune areas and heavy recreational pressure is diverted to less sensitive areas, perhaps portions of the original dunes could recover or be restored.

Other Recommendations

In addition to the recommendations provided for specific coastal areas, general recommendations are offered for consideration:

1. Naupaka ecosystems, found primarily in wind-exposed parts of O'ahu, should be generally protected from intensive recreational activity--particularly vehicular and pedestrian traffic. ORVs should be prohibited, perhaps by county ordinance, from operating on dunes and sandy beaches. Walkover structures for beach access through dunes should also be considered, especially for public parks.
2. General locations of the native coastal flora should be mapped and incorporated into the City and County's shoreline management area (SMA) to ensure that any development which may adversely affect native coastal habitats will be adequately

reviewed. The City and County's Department of Land Utilization, in cooperation with the State of Hawaii, was developing a map to note the locations of rare and endangered coastal plants for boundary revision purposes in 1980.

3. Research should be conducted on the effects of ORVs and trampling on the Hawaiian coastal flora. There is no available information applicable to Hawai'i which could be used to improve the management of sensitive coastal environments.

4. Native coastal flora, particularly on publicly owned lands, should be documented. A management program should be developed by appropriate agencies to protect significant habitats. Baseline data need to be collected for areas such as Ka'ena and periodic surveys should be conducted to monitor changes caused by recreational and other uses and to evaluate on-going management efforts. Maintenance personnel should be made aware of the existence of special plants on the premises in order to avoid accidental clearing or weeding.

5. Native coastal flora and habitats should be restored whenever possible as part of the landscaping of county beach parks--especially those suited for strand vegetation (e.g., Sandy Beach and Makapu'u). Such restoration projects would help to reestablish the former native vegetation, as well as reduce maintenance and operational costs (e.g., watering, weeding, mowing). Those areas would also be valuable for public educational purposes. Botanical gardens featuring coastal plants (e.g., the Maui Zoo and the Waha'ula Visitor Center, Hawaii Volcanoes National Park) could be an extension of this approach.

6. Public education is needed to increase the awareness and appreciation of Hawai'i's unique coastal plants and to illustrate their contribution to our well-being. Wise decisions affecting future use of areas harboring native plants will depend on having an informed public.

CONCLUSIONS

At one time, O'ahu had considerably more native coastal flora along its beaches and coastal lowlands. Grazing, cultivation, development, roads, and other disturbances have eliminated many coastal habitats and encouraged invasion by introduced plants. Today, recreational pressures and continued development threaten the remaining native coastal flora. What remains today is still impressive; however, the future of certain plants is uncertain.

A few plants at Ka'ena, Barber's Point, and Koko Head appear to require more urgent attention. More generally, naupaka ecosystems need more effective management to prevent further deterioration from ORVs and intensive recreational pressure. Kaloko and Makapu'u Beach Park, among others, should be considered for

coastal field trip sites and managed accordingly. Finally, public education is needed to ensure the perpetuation of habitats necessary for native coastal plants.

ACKNOWLEDGMENTS

Mahalo nui loa to the following individuals for their generous assistance and patience in providing valuable information and for reviewing the manuscript: Winona Char, Department of Botany, University of Hawaii at Manoa; Carolyn Corn, State Division of Forestry; Derral Herbst, U. S. Fish and Wildlife Service; Ken Nagata, Lyon Arboretum; Wayne Souza, Division of State Parks; Karen Tanoue, Sea Grant Publications; and Paul Weissich, Honolulu Botanic Gardens, City and County of Honolulu.

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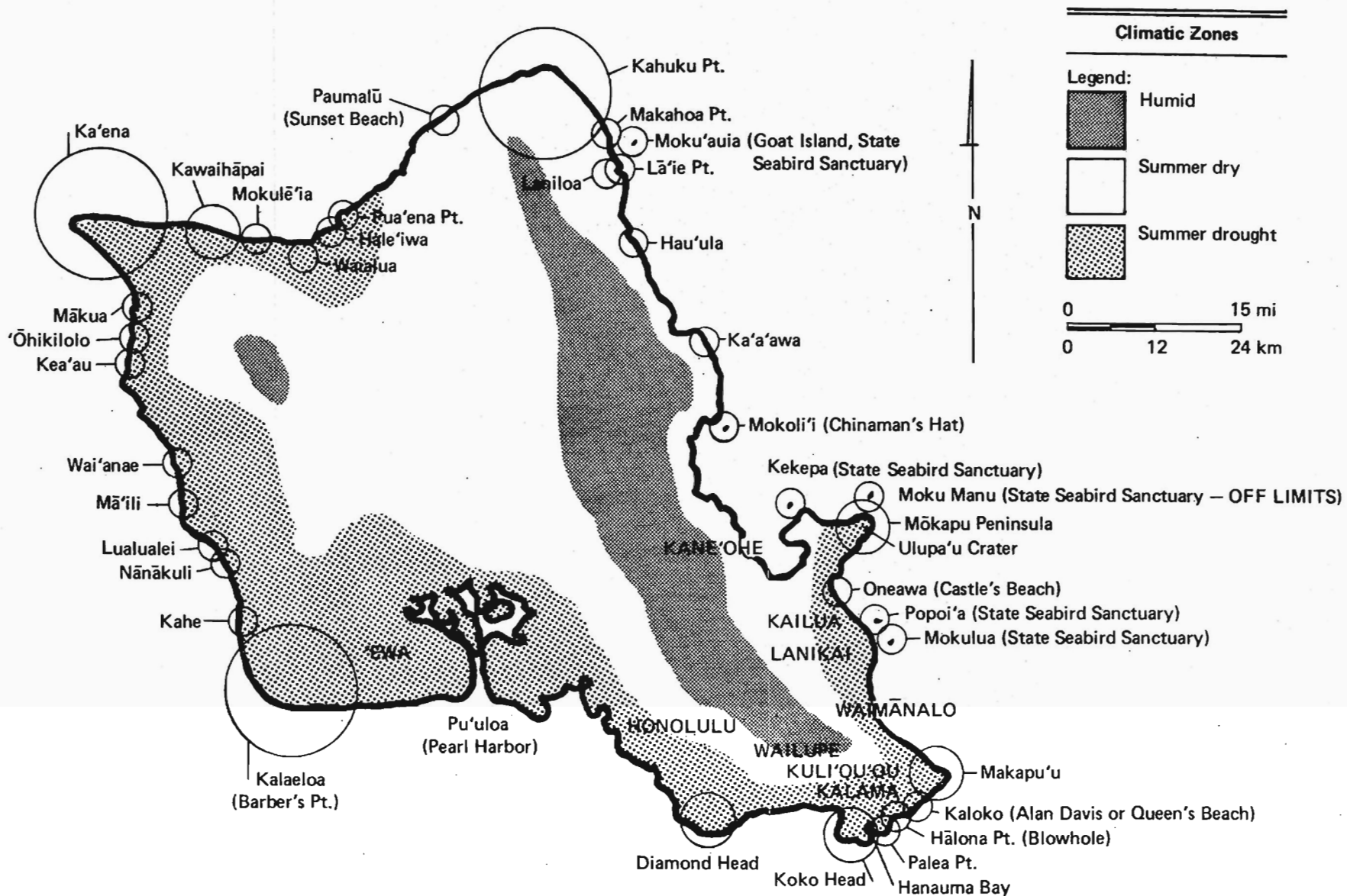


Figure 1. Generalized climatic zones of O'ahu and localities noted in text. (Adapted from Char and Balakrishnan, 1979)