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Technical Report 71

**Description and Map of the Plant Communities of
the Northeast Coastal Spray Zone of
Kalaupapa National Historical Park**

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Table of Contents

	Page
List of Tables	ii
List of Figures	ii
Abstract	1
Introduction	1
Study Area	
Location and General Description	1
Climate	1
Soils and Substrate	2
Past Hawaiian Activity	2
Methods and Materials	2
Results	
Plant Species	2
Plant Communities	3
Management Recommendations	
Feral Animals	5
Control of Alien Species	8
Conclusion	9
Acknowledgments	9
Literature Cited	9
Appendix	
Plant Species of Kalaupapa Spray Zone	16

List of Tables

Table :

1. Summary of the status of vascular plants in Kalaupapa spray zone	3
2. Plants in Kalaupapa spray zone declared noxious by Hawai'i State Department of Agriculture	3
3. Plants in Kalaupapa spray zone with the potential to disrupt archaeological sites	3
4. Species list of Kalaupapa spray zone plant communities	6

List of Figures

Figure :

1. Vegetation map of northeast coastal spray zone of Kalaupapa National Historical Park	10
2. Native sandy strand southeast of Kahio benchmark	12
3. Native sandy strand north-northwest of Kaupikiawa	13
4. Coastal spray zone north-northwest of Kaupikiawa	14
5. Alien subcoastal spray zone southwest of Kahio benchmark	15

Abstract

Two lichens, two ferns, and 66 flowering plants are recorded from the northeast coastal spray zone of Kalaupapa National Historical Park. Forty-four species (63%) are alien (introduced since 1778). Fourteen species have been declared noxious by the State of Hawai'i. Five species pose a potential threat to archaeological sites. One grass constitutes a fire hazard.

Five plant communities are distinguished and mapped within the northeast spray zone on the basis of species composition and substrate: 1) a native-dominated community on sandy strand directly in the salt spray, 2) a half-native community on flat basalt with clayey soil above sea cliffs in the most intense salt spray, 3) a native community on rocky strand slightly protected from salt spray, 4) a small area of native-dominated prostrate shrubs on raised basalt domes, and 5) an alien-dominated grassland less influenced by spray. In addition, an alien scrub community borders the spray zone. A total of 25 localized plant associations are distinguished within the five spray zone communities.

Management recommendations are for experimental exclosures to gauge the impact of feral herbivores, and for experimental salt water applications to control alien plants. The ecological diversity and intact nature of this native coastal vegetation argue for its sound management.

Introduction

This study of the vegetation of the windward spray zone of Kalaupapa peninsula was undertaken to address the following objective of the Kalaupapa National Historical Park General Management Plan (1980): to recognize inherent biotic resources and provide for their management and interpretation. The plan calls for identification of the type and extent of native and introduced species, and for techniques to preserve and manage these resources.

Study Area

Location and General Description

Kalaupapa National Historical Park is located midway along the northern coast of the island of Moloka'i. It

includes a low peninsula and three narrow valleys bordered by 500-1000 m high pali (cliffs). Most of the 10,000 acre Park is on State-owned land; 1250 acres is administered by the Department of Hawaiian Home Lands and a small area at Moloka'i Lighthouse is federally owned. The Park extends from Nihoa, on the coast west of Kalaupapa peninsula, to the east rim of Waikolu Valley, thus encompassing Waihanau, Wai'ale'ia, and Waikolu valleys. Only the windward northeast section of the peninsula is discussed in this study, however.

In the late Pleistocene, long after the main part of the island of Moloka'i was formed, a small shield volcano created the Kalaupapa peninsula. This shield was recently proposed as a national natural landmark. From the lip of Kauhako Crater, at 122 m elevation, the pahoehoe basalt slopes gradually to the coast, with little evidence of surface erosion (Fig. 1) (Macdonald et al. 1983). The study area lies below 45 m elevation.

As stated in the 1980 Management Plan, the Park's primary purposes are to minimize outside disturbance to the Kalaupapa patients, provide interpretation to limited numbers of tourists, and preserve significant historical, archaeological, cultural, and natural features.

Climate

The climate of Kalaupapa peninsula is largely determined by its direct exposure to the prevailing northeast trade winds, its low topography, and the pali rising from the southern base of the peninsula, high enough to induce some orographic precipitation.

The temperature is quite constant, with an average annual maximum of 27°C (81°F) and minimum of 20°C (68°F) at Kalaupapa settlement (Hawai'i Department of Land and Natural Resources 1983). In January the temperature averages 22°C (71°F) and in July, 25°C (77°F). The average diurnal range in temperature is 8°C (14°F).

Rainfall is low, averaging 1140 mm (45 inches) annually at Kalaupapa settlement (Hawai'i Department of Land and Natural Resources 1983). Precipitation is lowest between May and October, averaging 56 mm (2 inches) in July. The average for January is 140 mm (6 inches). Rainfall is probably slightly lower at the study area than at the settlement,

which is located closer to the cloud-forming pali of "topside" Moloka'i.

Soils and Substrate

The study area includes four soil types, as defined by the USDA Soil Conservation Service (Foote et al. 1972). The extreme windward coast from Kahi'u Point to 'Alau is considered rock outcrop, with > 90% rock. Two narrow inner coastal areas between Kahi'u Point and Kaupikiawa are mapped as Jaucus sand. Rock land with > 25% rock forms the interior in the Kaupikiawa region. The remaining interior, from the airstrip to the Kalawao road, and the coastline south of 'Alau are mapped as Kalaupapa very rocky silty clay loam, a shallow (< 0.4 m) ash substrate with lantana and pasture vegetation. There is thus relatively little soil development in the study area.

The present study found a more extensive area of sand than that indicated by the 1972 Soil Survey. With only a few discontinuities, sandy substrate extends from Kahio benchmark to Kaupikiawa.

Past Hawaiian Activity

The abundance of rock walls and other archaeological structures on Kalaupapa peninsula attests to its occupation both prior to and following European contact (Greene 1985). A full understanding of the duration and extent of settlement must await further archaeological investigation. It is difficult to ascertain what plant species grew in the study area at the time of European contact. Hawaiian burning and cultivation practices had most probably reduced the native vegetation component by 1778.

European introduction of cattle and horses to Moloka'i began a period of grazing that has continued up to the present. The cattle and horses brought in for the leprosy settlement ran loose, soon resulting in overgrazing of the peninsula (Greene 1985). In 1868, axis deer were released on Moloka'i, adding to the feral herbivores of Kalaupapa. Cattle, horses, donkeys, and mules were grazing on Kalaupapa peninsula and the adjoining valleys in 1885 (Greene 1985). Introduction of alien plant species since European contact has also altered the vegetation of the study area.

Since establishment of the Kalaupapa Leprosy Settlement in 1866, there has been fairly limited human

impact on the spray zone study area. While the Kalawao settlement (the primary settlement until 1890, and occupied to some extent until 1932) was not far from the study area, the limited mobility of the patient population effectively reduced its impact on the spray zone region. Evidence of localized sites of greater impact within the past century are the former boat landing south of Kuololimu and the Mormon beach house steps south of Lae Ho'olehua. The major human-induced impact on spray zone vegetation has almost certainly been feral herbivore grazing.

Methods and Materials

The northeast spray zone of Kalaupapa National Historical Park was surveyed in January 1987. Plants were identified in the field or from voucher specimens. Plant nomenclature follows St. John (1973) and Herbst (pers. comm.).

The local abundance of species was recorded using the Braun-Blanquet cover-abundance scale (Mueller-Dombois and Ellenberg 1974). To characterize each species more generally, the following abundance classification was also used: abundant, common, occasional, uncommon, rare.

Non-native plants were separated into two types. Polynesian introductions refer to those species introduced by the aboriginal Hawaiians prior to 1778. Historic introductions refer to all subsequent introductions.

Common names of plants are taken from St. John (1973), Neal (1965), and Porter (1975). The source of ethnobotanical information is Neal (1965).

The plant community map was made with the aid of the 1977 USGS Kaunakakai orthophotoquad, the 1967 Kaunakakai quadrangle and 1983 East Moloka'i USGS topographic maps, and the USDA Soil Conservation Service soil map (Foote et al. 1972).

Results

Plant Species

Two lichen species from two families, two ferns from two families, and 66 flowering plants from 26 families were found in the study area (Appendix). Sixty-three percent of the windward spray zone flora is alien, i.e.,

Table 1. Summary of the status of vascular plants in Kalaupapa spray zone

Status	Number of Species	Percent
Endemic	7	10
Indigenous	18	26
Historical introduction	44	63
Polynesian introduction	1	1

introduced since 1778 (Table 1). One-quarter of the flora is indigenous, 10% endemic, and 1% of Polynesian introduction.

Fourteen of the historic introductions are considered noxious by the Hawai'i State Department of Agriculture (Table 2). Five species pose a potential threat to archaeological sites (Table 3). Although those five species are at present uncommon in the study area, they could disrupt the extraordinarily abundant ancient rock walls and shelters (and have likely already done so in the alien scrub mauka (inland) of the spray zone). One grass species (*Panicum maximum*) produces a fine fuel that constitutes a major fire hazard.

Table 2. Plants in Kalaupapa spray zone declared noxious by Hawai'i State Department of Agriculture

Scientific name	Common name
<i>Abutilon grandifolium</i>	hairy abutilon
<i>Acacia farnesiana</i>	klu
<i>Cuscuta sandwichiana</i>	dodder
<i>Lantana camara</i>	lantana
<i>Momordica charantia</i>	balsam apple
<i>Plantago lanceolata</i>	narrow-leaved plantain
<i>Pluchea indica</i>	Indian pluchea
<i>Psidium guajava</i>	guava
<i>Schinus terebinthifolius</i>	Christmas berry
<i>Solanum sodomium</i>	apple of Sodom
<i>Sporobolus indicus</i>	West Indian dropseed
<i>Stachytarpheta jamaicensis</i>	Jamaica vervain
<i>Tricachne insularis</i>	sourgrass
<i>Xanthium saccharatum</i>	cocklebur

Plant Communities

In the vegetation of the windward spray zone, five communities were distinguished. In the most direct salt spray are two communities: a native-dominated sandy strand community (community H in Figs. 1-3) occurring between Kahio benchmark and Kaupikiawa, and a community found primarily above the cliffs south of Kaupikiawa, on relatively flat basalt with some clayey soil (community F, Figs. 1,4).

Another native community (S) occupies the rocky strand near Kahi'u Point at the north end of the airstrip, slightly more protected from the

Table 3. Plants in Kalaupapa spray zone with the potential to disrupt archaeological sites

Scientific name	Common name
<i>Acacia farnesiana</i>	klu
<i>Lantana camara</i>	lantana
<i>Pluchea indica</i>	Indian pluchea
<i>Prosopis pallida</i>	kiawe
<i>Psidium guajava</i>	guava

predominantly northeast trade winds than the first two communities.

An alien-dominated grassland (C, Fig. 5) occupies the remaining windward coast of the peninsula: most of the coast south of Kaupikiawa. This community also forms a less spray-influenced inland corridor extending from near Kahio benchmark and Moloka'i Lighthouse south to below Kuololimu. Within the alien grassland is a very localized distinct community (E) with a sizeable native component, on raised basalt domes northwest of Kaupikiawa.

In addition to these five spray zone communities is an alien scrub community (L). While it reaches the coastline south of Kuololimu, this community occurs predominantly above 20 m elevation, mauka of the alien grassland and the true spray zone.

More complete descriptions of these six communities, including localized plant associations, are given below. The abundance of each species in each community is given in Table 4.

H *Heliotropium anomalum*/*Scaevola taccada*/

Cynodon dactylon native sandy strand spray zone

Coastal spray zone on sand. Strand, dunes, and sandy flats with basalt outcrops (sometimes clayey soil) behind strand. Located on northern half of study area between Kahi'u point and Kaupikiawa. Makai (seaward) of roads, with predominantly native vegetation. Total cover of vegetation averages 20% at edge of strand and 70% further mauka (inland).

Disturbed by trampling (and presumably grazing) of large herbivores: horses, formerly cattle. Also disturbed by excavation of sand for cement-making.

Vegetation dominated primarily by *Scaevola taccada*, *Cynodon dactylon*, or *Heliotropium anomalum*. Mean vegetation height 0.15 m. Localized plant associations include:

At edge of strand:

- *Tournefortia argentea*/*Scaevola taccada* (total vegetation cover 20%)
- *Scaevola taccada*/*Ipomoea pes-caprae*
- *Heliotropium anomalum*/*Scaevola taccada*/*Euphorbia degeneri* (Fig. 2)

Slightly mauka:

- *Scaevola taccada*/*Cynodon dactylon* (Fig. 2)
- *Scaevola taccada*/*Sporobolus virginicus*
- *Sesuvium portulacastrum* (Fig. 3)
- *Heliotropium anomalum*/*Euphorbia degeneri* (50% cover)
- *Heliotropium anomalum*/*Fimbristylis pycnocephala* (with clayey soil) (75% cover)
- *Fimbristylis pycnocephala*/*Heliotropium anomalum* (with clayey soil)

Further mauka, grass-dominated:

- *Cynodon dactylon*/*Euphorbia degeneri* (60% cover)
- *Cynodon dactylon*/*Sesuvium portulacastrum* (Fig. 3)
- *Cynodon dactylon*/*Euphorbia degeneri*/*Fimbristylis pycnocephala*
- *Sporobolus virginicus*/*Euphorbia degeneri*/*Fimbristylis pycnocephala* (80% cover)

S *Scaevola taccada*/*Fimbristylis pycnocephala*
native protected rocky strand

Coastal spray zone on loose basalt. Rock with little sand or with little clayey soil. Less directly wind-influenced than community H. Located near Kahi'u Point, at northern tip of peninsula. Makai of roads, with predominantly native vegetation. Total cover of vegetation averages 60%.

Disturbed by airstrip construction and by limited trampling and grazing, since fence and airstrip should restrict access by feral animals.

Vegetation dominated primarily by *Scaevola taccada* or *Fimbristylis pycnocephala*. Mean vegetation height 0.25 m. Localized plant associations are:

- *Scaevola taccada*/*Sida fallax* / *Cynodon dactylon* (70% cover) on rock with clayey soil, southeast of airstrip (Fig. 5)
- *Fimbristylis pycnocephala*/*Euphorbia degeneri* (40% cover) on rock with sand, north of airstrip

F *Fimbristylis pycnocephala* raised clayey
spray zone

Coastal spray zone on basalt imbedded in clayey soil. Above windward cliffs (ca. 15 m elevation), in the path of most intense salt spray. Located northwest of and south of Kaupikiawa. Mostly makai of roads, with nearly half of vegetation cover native. Distribution of this community too localized to map precisely except at northernmost locality. It is therefore indicated within the C/F unit on the map. Community F occupies narrow strips extending from coastline indentations leeward up to or just mauka of the coast road. Total cover of vegetation averages 70%.

Disturbed by a few vehicle tracks. Possibly also subject to trampling and grazing by feral animals, although no evidence seen.

Vegetation dominated primarily by *Fimbristylis pycnocephala* or *Digitaria adscendens*. Mean vegetation height 0.05 m. Localized plant associations include:

- *Fimbristylis pycnocephala*/*Digitaria adscendens*/*Tetramolopium rockii* var. *rockii* (70% cover)
- *Fimbristylis pycnocephala*/*Panicum nubigenum*
- *Fimbristylis pycnocephala*/*Cynodon dactylon*/*Panicum nubigenum* (80% cover)
- *Fimbristylis pycnocephala*/*Digitaria adscendens*/*Sida fallax* (50% cover)

- *Fimbristylis pycnocephala*/*Sida fallax*/
Euphorbia degeneri (Fig. 4)
- *Digitaria adscendens*/*Fimbristylis pycnocephala*

E *Euphorbia celastroides* raised basalt domes

Domed basalt hills averaging 20 m in diameter and 6 m in height. Located northwest of Kaupikiawa. Very localized, just mauka of coast road, with about half the vegetation cover native. Prostrate shrubs are dominant. Total cover of vegetation averages 50%.

Probably subject to grazing disturbance, although no evidence seen.

Vegetation dominated primarily by *Euphorbia celastroides* var. *amplectans*. Mean vegetation height 0.1 m. Plant association is:

- *Euphorbia celastroides*/*Fimbristylis pycnocephala*/*Wikstroemia uva-ursi*

C *Cynodon dactylon*/*Digitaria adscendens* alien raised and subcoastal spray zone

Coastal and near-coastal spray zone on clayey soil with loose or imbedded basalt. Behind the strand and above windward cliffs. Extending along virtually the entire windward side of the peninsula. Mostly mauka of coast road, except above windward cliffs on southern half of coastline. Vegetation predominantly alien. Total cover of vegetation averages 80%. Upper elevation border not mapped precisely.

Disturbed by trampling and grazing of horses, formerly cattle, and deer.

Vegetation dominated primarily by *Cynodon dactylon* or *Digitaria adscendens*. Mean vegetation height 0.2 m. Localized plant associations include:

- *Cynodon dactylon*/*Digitaria adscendens*/
Sida fallax (85% cover) (Fig. 5)
- *Cynodon dactylon*/*Digitaria adscendens*/
Fimbristylis pycnocephala
- *Digitaria adscendens*/*Cynodon dactylon*
(75% cover)

L *Lantana camara*/*Schinus terebinthifolius* alien raised coastal scrub

Lower elevation inland slopes of clayey soil with loose and imbedded basalt. Wind- and spray-sculpted alien scrub. Extending from Moloka'i Lighthouse to Kalawao. Mauka of coast road except along southernmost km of peninsula's windward coast.

Total cover of vegetation averages 85%. Surveyed only near makai border; upper elevation limit not mapped.

Disturbed by trampling and grazing of horses, formerly cattle, and deer.

Vegetation dominated primarily by *Lantana camara* or *Schinus terebinthifolius*. Mean vegetation height 0.5 m. Localized plant associations (not comprehensive) include:

- *Lantana camara*/*Schinus terebinthifolius*
(75% cover) (Fig. 2)
- *Schinus terebinthifolius*/*Psidium guajava*

Management Recommendations

Feral Animals

Trampling and grazing by feral animals constitutes the primary management problem regarding spray zone vegetation. It was difficult to estimate the severity of the problem at the time the field work was conducted, as less browsing in makai areas of the peninsula would be expected during the wet winter months when green vegetation is abundant all over the peninsula.

Furthermore, the cattle population was removed from the peninsula several months prior to the survey, as part of the attempt to eliminate bovine tuberculosis from the island. The impact of cattle removal could not yet be judged when this survey was undertaken. Cattle feces were seen in the *Heliotropium anomalum* - dominated native sandy strand near Kahio benchmark and Kaupikiawa.

The group of six feral horses on the peninsula was seen grazing in the study area on two of the survey days. On one occasion, they were near the boundary of the weedy grassland (community C) and alien scrub (L) near 'Alau. On the other, they were in weedy grassland (C) and native sandy strand (H) near Kaupikiawa. Their adverse impact on native vegetation was clear from observing them rolling in the sand, and from the depth and extent of their hoofprints in the loose sand of the *Sesuvium* plant association. Horse feces were noted in the *Heliotropium anomalum* - dominated native sandy strand near Kahio benchmark and Kaupikiawa.

Table 4. Species list of Kalaupapa spray zone plant communities. Average Braun-Blanquet cover-abundance ratings¹ are given for each species in each of the six communities. Community L listings are incomplete. Nomenclature follows St. John (1973) and Herbst (pers. comm.).

		Plant Community					
		H	S	F	E	C	L
Lichenes							
Physiaceae	<i>Buellia</i> sp.	+	+	+	+	+	+
Teloschistaceae	<i>Caloplaca</i> sp.	+	+	+	+	+	+
Pteridophyta							
Aspidiaceae	<i>Cyrtomium falcatum</i>					r	
Psilotaceae	<i>Psilotum nudum</i>					r	
Monocotyledones							
Cyperaceae	<i>Cyperus javanicus</i>		r				
	<i>Fimbristylis pycnocephala</i>	1	1	2	1	+	
Gramineae	<i>Cynodon dactylon</i>	2	1			2	1
	<i>Digitaria adscendens</i>	r	+	1	+	2	1
	<i>Panicum maximum</i>					+	
	<i>Panicum nubigenum</i>	r	r	+			
	<i>Setaria glauca</i>		r				
	<i>Sporobolus indicus</i>					r	
	<i>Sporobolus virginicus</i>	+	r				
	<i>Tricachne insularis</i>					r	
Dicotyledones							
Alzooaceae	<i>Sesuvium portulacastrum</i>	+	+	+			
	<i>Tetragonia tetragonioides</i>	r					
Anacardiaceae	<i>Schinus terebinthifolius</i>		r			+	3
Boraginaceae	<i>Heliotropium amplexicaule</i>					+	
	<i>Heliotropium anomalum</i>						
	var. <i>argenteum</i>	2	+				
	<i>Heliotropium curassavicum</i>	r				r	
	<i>Tournefortia argentea</i>	r					
Chenopodiaceae	<i>Atriplex semibaccata</i>		r				
Compositae	<i>Eclipta alba</i>					r	
	<i>Emilia javanica</i>				+	+	
	<i>Erigeron canadensis</i>					+	
	<i>Pluchea indica</i>				+		
	<i>Reichardia picroides</i>	r	r	r		+	
	<i>Sonchus oleraceus</i>		r	r	+	+	
	<i>Synedrella nodiflora</i>					r	
	<i>Tetramolopium rockii</i> var. <i>rockii</i>			+			
	<i>Tridax procumbens</i>					r	
	<i>Xanthium saccharatum</i>					r	

¹ 3 = 25-50% cover, 2 = 5-25% cover, 1 = 1-5% cover, + = < 1% cover with numerous individuals, r = one to several individuals.

		Plant Community					
		H	S	F	E	C	L
Convolvulaceae	<i>Cuscuta sandwiciana</i>	r					
	<i>Ipomoea congesta</i>					r	
	<i>Ipomoea pes-caprae</i>	+	+			+	
	<i>Jacquemontia sandwicensis</i>		r			r	
Cruciferae	<i>Coronopus didymus</i>					r	
	<i>Lobularia maritima</i>					r	
Cucurbitaceae	<i>Momordica charantia</i>					+	
Euphorbiaceae	<i>Euphorbia celastroides</i>						
	var. <i>amplectans</i>				1		
	<i>Euphorbia degeneri</i>	1	+	+		r	
	<i>Euphorbia hirta</i>					r	
	<i>Phyllanthus debilis</i>		r			r	
Goodeniaceae	<i>Scaevola taccada</i>	1	2	r	+		
Leguminosae	<i>Acacia farnesiana</i>					r	
	<i>Cassia leschenaultiana</i>					r	
	<i>Desmodium tortuosum</i>					+	
	<i>Desmodium triflorum</i>		r		+	1	
	<i>Mimosa pudica</i> var. <i>unijuga</i>					r	
	<i>Phaseolus lathyroides</i>					r	
	<i>Prosopis pallida</i>					r	
Malvaceae	<i>Abutilon grandifolium</i>					r	
	<i>Malvastrum coromandelianum</i>					+	
	<i>Sida fallax</i>	+	2	+	+	+	+
Myrtaceae	<i>Psidium guajava</i>					r	2
Nyctaginaceae	<i>Boerhavia diffusa</i>	r	+			+	
Oxalidaceae	<i>Oxalis corniculata</i>		r			+	
Plantaginaceae	<i>Plantago lanceolata</i>		+			r	
Portulacaceae	<i>Portulaca lutea</i>	r	r	r			
	<i>Portulaca pilosa</i>	+	+	+	+	+	
Primulaceae	<i>Anagallis arvensis</i>					+	
Solanaceae	<i>Lycium sandwicense</i>	r	+				
	<i>Solanum sodomium</i>					r	
Sterculiaceae	<i>Waltheria americana</i>		r			r	
Thymelaeaceae	<i>Wikstroemia uva-ursi</i>	+	1	+	1	+	+
Turneraceae	<i>Turnera ulmifolia</i>					r	
Umbelliferae	<i>Centella asiatica</i>					r	
Verbenaceae	<i>Lantana camara</i>		+	r	+	1	3
	<i>Stachytarpheta jamaicensis</i>		r		+	+	
	<i>Vitex ovata</i>	r					

The only evidence of feral axis deer in the study area was in the form of feces in the weedy grassland (community C) mauka of 'Alau. Residents of Kalaupapa maintained that deer activity on the peninsula is primarily confined to the area of Kalaupapa settlement.

One of two management procedures is recommended regarding feral animals. Cattle and horses appear to constitute the main herbivore pressure on the spray zone vegetation. It is presently uncertain whether cattle will be reintroduced to the peninsula. If cattle are not reintroduced, then simply confining the small group of feral horses to fenced pasture land near the settlement should alleviate grazing and trampling of the native coastal vegetation. If horses and cattle are thus eliminated from the study area, sufficient management would be provided by periodic monitoring (e.g., every four months) for evidence of feral axis deer. This monitoring could be done by either Kalaupapa Park personnel, NPS personnel from elsewhere in Hawaii, or a biologist contracted by CPSU-UH.

A second management procedure should be followed if the feral horses are not confined or if cattle are reintroduced to Kalaupapa. To help assess the actual impact of these feral herbivores on spray zone vegetation, several experimental exclosures should be set up and monitored. The primary site would be the *Sesuvium*-dominated association on deep sand just northwest of Kaupikiawa (Fig. 3), including the adjacent (just mauka) *Cynodon/Sesuvium* association, and perhaps the adjacent *Cynodon/Euphorbia degeneri/Fimbristylis* association at the north end of that sandy area (Fig. 4). The size of this exclosure should be about 250 m².

A second exclosure about 100 m² in area should be erected in the *Heliotropium anomalum/Euphorbia degeneri* association in the native sandy strand community just west of Kahio benchmark. The lower stature of vegetation outside the fence around the northeast end of the airstrip indicates probable grazing pressure in this area (Fig. 5).

To determine whether grazing might have a positive effect on native vegetation (by checking the growth of alien grasses), a third exclosure should be set up in the *Digitaria/Cynodon* association southwest of Kaupikiawa, where the coast road turns mauka (Fig. 3). The fate of remnant natives such as *Fimbristylis*,

Euphorbia degeneri, and *Sida* could be monitored in this 100 m² exclosure.

The exclosures should be designed to exclude horses, cattle, and axis deer. Fencing 2.5 m high is recommended, either five strands of barbed wire at 0.5 m intervals or hog wire. The exclosures could be erected and maintained by Kalaupapa Park personnel, with assistance regarding placement and dimensions from a botanist on the NPS Hawaii staff or contracted by CPSU-UH. Monitoring of vegetation within and outside the exclosures should be carried out by such a botanist at four- to six-month intervals.

If exclosures are found to favor the growth, vigor, and competitiveness of native species, fencing of larger areas of the spray zone should be considered. The population of *Tetramolopium rockii* var. *rockii* (endemic to north Molokai) (perhaps 500 m² in area) just above the coastal cliffs south of 'Alau and north of the concrete remains of the barge-loading boom, would be a prime candidate for fencing (Fig. 3). The Park's 1980 Management Plan suggests that fencing may be advisable to protect natural features. It also notes that biological communities on the peninsula's windward coast may require special protective measures. Because feral herbivores contain the growth of undesirable vegetation along the Kalawao road, fencing of the entire peninsula (e.g., at Kalawao road) is probably an unacceptable alternative.

Control of Alien Species

The dominance of alien plants along roads through the study area indicates that disturbance favors aliens over native species. This is particularly apparent on the least-used vehicle tracks, such as turnoffs to the caves south of Kaupikiawa. There introduced *Cynodon* clearly displaces the native *Fimbristylis*.

The distribution of the largely native *Fimbristylis* raised clayey spray zone community within the *Cynodon/Digitaria* alien raised spray zone community suggests a potential means of controlling alien species. South of Kaupikiawa, the *Fimbristylis* community is confined to narrow strips in the path of the most intense spray from indentations in the coastline. Since high concentrations of salt may favor native vegetation, experimental salt water applications to the surrounding alien grassland might return it to native dominance.

Test plots should be designed to evaluate the optimal time for treatment, minimum number of treatments necessary, and build up of salt. A possible method would be for Kalaupapa Park personnel to fill a clean oil drum halfway with salt water at an easily accessible beach, such as the one north of Kalaemilo. They could then truck the drum to the test site and spray the salt water from the perimeter of the test plots with an Indian fire pump (portable five-gallon pump). Six test plots, each 9 m², could be located (Fig. 3) and staked out by a botanist hired by NPS. For an initial three-month period, three plots could receive one five-gallon application per week, and the other three plots a two-gallon application per week. Then, after field assessment by the botanist, the method could be modified for further testing. Consideration of the effectiveness and economics of this method of weed control should precede its wider implementation. The 1980 Management Plan recognizes that special methods to control or remove alien species may be required in this study area.

Since the disturbance of roads and trampling adversely impacts native vegetation, it is clear that minimal human impact is optimal for the spray zone vegetation. As many residents of Kalaupapa remarked, the relatively intact nature of the native windward spray zone vegetation is largely due to the residents' lack of contact with that area. This bodes well for the future of the spray zone vegetation, so long as current measures of visitor control are in effect. However, after the Kalaupapa patients have lived out their lives, and a greater influx of visitors is planned for, serious consideration must be given to human impact on the native spray zone vegetation. The 1980 Management Plan notes that restrictions on the use of this area may be necessary.

Conclusion

In contrast to most coastal areas of the State, the Kalaupapa windward spray zone contains an extraordinarily diverse, extensive, and intact native flora. Several plant species have quite restricted distributions (e.g., *Tetramolopium rockii* var. *rockii*, endemic to north Moloka'i). Most importantly, the northeast coast of Kalaupapa supports a great diversity of habitats (e.g., dune, rocky strand, sea cliff) with a parallel diversity of native plant associations, too localized to be adequately mapped in this study. This ecological diversity within a single 3.5 km (2 mi.)

stretch of coast constitutes a biological treasure well worth preserving. Its designation as National Park and its remarkably intact present condition argue for its proper maintenance.

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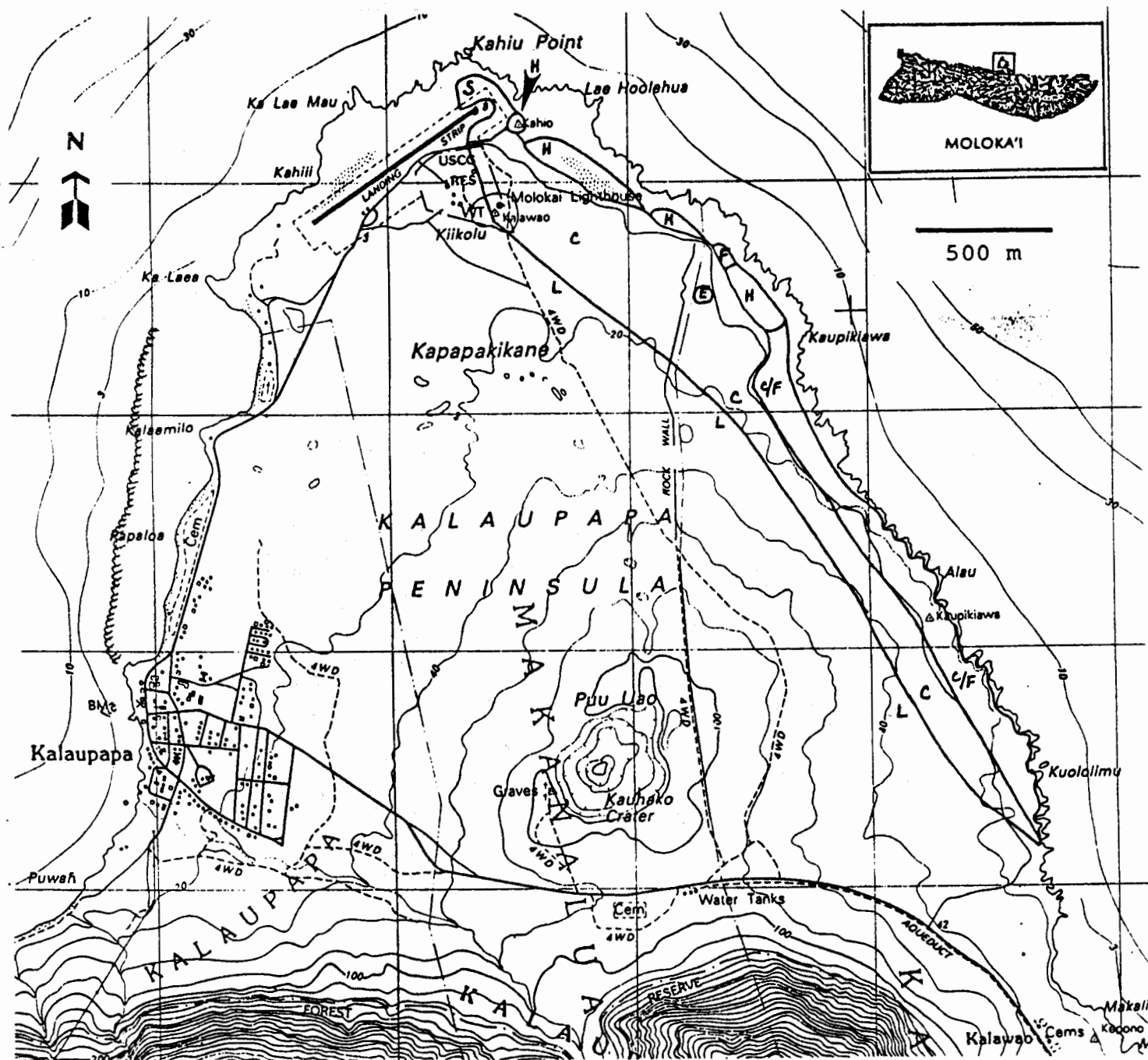


Fig. 1

Vegetation map of northeast coastal spray zone of Kalaupapa National Historical Park. Mapped on 1983 USGS East Moloka'i 1:25,000 topographic map. C/F refers to occurrence of community F within matrix of community C. Plant communities are as follows:

- H *Heliotropium anomalum*/*Scaevola taccada*/*Cynodon dactylon* native sandy strand spray zone (Figs. 2,3)
- S *Scaevola taccada*/*Fimbristylis pycnocephala* native protected rocky strand
- F *Fimbristylis pycnocephala* raised clayey spray zone (Fig. 4)
- E *Euphorbia celastroides* raised basalt domes
- C *Cynodon dactylon*/*Digitaria adscendens* alien raised and subcoastal spray zone (Fig. 5)
- L *Lantana camara*/*Schinus terebinthifolius* alien raised coastal scrub

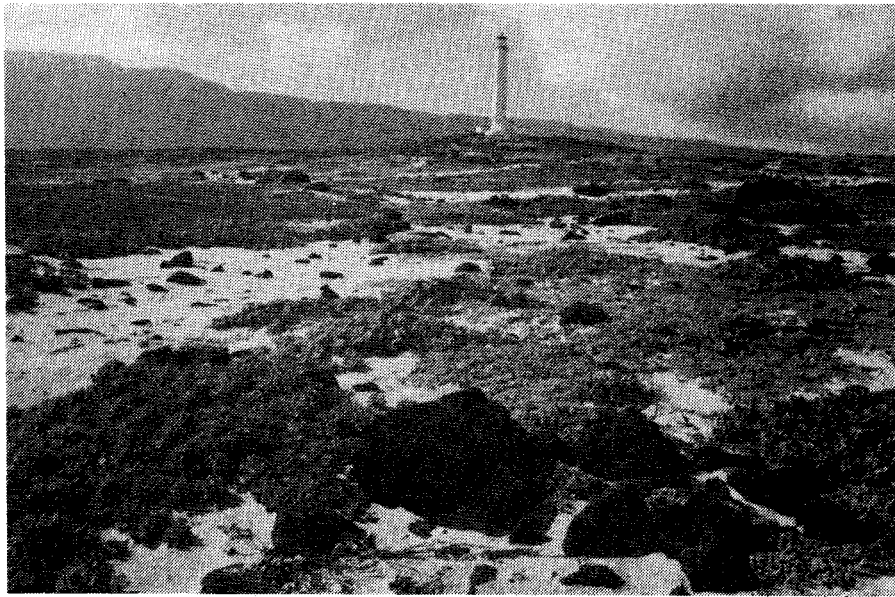


Fig. 2

Native sandy strand spray zone with basalt outcrops (community H) southeast of Kahio benchmark. In foreground, *Heliotropium anomalum*/*Scaevola taccada*/*Euphorbia degeneri* association. In middle distance at left, *Scaevola taccada*/*Cynodon dactylon* association. In far distance below vehicle, *Cynodon dactylon*/*Digitaria adscendens*/*Sida fallax* association (community C). Along ridgeline left of lighthouse, *Lantana camara*// *Schinus terebinthifolius* association (community L).

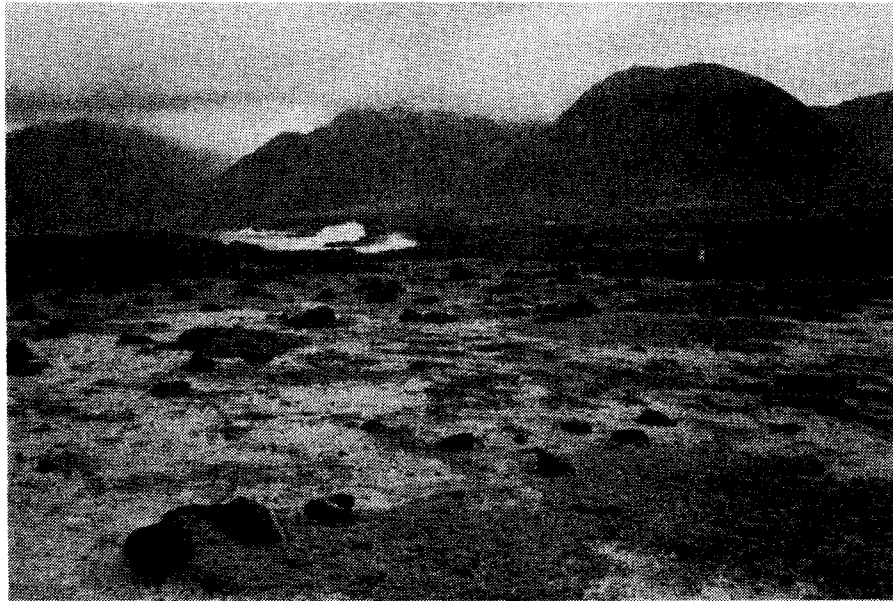


Fig. 3

Native sandy strand spray zone with basalt outcrops (community H) north-northwest of Kaupikiawa. In right foreground, *Heliotropium anomalum*. In middle distance, *Sesuvium portulacastrum* association on deep sand, disturbed by feral horses and suggested for first exclosure. To right of human figure, *Cynodon dactylon*/*Sesuvium portulacastrum* association, also part of first exclosure. Behind human figure, *Cynodon dactylon*/*Digitaria adscendens* association (community C), suggested for third exclosure. At point this side of farthest point along peninsula, *Fimbristylis pycnocephala*/*Digitaria adscendens*/*Tetramolopium rockii* association (community F), suggested for a later exclosure. In makai background, *Cynodon dactylon*/*Fimbristylis pycnocephala*/*Digitaria adscendens* association (C/F community matrix), suggested for experimental saltwater application plots.

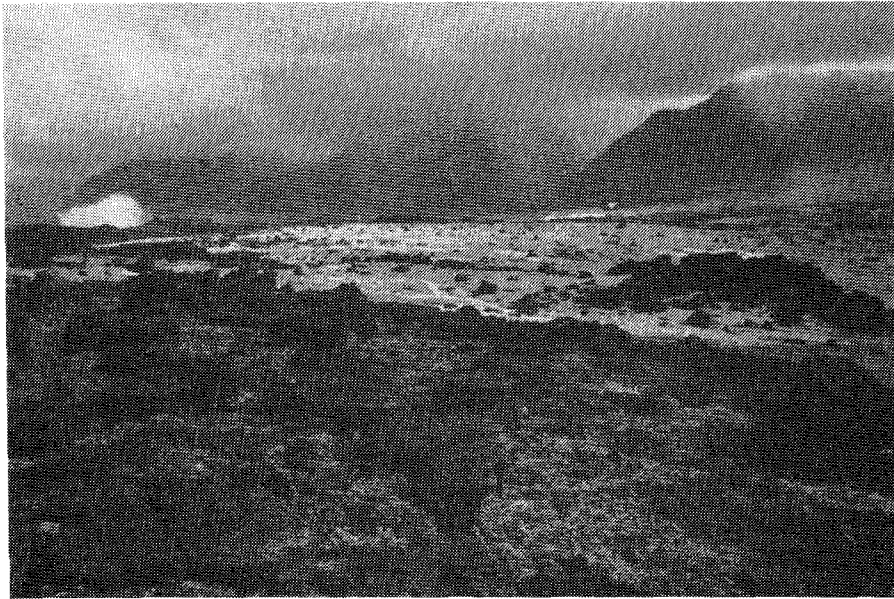


Fig. 4

Coastal spray zone on basalt imbedded in clayey soil (community F) north-northwest of Kaupikiawa. In foreground, *Fimbristylis pycnocephala*/*Sida fallax*/*Euphorbia degeneri* association, suggested as extension of first exclosure. In middle distance, *Heliotropium anomalum* on sand (community H). In far distance left of center, *Sesuvium portulacastrum* association on deep sand, also part of first exclosure. In far distance at center, *Cynodon dactylon*/*Sesuvium portulacastrum* association, also included in first exclosure. In middle to far distance at right, *Cynodon dactylon*/*Digitaria adscendens* alien subcoastal community (community C).

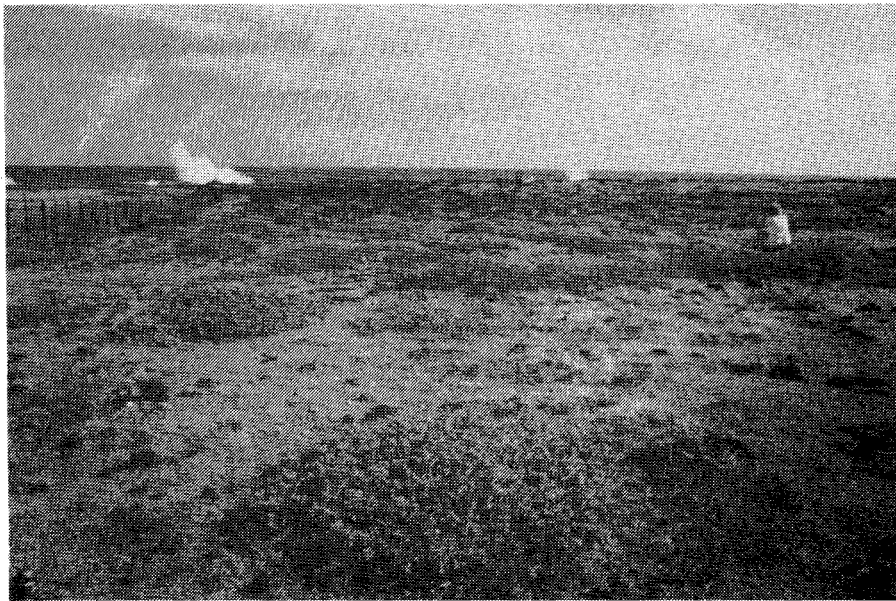


Fig. 5

Alien subcoastal spray zone on clayey soil with imbedded basalt (community C), just southwest of Kahio benchmark. In foreground and middle distance, *Cynodon dactylon*/*Digitaria adscendens*/*Sida fallax* association with localized *Wikstroemia uva-ursi*. In far distance right of center, *Heliotropium anomalum*/*Euphorbia degeneri* association on sand (community H), suggested for second exclosure. In far distance beyond fence at left, *Scaevola taccada*/*Sida fallax*/*Cynodon dactylon* association (community S) alongside airstrip.

Appendix

Plant Species of Kalaupapa Spray Zone

Lichens

Physiaceae

Buellia sp.

Indigenous

Common on basalt boulders throughout study area, except very close to shoreline.

Teloschistaceae

Caloplaca sp.

Indigenous

Common on basalt boulders throughout study area, except very close to shoreline.

Ferns and Fern Allies

Aspidiaceae

Cyrtomium falcatum (Langsd. & Fisch.) Presl
ka'ape'ape

Historic introduction

Uncommon, protected by rocks in spray zone above coastal cliffs.

Psilotaceae (Whisk Fern Family)

Psilotum nudum (L.) Beauv.
moa, pipi

Indigenous

Rare, between basalt boulders in interior weedy grassland. Used for tea and leis; spores used for talcum.

Flowering Plants

MONOCOTYLEDONES

Cyperaceae (Sedge Family)

Cyperus javanicus Houtt.

Indigenous

'ahu'awa, 'ehu'awa, marsh cypress

Rare, between basalt boulders in protected rocky strand near airstrip. Stem fiber used to strain 'awa, and as fiber for rope.

Fimbristylis pycnocephala Hbd.

Indigenous

Abundant on basalt or clayey substrate in spray zone, especially in most direct path of salt spray above coastal cliffs (Fig. 4). Common on sandy inner strand. Occasional in weedy interior grassland, where displaced by *Cynodon* and *Digitaria*.

Gramineae (Grass Family)

Cynodon dactylon (L.) Pers.

Historic introduction

Bermuda grass, manienie, mahiki

Common in less rocky areas of spray zone. Especially abundant on sandy flats of inner strand. Most widespread in weedy interior grassland. Used for lawns.

Digitaria adscendens (HBK.) Henr.

Historic introduction

Henry's crabgrass

Common in interior weedy grassland and spray zone above coastal cliffs on clayey soil. Used for lawns.

Panicum maximum Jacq.

Historic introduction

Guinea grass

Uncommon in interior weedy grassland, protected by ancient rock walls. Heavy infestations could disturb archaeological sites. Used for ground cover and forage in pastures.

Panicum nubigenum Kunth

Endemic

Locally common on clayey soil and imbedded basalt in spray zone above coastal cliffs. Uncommon on sandy strand.

Setaria glauca (L.) Beauv.

Historic introduction

yellow foxtail, yellow bristlegrass

Rare, protected by boulders in protected rocky strand near airstrip.

Gramineae (Grass Family) (Cont'd)

Sporobolus indicus (L.) R. Br.
West Indian dropseed

Historic introduction

Rare, protected by boulders in interior weedy grassland. Declared noxious by Hawai'i Department of Agriculture (HDOA).

Sporobolus virginicus (L.) Kunth

Indigenous

beach dropseed, seashore rushgrass, 'aki'aki, manienie-maoli, manienie-'aki'aki

Locally common on sandy flats of inner strand in spray zone.

Tricachne insularis (L.) Nees
sourgrass, West Indian sourgrass

Historic introduction

Uncommon, protected by ancient rock walls in interior grassland. Declared noxious by HDOA.

DICOTYLEDONES

Aizoaceae (Carpetweed Family)

Sesuvium portulacastrum (L.) L.
'akulikuli, sea purslane

Indigenous

Widespread along coastline on sand, clayey, and basalt substrates. Locally common on sandy strand. Subject to trampling damage on deep sand at Kaupikiawa (Fig. 3).

Tetragonia etragonoides (Pallas) Ktze.
New Zealand spinach

Historic introduction

Rare in sandy depressions at Kaupikiawa. Used for greens.

Anacardiaceae (Mango Family)

Schinus terebinthifolius Raddi

Historic introduction

Christmas berry, Brazilian peppertree, nani-o-Hilo, wilelaiki

Occasional in weedy interior grassland, protected by boulders. Abundant in weedy interior scrub. Severely deformed by wind and spray, typically <0.5 m tall. Red fruit clusters used in leis and wreaths. Heavy infestations could disturb archaeological sites. Declared noxious by HDOA.

Boraginaceae (Heliotrope Family)

- Heliotropium amplexicaule* Vahl
heliotrope
Historic introduction
Uncommon in weedy interior grassland. Used as ornamental.
- Heliotropium anomalum* var. *argenteum* Gray
hinahina-ku-kahakai
Indigenous
Widespread along coastline on sandy and clayey substrates. Locally abundant on sandy strand (Figs. 2, 3). Used for leis and for tea.
- Heliotropium curassavicum* L.
nena, kipukai, hinahina, seaside heliotrope
Indigenous
Rare on shallow sandy strand. Used for tea.
- Tournefortia argentea* L. f.
tree heliotrope, velvet leaf
Historic introduction
Uncommon on sand at outer limit of strand vegetation. Used for shade, greens.

Chenopodiaceae (Goosefoot Family)

- Atriplex semibaccata* R. Br.
Australian salt bush, semibaccate salt bush
Historic introduction
Rare, between boulders near airstrip. Used for forage.

Compositae (Sunflower Family)

- Eclipta alba* (L.) Hassk.
false daisy
Historic introduction
Rare in weedy interior grassland. Used medicinally in the Orient: externally for skin diseases and hair, internally as a purgative. Also used for greens.
- Emilia javanica* (Burm. f.) C. B. Robins.
red pua-lele
Historic introduction
Occasional in weedy interior grassland. Leaves eaten in Malaysia.
- Erigeron canadensis* L.
Canada fleabane, horseweed, ilioha, lani-wela
Historic introduction
Uncommon in weedy interior grassland. Oil used as insect repellent.
- Pluchea indica* (L.) Less.
Indian pluchea
Historic introduction
Occasional in crevices between basalt rocks of raised domes near Kaupikiawa. Used medicinally: externally as a poultice, internally for fever. Also used for greens. Declared noxious by HDOA.

Compositae (Sunflower Family) (Cont'd)

Reichardia picroides (L.) Roth
picridium

Historic introduction

Occasional throughout study area.

Sonchus oleraceus L.
sow thistle, pua-lele

Historic introduction

Uncommon on clayey and rock substrates away from most intense salt spray. Leaves and roots used medicinally for indigestion and as a tonic. Also used in Europe for greens and fodder.

Synedrella nodiflora (L.) Gaertn.
synedrella

Historic introduction

Rare in interior weedy grassland. Used medicinally in Malaya for poultices.

Tetramolopium rockii Sherff var. *rockii* S

Endemic

Locally common on clayey and imbedded basalt substrate above coastal cliffs in path of intense salt spray. Limited to coast south of 'Alau. Endemic to north Moloka'i.

Tridax procumbens L.
coat buttons, hierba del torro

Historic introduction

Rare in weedy interior grassland near Moloka'i Lighthouse. Leaves used in Central America as an insecticide.

Xanthium saccharatum Wallr.
cocklebur, kikania

Historic introduction

Uncommon, protected by boulders in weedy interior grassland. Declared noxious by HDOA.

Convolvulaceae (Morning-glory Family)

Cuscuta sandwicensis Choisy
kauna'oa, kauna'oa-lei, dodder

Endemic

Rare, on sandy, clayey ground near airstrip. Used for leis. Declared noxious by HDOA.

Ipomoea brasiliensis (L.) Sweet
pohuehue, beach morning glory

Indigenous

Widespread, but occasional on sandy and clayey substrates. Locally common at outer edge of sandy strand. Extends into weedy interior grassland on sandy ground below Moloka'i Lighthouse. Many recently dead vines apparent. Roots and stems used as famine food, although poisonous in quantity. Vines used in fishing; seeds used medicinally as a cathartic.

Ipomoea congesta R. Br.
koali-'awahia, koali-'awa, morning glory

Indigenous

Uncommon in protected depressions of weedy interior grassland near Moloka'i Lighthouse. Stems and roots used medicinally externally for bruises and broken bones. Vines used as swings.

Convolvulaceae (Morning-glory Family) (Cont'd)

Jacquemontia sandwicensis Gray
pa'u-o-Hi'i-'aka

Endemic

Uncommon on clayey protected strand near airstrip and in weedy interior grassland.

Cruciferae (Mustard Family)

Coronopus didymus (L.) Sm.
swine cress, wartcress

Historic introduction

Uncommon in weedy interior grassland.

Lobularia maritima (L.) Desv.
sweet alyssum

Historic introduction

Uncommon in weedy interior grassland. Used as an ornamental. New record for Moloka'i.

Cucurbitaceae (Gourd, Squash Family)

Momordica charantia L.
balsam apple, bitter melon

Historic introduction

Uncommon in weedy interior grassland, protected by boulders or ancient rock walls. Green fruit eaten along with young shoots and leaves. Declared noxious by HDOA.

Euphorbiaceae (Spurge Family)

Euphorbia celastroides var. *amplectans* (Sherff) Deg. & Deg.

Endemic

Locally common growing prostrate on raised basalt domes northwest of Kaupikiawa.

Euphorbia degeneri Sherff
koko, 'akoko, beach spurge

Endemic

Widespread in spray zone, on sandy, rocky, and clayey substrates. Most common on sand.

Euphorbia hirta L.
garden spurge, hairy spurge, old blood, golondina, koko-kahiki

Historic introduction

Uncommon in weedy interior grassland.

Phyllanthus debilis Klein ex Willd.
phyllanthus weed

Historic introduction

Uncommon in weedy interior grassland and on clayey protected strand near airstrip.

Goodeniaceae (Naupaka Family)

Scaevola taccada (Gaertn.) Roxb.
naupaka-kahakai, huahekili

Indigenous

Common on rocky and sandy strand (Fig. 2). Locally abundant on rocks at outer limit of strand vegetation. Locally common on raised basalt domes near Kaupikiawa. Leaves used medicinally to treat indigestion, and used for poultices. Leaves cooked for greens.

Leguminosae (Pea Family)

Acacia farnesiana (L.) Willd.
klu, kolu, aroma, popinac

Historic introduction

Rare in weedy interior grassland. Flowers yield perfume, stems produce a glue. Declared noxious by HDOA. Heavy infestations could disturb archaeological sites.

Cassia leschenaultiana DC.
partridge pea, lauki

Historic introduction

Rare in weedy interior grassland. Roots used medicinally in India for stomach trouble.

Desmodium tortuosum (Sw.) DC.
Florida beggarweed

Historic introduction

Uncommon in weedy interior grassland. Used as fodder.

Desmodium triflorum (L.) DC.
three-flowered beggarweed

Historic introduction

Common in weedy interior grassland. Used as fodder.

Mimosa pudica var. *unijuga* (Duchass. & Walp.) Griseb.
sensitive plant, pua-hilahila, hilahila

Historic introduction

Uncommon in weedy interior grassland.

Phaseolus lathyroides L.
cow pea, wild bush bean

Historic introduction

Rare in weedy interior grassland. Used for fodder.

Prosopis pallida (Humb. & Bonpl. ex Willd.) HBK.
kiawe, algaroba, mesquite

Historic introduction

Rare, protected by boulders in weedy interior grassland. Pods used for fodder, wood for fuel, flowers for honey, trees for reforestation. This species could disturb archaeological sites.

Malvaceae (Hibiscus Family)

Abutilon grandifolium (Willd.) Sweet
hairy abutilon, flowering maple, ma'o

Historic introduction

Uncommon in weedy interior grassland, protected by boulders and ancient rock walls.
Declared noxious by HDOA.

Malvastrum coromandelianum (L.) Garcke
false mallow

Historic introduction

Uncommon in weedy interior grassland. Used for poultices; some value as fodder; used for brooms in West Indies.

Sida fallax Walp.
'ilima

Indigenous

Widespread throughout study area, extending inland into weedy interior scrub. Locally abundant in protected rocky strand with clayey soil near airstrip. Used for leis; some forms used medicinally.

Myrtaceae (Myrtle Family)

Psidium guajava L.
guava, kuawa

Historic introduction

Common in weedy interior scrub, extending occasionally into weedy interior grassland. Severely deformed by wind and spray, typically <0.5 m tall. Fruit used for food; leaf buds used as an astringent tea. Declared noxious by HDOA.

Nyctaginaceae (Four o'clock Family)

Boerhavia diffusa L.
alena

Indigenous

Occasional on all substrates, from inner strand to weedy interior grassland. Roots used medicinally. Used as food in Western Pacific.

Oxalidaceae (Wood Sorrel Family)

Oxalis corniculata L.
lady's sorrel, yellow wood sorrel, 'ihi, 'ihi-'ai, 'ihi-'awa

Polynesian introduction

Occasional in weedy interior grassland and protected rocky strand with clayey soil near airstrip. Leaves used medicinally.

Plantaginaceae (Plantain Family)

Plantago lanceolata L.
narrow-leaved plantain, buckthorn plantain

Historic introduction

Occasional in weedy interior grassland and protected rocky strand with clayey soil near airstrip. Declared noxious by HDOA.

Portulacaceae (Purslane Family)

Portulaca lutea Soland. ex Forst. f.
'ihi, native yellow portulaca

Indigenous

Uncommon on sandy and clayey substrates in native-dominated spray zone communities.

Portulaca pilosa L.
'ihi

Historic introduction

Common on sandy and clayey substrates throughout study area.

Primulaceae (Primrose Family)

Anagallis arvensis L.
scarlet pimpernel, poor man's weatherglass, shepherd's weatherglass
Occasional in weedy interior grassland.

Historic introduction

Solanaceae (Nightshade Family)

Lycium sandwicense Gray
'ohelo-kai, 'ae'ae, 'akulikuli-'ae'ae, 'akulikuli-'ohelo

Indigenous

Locally common among basalt boulders in spray zone, near airstrip and north of Kaupikiawa.

Solanum sodomaeum L.
apple of Sodom, yellow-fruited popolo, thorny popolo, popolo-kikania

Historic introduction

Uncommon in weedy interior grassland, protected by ancient rock walls. In Africa, leaves and fruit used medicinally for skin disease, fruit for toothache, and root for colic.

Sterculiaceae (Cocoa Family)

Waltheria americana L.
hi'a-loa, 'uha-loa, kanaka-loa

Indigenous

Uncommon in weedy interior grassland and in protected strand near airstrip. Plants not vigorous. Juice of root used medicinally as pain reliever, e.g., sore throats.

Thymelaeaceae ('Akia Family)

Wikstroemia uva-ursi Gray
'akia

Endemic

Widespread throughout study area, extending into weedy interior scrub. Locally abundant in protected strand east of airstrip. Hummock-like growth form due to wind and spray (Fig. 5).

Turneraceae (Turnera Family)

Turnera ulmifolia L.
yellow alder, marilopez

Historic introduction

Rare in weedy interior grassland.

Umbelliferae (Carrot Family)

Centella asiatica (L.) Urban
Asiatic pennywort, pohekula

Historic introduction

Uncommon in weedy interior grassland. Used as forage. Used in Asia for colds and skin and circulatory diseases. Also used for greens.

Verbenaceae (Verbena Family)

Lantana camara L.
lantana, lakana, mikinolia-hihiu

Historic introduction

Widespread, protected by boulders, present in all communities except sandy strand. Locally common in weedy interior grassland; abundant in weedy interior scrub. Severely deformed by wind and spray; typically <0.3 m in height. Used as an ornamental. Declared noxious by HDOA.

Stachytarpheta jamaicensis (L.) Vahl
Jamaica vervain, owi, oi

Historic introduction

Uncommon in weedy interior grassland. Used medicinally in Latin America. Declared noxious by HDOA.

Vitex ovata Thunb.
pohinahina, polinalina, kolokolo-kahakai, beach vitex

Indigenous

Uncommon, but forming localized dense stands on sand dunes of inner strand.