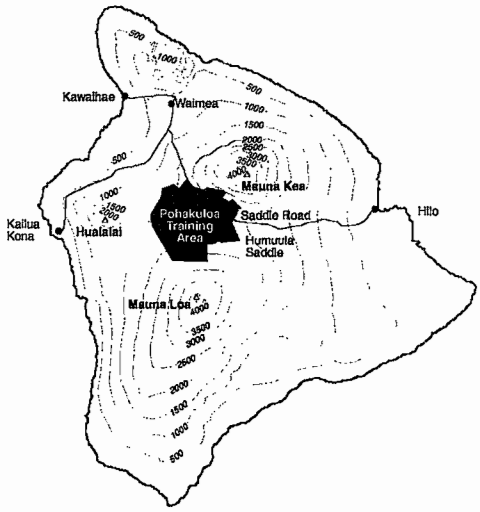
PLANT COMMUNITIES OF POHAKULOA TRAINING AREA

Hawaii



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1997

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ACKNOWLEDGMENTS

We wish to thank the commanding officers of Pohakuloa Training Area, Hawaii (PTA), and the men and women under their direction, for their patience and support during the field work for this study.

We give special thanks to Trisha Tierney who assisted in much of the field surveys, delineations of vegetation types, and various drafts of the plant community map. Thanks to Tracy Wager and Eric Galyon for the excellent book layout and patience during revisions, additions, and changes. Jerry Steenson produced many of the early drafts of the map. Thanks to Gary Senseman and the team at the CEMML GIS and Remote Sensing Laboratory for producing the current version contained in this book. The following LCTA crew members spent long hours in field collecting the data which yielded much of the plant community information: Paul Block, Brendan Close, Kerry Hawk, Eamon O'Regan, Carlo Popolizio, Keith Schulz, and Dawn Strom. Thank you for your dedication.

Funding was from the Department of Defense LEGACY Resource Management Program, U.S. Army Integrated Training Area Management Program (ITAM), Land Condition-Trend Analysis Program (LCTA), U.S. Army Garrison-Hawaii, Pacific Ocean Division of the U.S. Army Corps of Engineers, and the U.S.D.A. Forest Service Rocky Mountain Forest and Range Experiment Station. Because this work was supported by federal resources, we followed the government style of not including diacritical marks in Hawaiian words. Place names and locations were taken from the installation map Sheet PTA, Series W7315, Edition 5-29, Pohakuloa Training Area.

Photographs of the communities were by the authors, Trisha Tierney, and Brendan Close.

This work is intended to be a "sister" volume to Rare Plants of Pohakuloa Training Area, Hawaii by the senior author; however, the reader will immediately notice that the introductory materials are very similar, up to the Flora section, between the two pieces. The duplication of information was intentional. The original remarks were drawn from papers and installation reports prepared by, or with the assistance of, Chris Bern.

1 Introduction

The U.S. Army is the principal user on over 10 million hectares of public land. In order to be better stewards of these lands and their natural resources, the Land Condition–Trend Analysis (LCTA) Program was designed to inventory and monitor the Army's lands. Primary objectives of the program are to assist the installations' natural resource managers in sustaining training lands needed to accomplish the military mission and to provide a standardized method of data collection, analyses, and reporting.

One of the major components of LCTA is a floristic inventory. An attempt is made to collect, identify, verify, and archive all the vascular plant taxa found on an installation. The gathering phase occurs during all growing seasons for several years to guarantee as thorough a collection as possible. The floristic inventory is used to document the occurrence of state or federally listed threatened or endangered species, compose species and ecological checklists, train personnel in plant identification, ensure thorough environmental documentation (environmental assessments and impact statements), and standardize nomenclature and taxonomic concepts for the installation.

Another major component of LCTA is the establishment of permanent field plots used to document the vegetational, edaphic, topographic, and disturbance characteristics of the installation (Diersing et al. 1992). Ground cover, aerial cover, woody plant density, slope length, slope gradient, substrate information, and disturbance estimates are collected at each plot. Two of the most important uses of the plot data are to delineate or describe plant communities and characterize endangered species habitat. Nearly 350 LCTA plots have been established at Pohakuloa Training Area (PTA).

Shaw (1997) has summarized the floristic inventory and rare plant survey data. Bern (1995) has consolidated and reported much of the LCTA plot information. The following is intended to briefly introduce the physical features of PTA, describe the ecological characteristics of each of the plant communities delineated on the vegetation map of the installation prepared by Castillo et al. (1997), and provide an ecological checklist for the various communities. Format follows a similar report for the Pinon Canyon Maneuver Site, Colorado (Shaw et al. 1989).

Location

PTA is situated near the center of the island of Hawaii, the largest, youngest, and southern-most island in the Hawaiian Archipelago (Figure 1). The 49,602–ha installation occupies most of a large plain or saddle formed by the convergence of three volcanoes (Figure 2). Mauna Kea (4205 m) lies to the northeast, Mauna Loa (4169 m) to the south, and Hualalai (2521 m) to the west.

Saddle Road (State Highway 200 or Kaumana Road) crosses the northern edge of the installation (Figure 3). Hilo is approximately 58 km to the east of PTA, and Kawaihae is 56 km to the northwest.

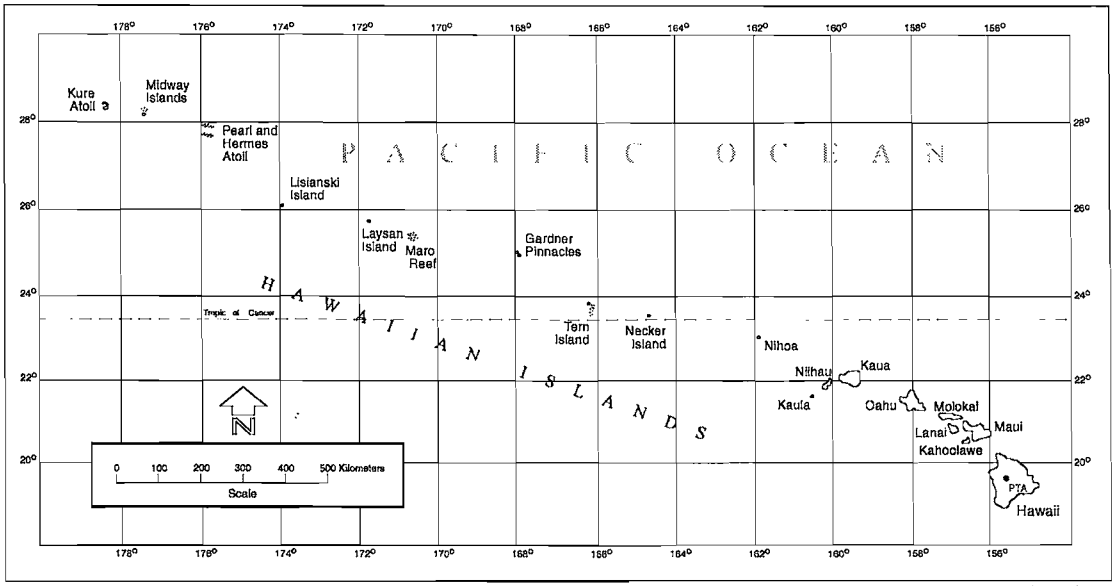


Figure1. The geographic location of Hawaii and its proximity to the other islands in the Hawaiian Archipelago (Wagner et al. 1990).

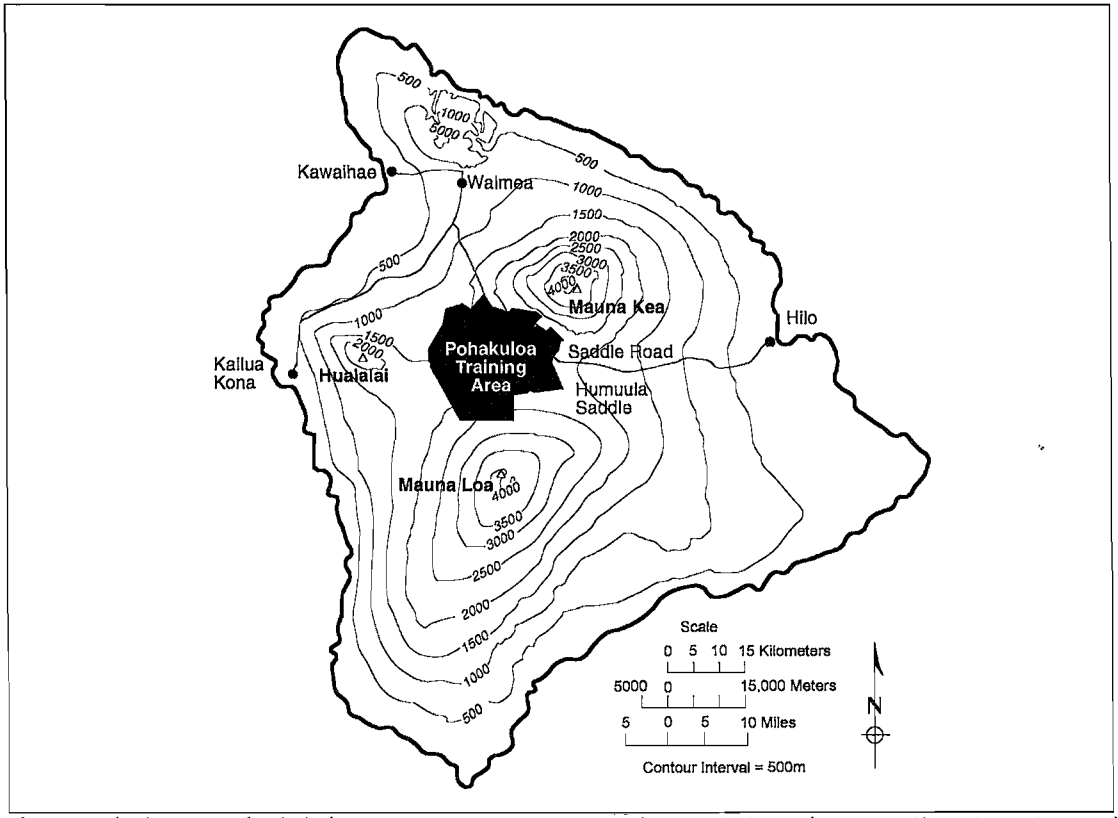


Figure 2. The location of Pohakuloa Training Area on Hawaii and its proximity to the Mauna Kea, Mauna Loa, and Hualalai volcanoes.

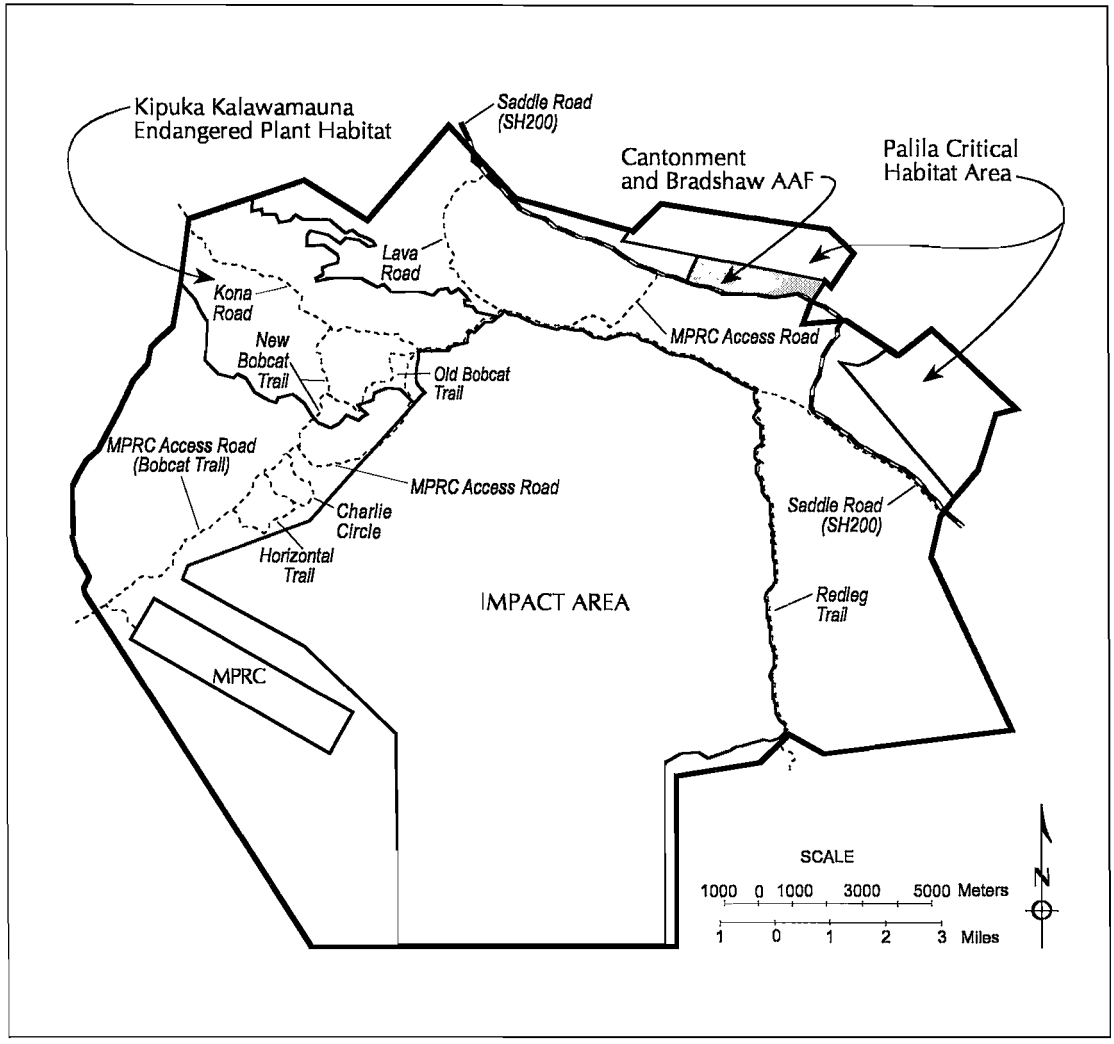


Figure 3. Major roads, trails, landmarks and training features on Pohakuloa Training Area, Hawaii.

Military Activities

Saddle Road was built in 1942 by the U.S. Army to provide access between Hilo on the east and Waimea on the north. Subsequently, Bradshaw Army Airfield and the cantonment area were built and became known the Saddle Training Area. In 1955 the installation was designated as a year-round training facility, now known as Pohakuloa Training Area.

The primary mission of PTA is to provide a combat training area for full-scale live firing and field training exercises. Military units that utilize the installation include the 25th Infantry Division (Light) at Schofield Barracks, Army National Guard, Army Reserves, 1st Expeditionary Brigade of the U.S. Marine Corps, and visiting allied troops. The U.S. Air Force and U.S. Navy also use the impact area for bombing practice.

Geology

Obviously, volcanic activities gave rise to the landscapes that comprise the area presently occupied by the installation. Mauna Kea substrates are restricted to the northern portion of the installation, and are made up of two series of flows, the Laupahoehoe and the Hamakua (Figure 4). The Laupahoehoe series formed during the Holocene, while the Hamakua series dates from the Pleistocene (MacDonald 1949). Cinder cones (puu), a predominant feature of the northern part of the installation, are remnants of the Hamakua series.

The majority of PTA is composed of Mauna Loa substrates (Figure 4) dating from the latter stages of the Pleistocene. Most of these depositions belong to the Kau series and represent part of the shield-building phase of the volcano (Stearns & MacDonald 1946, Langeheim & Clauge 1987). Five historical Mauna Loa flows occur on the installation (Figure 4).

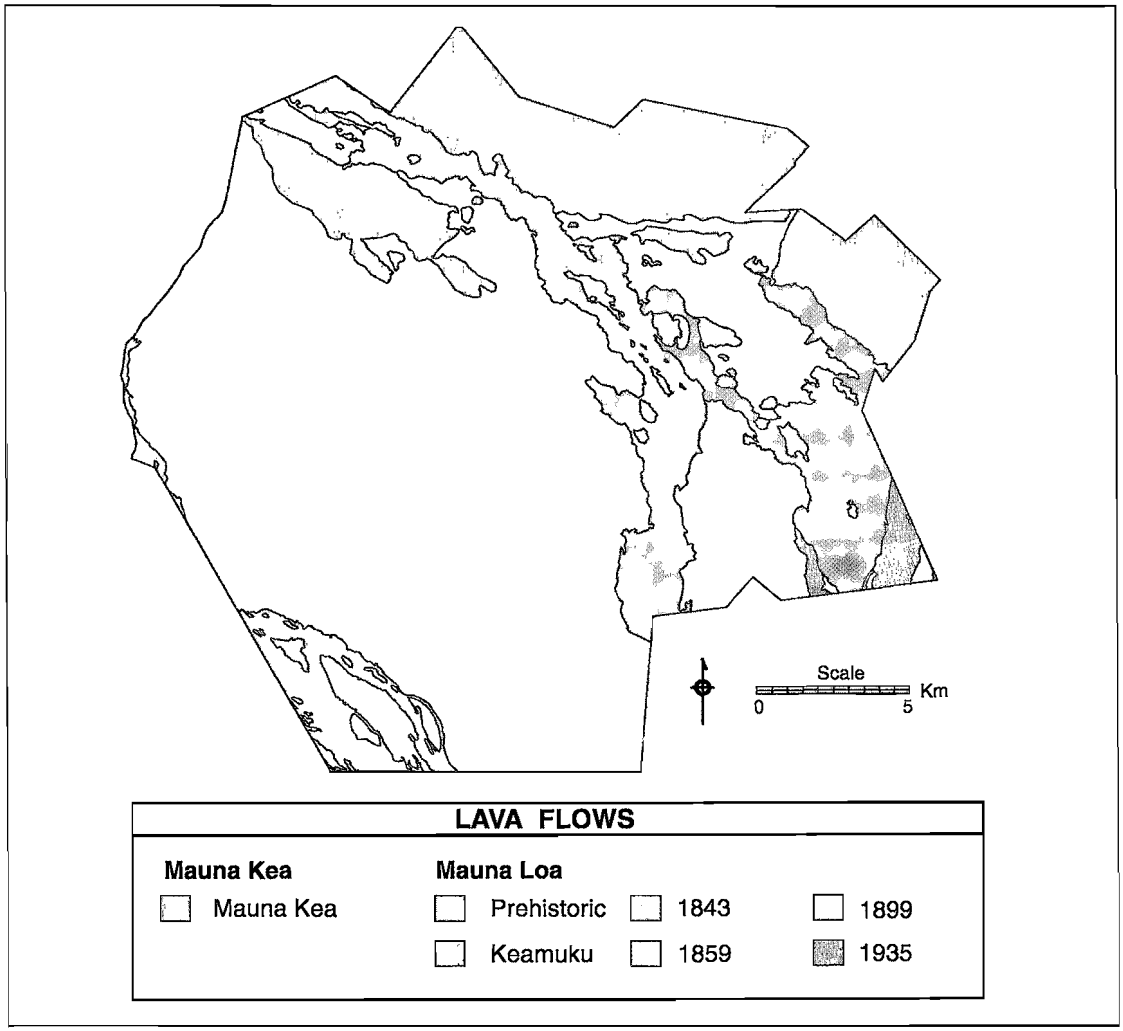


Figure 4. Distribution of prehistoric Mauna Kea and prehistoric and historic Mauna Loa lava flows on Pohakuloa Training Area, Hawaii (Wolfe and Morris 1996).

Soils

Soils are poorly developed on the installation due to the very recent (Pleistocene and Holocene) deposition of the majority of the substrates. Sato et al. (1973) has broadly classified the soils on PTA as lava flow associates. These associates are typically gently sloping to steep, excessively drained, and nearly barren lava flows. Ten such soil types have been designated on the installation (Figure 5); however, two lava types (pahoehoe and aa) cover over 80% of the area. The most highly developed soils occur on the older Mauna Kea substrates, which usually consist of a thin layer of soil, cinder, or ash deposits. Also, a small amount of eolian sands have accumulated on the installation.

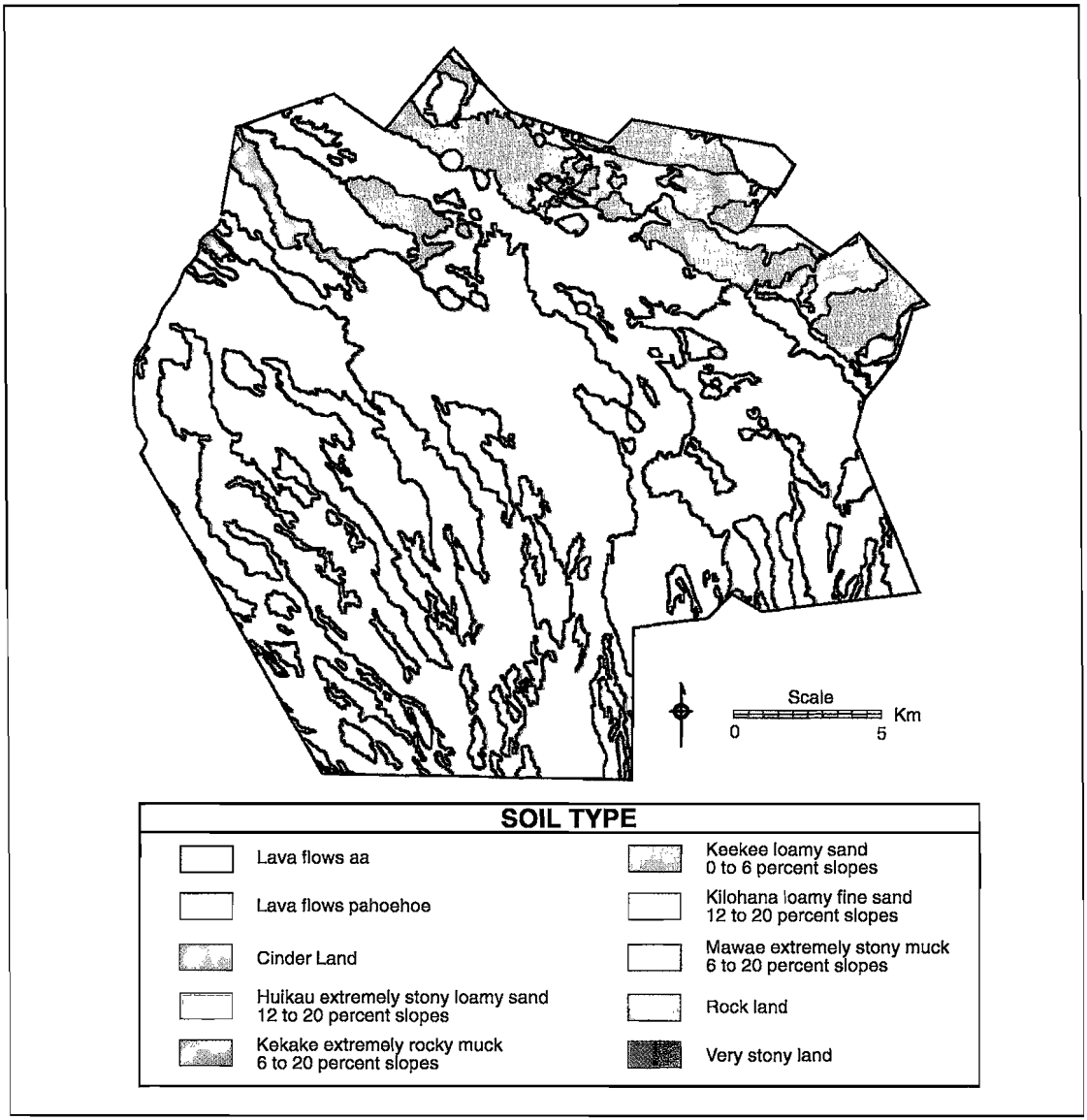


Figure 5. Distribution of soil types on Pohakuloa Training Area, Hawaii (Sato et al. 1973).

Topography

The topography of the installation is nearly flat to gently rolling. While the overall slope is about 6%, it varies widely across the area. Aspect is slightly west-north-west. The steepest areas are found in the northern part of the installation on the lower slopes of Mauna Kea and on the cinder cones (puu). The highest point (approximately 2713 m) is in the southeastern corner of the installation on the lower slopes of Mauna Loa. The lowest point is about 1265 m near the northwestern boundary (Figure 6).

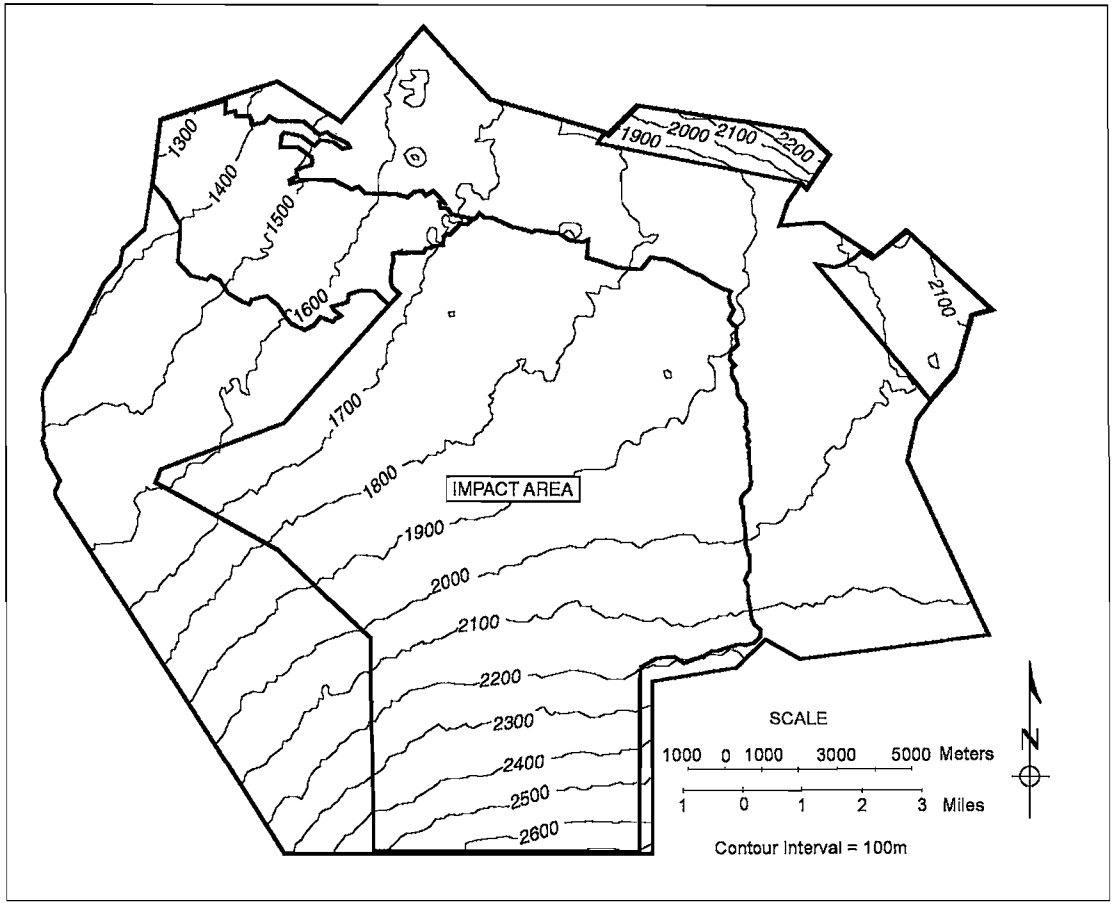


Figure 6. Topography of Pohakuloa Training Area, Hawaii.

Climate

The climate at PTA is classified as cool tropical (upper montane to alpine) (Loope and Scowcroft 1985). The 29-year average annual precipitation at Bradshaw Army Airfield (1862 m) on the northern edge of the installation is 37.4 cm. Most of the installation is above the thermal inversion layer, thus, it is not influenced by the tradewind-orographic rainfall regime. Moisture charac-

teristically carried by the summer easterly tradewinds is lost as precipitation with an increase in elevation and rarely reaches PTA. Highest monthly precipitation generally occurs in the winter months (Nov-Feb) in conjunction with Kona storms. Occasionally, moist air trapped below the inversion layer will rise into the saddle area in the late afternoon. Precipitation from condensation on vegetation can then occur and may even equal that from rainfall (Sato et al. 1973).

The average annual temperature is 12.8° C with little monthly fluctuation. Diurnal temperature variation is greater than seasonal variations. The growing season at PTA is almost year-round; however, adequate moisture for plant growth is limiting during June and July (Figure 7).

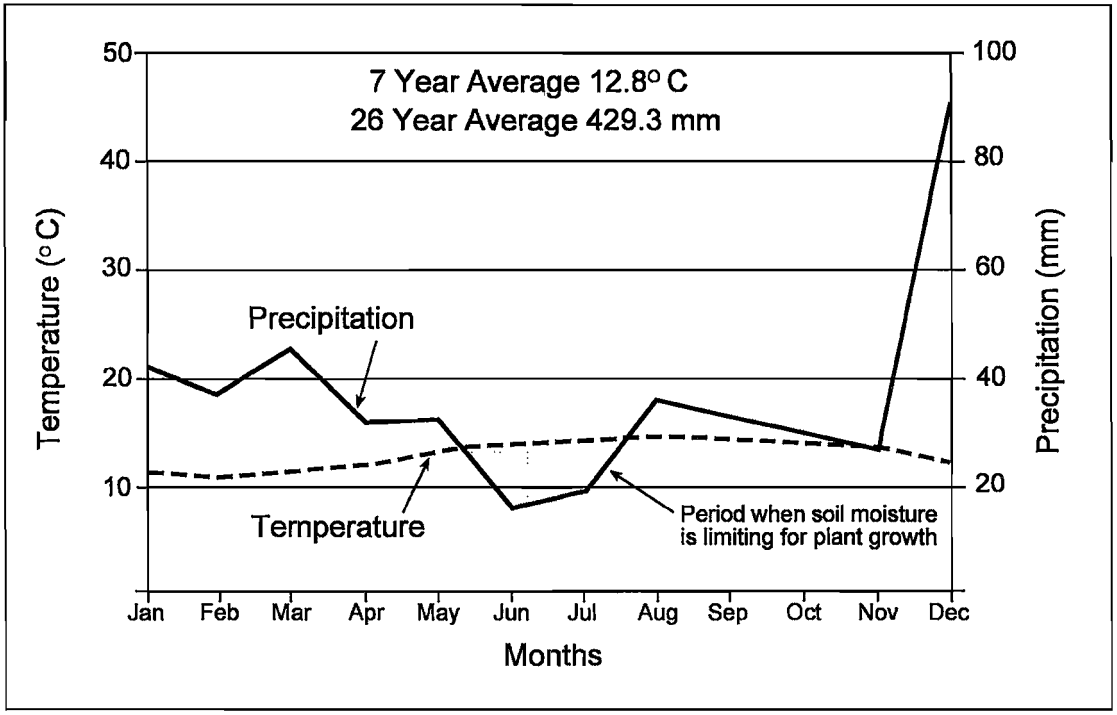


Figure 7. Climatic diagram from data taken at Bradshaw Army Airfield, Pohakuloa Training Area, Hawaii.

Flora

A vascular plant survey of PTA has been ongoing since November 1988. A total of 69 families, 190 genera, and 270 taxa have been collected from the installation and verified, and the list continues to increase as more botanical and natural resource surveys are conducted. Herbs (47%), grasses (16%), and shrubs (13%) are the major life forms. Most of the taxa are perennials (67%), while annuals and biennials constitute 25% and 8%, respectively. Approximately 38% of the plants found at PTA are endemic or indigenous to the Hawaiian Islands. Conversely, about 62% are naturalized or alien species. Wagner et al. (1990) was invaluable for identifying the flora.

Twenty-three rare plants have been verified from the installation (Table 1). Eleven taxa are Federally listed as endangered, one is classified as threatened, and eight taxa are listed as "species of concern." The species of concern classification corresponds to the previously-used Federal "cat-

egory 2 candidate species." Species of concern are plants that are becoming extinct in part of their range and need to be closely monitored for further declines. Additional threats to these taxa might prompt actions to list them as endangered or threatened. Three of the rare taxa do not have any classification. *Hesperocnide sandwicensis* was once proposed for listing as endangered but was found to be much more abundant than originally thought. It is included, however, because the species is restricted to the saddle region and should be monitored. *Portulaca villosa* is included because it is rare to find it growing at the elevation of PTA. *Tetramolopium diersingii* is a new species to science which should be considered for inclusion on the endangered species list because it is known only from three small populations on the installation. Previously this species was identified as *T. lepidotum* on posters and reports for PTA.

More information concerning the rare species' nomenclatural history, historical and current distribution, and threats can be found in Bruegmann et al. 1994, Bruegmann 1995, Canfield et al. 1994, Herbst et al. 1992a and 1992b, Herbst and Fay 1979, and Mehrhoff 1994 and the most current U.S. Fish and Wildlife Service Species List for Hawaii.

Wildfire, feral animals, and competition with alien plant species are the greatest threats to rare plant species on PTA (Table 1). Fire (whether caused by lightning, vulcanism, or human activities)

Table 1. List of rare plants documented to occur on Pohakuloa Training Area, Hawaii. Federal status is based on the current U.S. Fish and Wildlife Service listing (E=endangered; N=none, but known to be rare or restricted in distribution; S=species of concern; and T=threatened). Threats are based on potential (P) or observed impacts (T) to the rare plants on the installation (1=wildfire; 2=competition from alien plants; 3=browsing, grazing, or rooting by feral sheep, goats, and/or pigs; 4=habitat degradation; 5=military activities; 6=small numbers; and 7=dust).

Species	Status	Threats						
		1	2	3	4	5	6	7
Asplenium fragile var. *insulare*	E	P	-	T	-	-	P	-
Chamaesyce olowaluana	S	T	P	T	T	-	-	P
Eragrostis deflexa	S	-	T	-	-	-	-	-
Exocarpos gaudichaudii	S	P	-	-	P	-	P	-
Festuca hawaiiensis	S	-	P	-	-	-	P	-
Haplostachys haplostachya	E	T	T	T	P	P	-	P
Hedyotis coriacea	E	P	P	T	-	-	T	-
Hesperocnide sandwicensis	N	P	-	-	-	P	-	-
Melicope hawaiensis	S	P	-	P	P	-	-	-
Neraudia ovata	E	-	-	T	P	-	T	-
Portulaca sclerocarpa	E	-	-	P	-	-	T	-
Portulaca villosa	N	P	-	P	-	-	-	-
Schiedea pubescens	S	P	P	T	-	-	P	-
Silene hawaiiensis	T	P	P	T	-	P	-	P
Silene lanceolata	E	T	T	T	-	-	-	P
Solanum incompletum	E	P	-	T	-	-	T	-
Spermolepis hawaiiensis	E	P	-	P	-	P	-	-
Stenogyne angustifolia	E	T	T	T	-	T	-	-
Tetramolopium arenarium	E	T	T	-	-	-	T	-
T. consanguineum var. *leptophyllum*	S	-	-	-	-	T	-	-
T. diersingii	N	P	-	T	-	-	T	-
T. humile var. *sublaeve*	S	-	-	P	P	-	-	P
Zanthoxylum hawaiiense	E	P	-	T	P	-	-	-

not only impacts the plants, but can also alter the habitat that sustains the species' populations. For example, in July 1994 a wildfire was started by lightning on state lands downslope from and to the west of PTA. The fire moved upslope onto the installation and, in two days, consumed nearly two-thirds of the Kipuka Kalawamauna Endangered Plants Habitat. Populations of *Haplostachys haplostachya, Silene hawaiiensis, S. lanceolata, Stenogyne angustifolia,* and *Tetramolopium arenarium* were impacted negatively by the conflagration (Figure 8a). Luckily, no plant species was driven to extinction by the wildfire; although nearly half of the known individuals of *T. arenarium* were killed. Building and maintaining firebreaks, controlling fuel load along roads, and reducing the use of tracers and smoke/obscurants during dry periods can greatly reduce the risk and spread of wildfires.

Negative impacts resulting from the activities of feral sheep, goats, and pigs have a significant influence on the health, vigor, reproduction, and survival of many of the rare plant species found on the installation. Individuals or entire populations of *Chamaecyse olowaluana, Hedyotis coriacea, Neraudia ovata, Silene hawaiiensis, S. lanceolata, Solanum incompletum,* and *Zanthoxylum hawaiiense* have been destroyed by sheep and or goats (Figure 8b). Many of these rare plant species appear to be highly palatable and are sought by the animals, which also facilitates the dispersal of "alien" plant species around the installation. Pigs have been observed consuming the succulent taproot of *S. hawaiiensis* plants. Most damage by feral pigs, however, is caused by rooting, which disturbs the soil surface and allows alien species to invade the sites. Fencing endangered species' habitats is an easy method of eliminating damage by feral animals. Caging individual plants or small populations is another alternative. Increased hunting pressure and allowing hunters to use high-powered rifles might decrease feral animal populations, thereby reducing their impact on rare plant species.

Competition between rare and alien plant species for water, nutrients, light, space, and pollinators is becoming a greater threat on PTA. *Pennisetum setaceum* (fountain grass) is invading and, in many cases, dominating native plant habitats on the installation (Figure 8c). Other alien species, like *Passiflora mollissima* (banana poka) and *Senecio mikanioides* (German ivy), are potential problems as well. Obviously, weed control and minimizing the spread of alien species across the installation are the most logical solutions to the alien species problem.

Military activities, other than fire, have little impact on the rare plants. Occasionally, a rare plant or two might be crushed by foot or vehicular traffic. Dust created by traffic could negatively impact a rare species if it is growing near a road (Figure 8d). Shaw et al. (1990) found that only about 4% of the installation outside of the impact area had been disturbed by military activities. Most of this disturbance was in fixed artillery firing points, bivouac sites, and firing ranges. Many of the rare species inhabit remote areas of PTA with little or no chance of being disturbed by military training activities. Reducing the risk of military impacts on the rare plants can be accomplished easily by locating training activities away from areas with sensitive species.

Figure 8. Examples of impacts to the rare plants on Pohakuloa Training Area, Hawaii. *Clockwise from upper left:* (a) impact of wildfire on vegetation within Kipuka Kalawamauna Endangered Plants Habitat; (b) ***Chamaesyce olowaluana*** individual severely damaged by feral ungulates; (c) ***Pennisetum setaceum***, an alien grass species out-competing ***Haplostachys haplostachya***, an endangered species; (d) dust raised by military vehicle during training maneuvers.

2 Community Descriptions

This chapter provides an account of the 24 plant communities delineated on Pohakuloa Training Area (PTA). A "menu" format was used to ensure uniformity in descriptions. First, the map reference number is given. This number corresponds to the plant community numbering system used by Castillo et al. (1997) on the vegetation map of the installation. Next, substrate, area, and elevational range are provided for each community. Substrate is based on volcano of origin (Mauna Kea or Mauna Loa) and type (aa, ash, cinder, pahoehoe). Area and elevational range are given in metric and English units. The Other Classifications section relates the communities defined in this book to plant community descriptions or delineations found in other reports or books [Jacobi (1990), Gagne & Cuddihy (1990), Shaw & Douglas (1991)]. Referring to these other classifications might give the reader further insight into the structure and extent of the plant communities found on PTA. Rare plant species found in each community are listed along with characteristic associated species. Finally, a comments section is provided for each community that supplies additional information on the structure of the communities. Density estimates for woody plants is drawn from LCTA belt transect data. Woody and herbaceous aerial cover estimates are from LCTA line transect data. Refer to Diersing et al. (1992) and Bern (1995) for detailed information on LCTA methods for locating plots, plot design, and data analyses.

A single photograph is used to augment the "menu" information and to give the reader a visual representation of each community.

A copy of the installation plant community map by Castillo et al. (1997) is located in the pocket at the rear of the book. A stratified random sample was used to determine mapping accuracy. Twenty points were randomly assigned to each of the 24 plant communities (480 points). The only constraint was that points had to be outside of the impact area and more than 100m from a community boundary. Points were visited without a community map and the vegetation was classified into one of the 24 categories. Field identified communities were compared to the classification found on the map, and the percentage of correctly identified points was calculated. Mapping accuracy was determined to be 96%.

A loose–leaf ring binder format with no pagination was used so corrections and additions could be easily made.


Barren Lava

1 Barren Lava

Map Reference Number: 1

Substrate: Mauna Loa aa and pahoehoe

Area: 12,007 ha (29,647 ac)

Elevational Range: 1340–2715 m (4400–8900 ft)

Other Classifications:

Jacobi (1990): D:

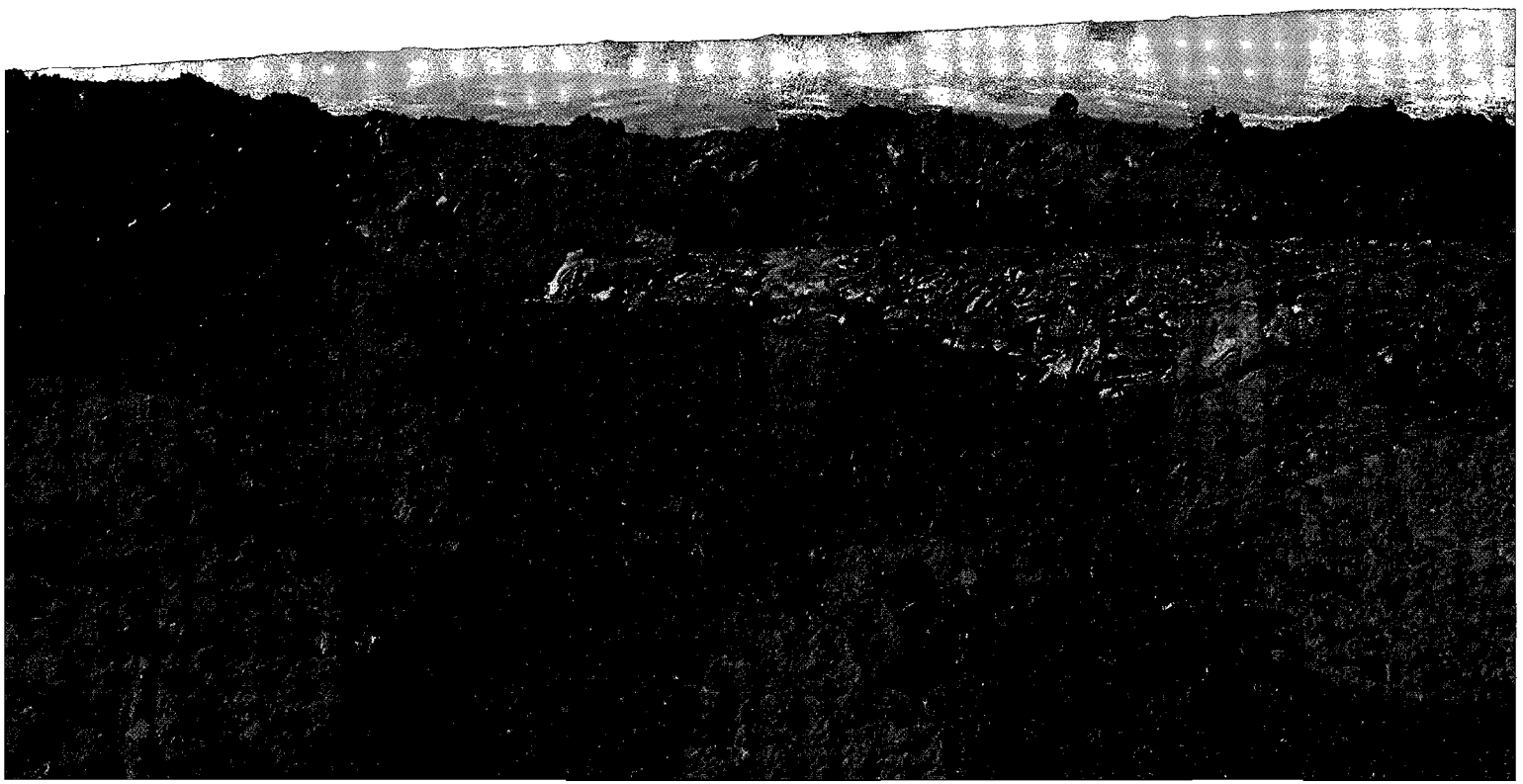
Gagne & Cuddihy (1990): N/A

Shaw & Douglas (1991): Sparse MEPO5, Open MEPO5

Rare Plant Species: *Asplenium fragile, Chamaesyce olowaluana, Eragrostis deflexa, Portulaca sclerocarpa, Silene hawaiiensis, Tetramolopium consanguineum*

Associated Taxa: *Dodonaea viscosa, Metrosideros polymorpha, Styphelia tameiameiae*

Comments: Barren lava is the largest cover type at PTA and occupies approximately one fourth of the installation. Rate of primary succession is governed by precipitation. In the saddle region, succession is retarded due to the relatively low rainfall and slow soil development at these elevations. Lichen (*Stereocaulon vulcani*) and ferns (*i.e. Pellea ternifolia*) are some of the first plants to establish on the lava. The tree, *Metrosideros polymorpha*, and shrubs, *Dodonaea viscosa* and *Styphelia tameiameiae*, are some of the first flowering plants to colonize the lava. *Pennisetum setaceum* (fountain grass) is invading many of the barren lava flows and is changing the natural primary successional pattern on these sites. At these elevations, pahoehoe appears to support vegetation more rapidly than does aa.



Community 1: Barren Lava


Sparse *Metrosideros* Treeland

2 Sparse *Metrosideros* Treeland

Map Reference Number: 2

Substrate: Mauna Loa aa and pahoehoe

Area: 5214 ha (12,873 ac)

Elevational Range: 1402–2317 m (4600–7600 ft)

Other Classifications:

Jacobi (1990): D:Me

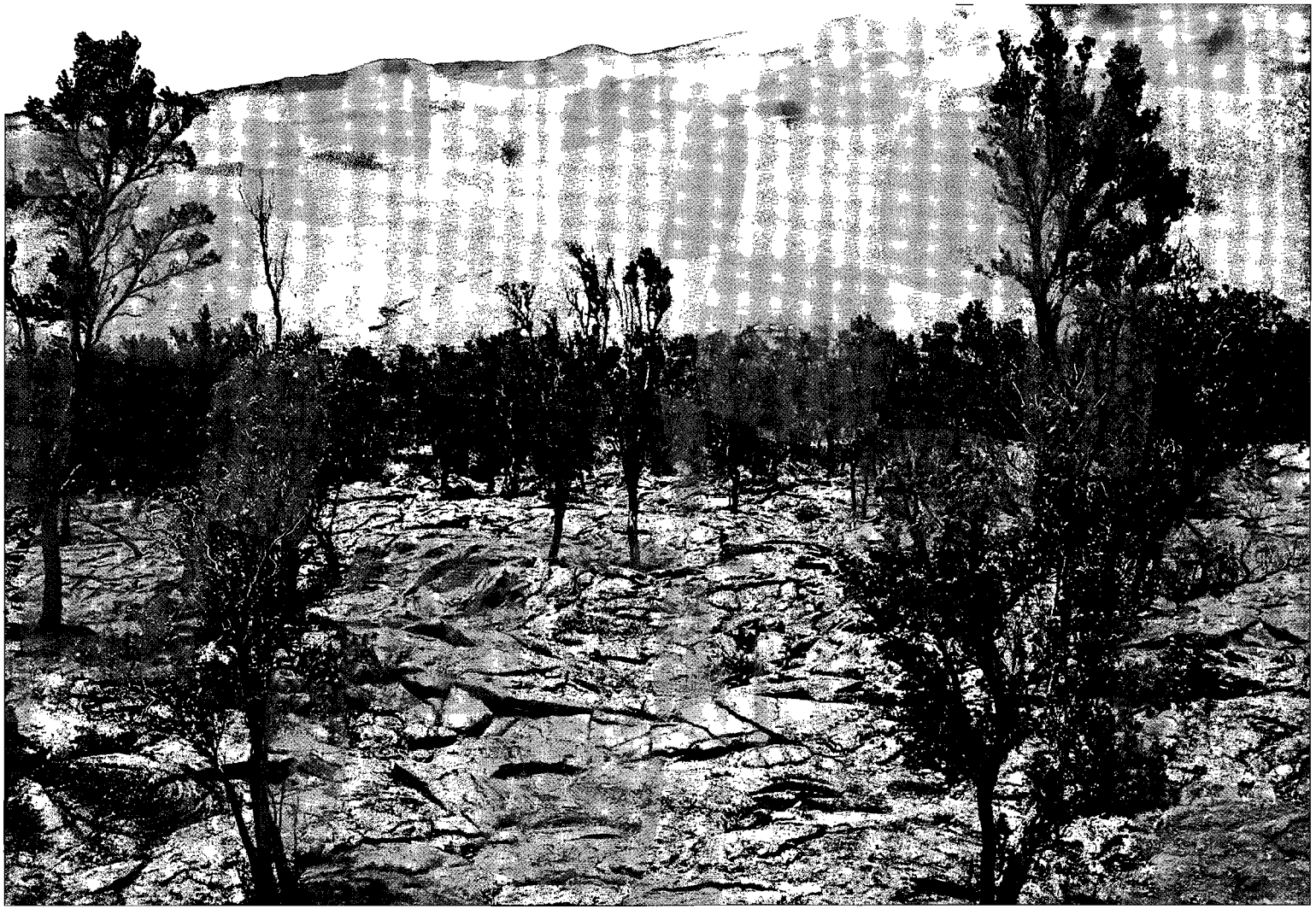
Gagne & Cuddihy (1990): Ohia (*Metrosideros*) Montane Dry Forest, Ohia (*Metrosideros*) Subalpine [Dry] Forest

Shaw & Douglas (1991): Bare, Sparse MEPO5, Open MEPO5

Rare Plant Species: *Asplenium fragile, Eragrostis deflexa, Festuca hawaiiensis, Hedyotis coriacea, Silene hawaiiensis, S. lanceolata, Stenogyne angustifolia, Tetramolopium consanguineum, T. humile, Zanthoxylum hawaiiense*

Associated Taxa: *Dodonaea viscosa, Styphelia tameiameiae*

Comments: Sparse *Metrosideros* Treeland occurs on relatively young lava flows and represents the first plant community to establish on barren lava. Total woody plant density is approximately 2100 plants/ha. The overstory is dominated by *Metrosideros polymorpha* (207 plants/ha), while the understory is characterized by *Dodonaea viscosa* (572 plants/ha) and *Styphelia tameiameiae* (547 plants/ha). At higher elevations, *Vaccinium reticulatum* becomes frequent. The herbaceous layer is very sparse and dominated by *Carex wahuensi, Ehrharta stipoides,* and *Pennisetum setaceum.*



Community 2: Sparse *Metrosideros* Treeland

Open *Metrosideros* Treeland with sparse shrub understory

3 Open *Metrosideros* Treeland with sparse shrub understory

Map Reference Number: 3

Substrate: Mauna Loa aa & pahoehoe

Area: 10,064 ha (24,849 ac)

Elevational Range: 1300–2000 m (4600–7600 ft)

Other Classifications:

Jacobi (1990): D:Me(ns)

Gagne & Cuddihy (1990): Ohia (*Metrosideros)* Montane Dry Forest, Ohia (*Metrosideros)* Subalpine [Dry] Forest

Shaw & Douglas (1991): Open MEPO5

Rare Plant Species: *Asplenium fragile, Chamaesyce olowaluana, Eragrostis deflexa, Festuca hawaiiensis, Haplostachys haplostachya, Hedyotis coriacea, Hesperocnide sandwicensis, Neraudia ovata, Portulaca sclerocarpa, Silene hawaiiensis, Solanum incompletum, Stenogyne angustifolia, Tetramolopium consanguineum, Zanthoxylum hawaiiense*

Associated Taxa: *Dodonaea viscosa, Osteomeles anthyllidifolia, Styphelia tameiameiae*

Comments: The Open *Metrosideros* Treelands are some of the most important communites based on biodiversity and number of endangered species. Average tree density is 3622 plants/ha in this community with a sparse shrub understory. *Metrosideros polymorpha* is the dominant overstory species and *Dodonaea viscosa* (1470 plants/ha) and *Styphelia tameiameiae* (1985 plants/ha) are the most common understory shrub species. *Dubautia linearis* is an important interstitial shrub species in this community. Invasion by *Pennisetum setaceum* is most prevalent in this *Metrosideros* treeland.

Community 3: Open *Metrosideros* Treeland with sparse shrub understory

Open *Metrosideros* Treeland with dense shrub understory

4 Open *Metrosideros* Treeland with dense shrub understory

Map Reference Number: 4

Substrate: Mauna Loa aa and pahoehoe

Area: 4087 ha (10,092 ac)

Elevational Range: 1366–1646 m (4480–5400 ft)

Other Classifications:

Jacobi (1990): D:Me(ns)

Gagne & Cuddihy (1990): Ohia (*Metrosideros)* Montane Dry Forest, Ohia (*Metrosideros)* Subalpine [Dry] Forest

Shaw & Douglas (1991): N/A

Rare Plant Species: *Asplenium fragile, Chamaesyce olowaluana, Eragrostis deflexa, Festuca hawaiiensis, Haplostachys haplostachya, Hedyotis coriacea, Hesperocnide sandwicensis, Portulaca sclerocarpa, Silene hawaiiensis, S. lanceolata, Stenogyne angustifolia, Tetramolopium consanguineum, T. diersingii, Zanthoxylum hawaiiense*

Associated Taxa: *Coprosma montana, Dodonaea viscosa, Osteomeles anthyllidifolia, Styphelia tameiameiae, Wikstroemia phillyreifolia*

Comments: Obviously, the major difference between Open *Metrosideros* Treeland with sparse understory and Open *Metrosideros* Treeland with dense understory is the size and number of shrubs beneath the canopy. Lava flow age is slightly older in this community than in the previous two *Metrosideros* Treelands. Overstory is dominated by *Metrosideros polymorpha* (255 plants/ha) in this community. *Dodonaea viscosa* (3902 plants/ha), *Styphelia tameiameiae* (1983 plants/ha) and *Osteomeles anthyllidifolia* (1070 plants/ha) are the most common shrubs. Aerial cover estimates indicate that *Crassula sieberiana* and *Pennisetum setaceum* are the major herbaceous species.

Community 4: Open *Metrosideros* Treeland with dense shrub understory

Intermediate *Metrosideros* Mixed Treeland

5 Intermediate *Metrosideros* Mixed Treeland

Map Reference Number: 5

Substrate: Mauna Loa aa and pahoehoe

Area: 511 ha (1262 ac)

Elevational Range: 1378–1585 m (4520–5200 ft)

Other Classifications:

Jacobi (1990): D:Me, nt (ns,xg)

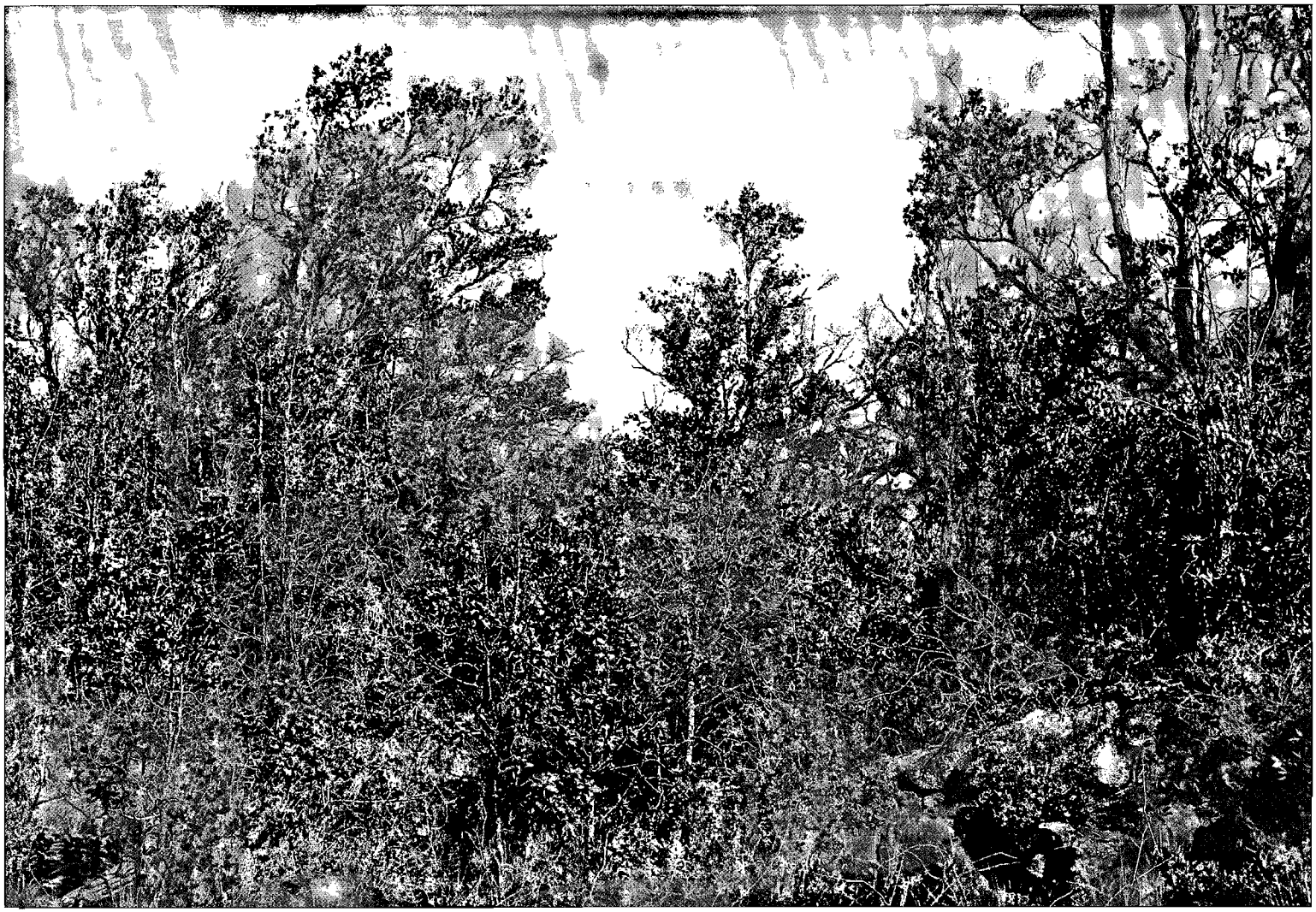
Gagne & Cuddihy (1990): [Dry] Forest

Shaw & Douglas (1991): N/A

Rare Plant Species: *Chamaesyce olowaluana, Eragrostis deflexa, Festuca hawaiiensis, Hesperocnide sandwicensis, Portulaca sclerocarpa, Silene lanceolata, Stenogyne angustifolia, Tetramolopium consanguineum, Zanthoxylum hawaiiense*

Associated Taxa: *Alyxia oliviformis, Coprosma montana, Dodonaea viscosa, Myoporum sandwicensis, Myrsine lanaiensis, Osteomeles anthyllidifolia, Pittosporum* spp., *Santalum paniculatum, Styphelia tameiameiae, Wikstroemia phillyreifolia*

Comments: Development and diversity of woody plants is most pronounced within the Intermediate *Metrosideros* Mixed Treeland community. To our knowledge, this community type is unique to the upper montane dry forests found on the installation. Total woody plant density within this community is 4783 plants/ha. *Metrosideros polymorpha* is becoming less dominant (25 plants/ha), and *Myrsine lanaiensis* (580 plants/ha), *Sophora chrysophylla* (295 plants/ha), and *Myoporum sandwicensis* (167 plants/ha) form a mid-story canopy. *Dodonaea viscosa* (2675 plants/ha), *Osteomeles anthyllidifolia* (508 plants/ha), and *Styphelia tameiameiae* (396 plants/ha) form a distinct shrub layer. *Pennisetum setaceum* is heavily infesting this community, and there is the potential for a catastrophic wildfire which would greatly alter the structure of this unique treeland.



Community 5: Intermediate *Metrosideros* Mixed Treeland

Open *Dodonaea* Shrubland

6 Open *Dodonaea* Shrubland

Map Reference Number: 6

Substrate: Mauna Kea and Mauna Loa aa, pahoehoe, ash and cinder

Area: 1162 ha (2869 ac)

Elevational Range: 1700–2300 m (5600–7560 ft)

Other Classifications:

Jacobi (1990): D:ns(ng–xg)

Gagne & Cuddihy (1990): Aalii (*Dodonaea*) Montane [Dry] Shrubland

Shaw & Douglas (1991): N/A

Rare Plant Species: *Chamaesyce olowaluana, Eragrostis deflexa, Haplostachys haplostachya, Hesperocnide sandwicensis, Portulaca villosa, Silene hawaiiensis, S. lanceolata, Stenogyne angustifolia, Tetramolopium consanguineum*

Associated Taxa: *Chenopodium oahuense, Eragrostis atropioides, Myoporum sandwicensis*

Comments: The Open *Dodonaea* Shrubland is found predominantly on older Mauna Kea substrates on the northern and western parts of the installation. Total woody plant density in this community is nearly 7000 plants/ha. *Dodonaea viscosa* is the most common shrub (2883 plants/ha). *Sida fallas* (2367 plants/ha) and *Chenopodium oahuense* (1560 plants/ha) are also prevalent. *Eragrostis atropioides* is the dominant herbaceous plant (62% relative aerial cover). *Pennisetum setaceum* and *Rhynchelytrum repens* are invading disturbed areas within the community. Wildfire may play a role in maintaining low density of less resistant shrub species.

Community 6: Open *Dodonaea* Shrubland

Dense *Dodonaea* Shrubland

7 Dense *Dodonaea* Shrubland

Map Reference Number: 7

Substrate: Mauna Loa pahoehoe and ash

Area: 34 ha (85 ac)

Elevational Range: 1616–1768 m (5300–5800 ft)

Other Classifications:

Jacobi (1990): D:ns(nh)

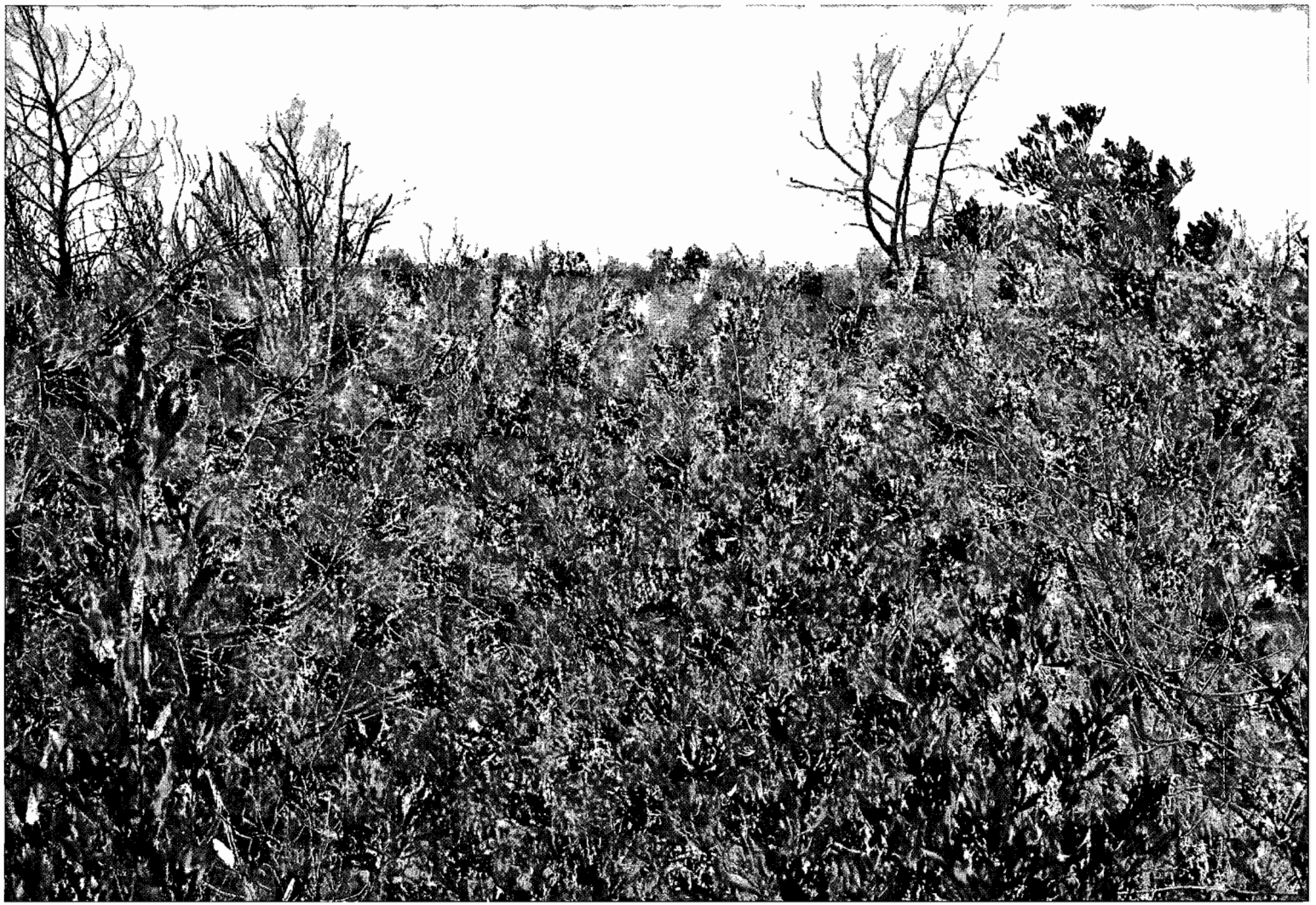
Gagne & Cuddihy (1990): Aalii (*Dodonaea*) Montane [Dry] Shrubland

Shaw & Douglas (1991): Dense DOVI/STTA w/SILA, Dense DOVI/STTA w/STAN

Rare Plant Species: *Eragrostis deflexa, Festuca hawaiiensis, Hesperocnide sandwicensis, Portulaca villosa, Silene lanceolata, Stenogyne angustifolia, Tetramolopium consanguineum*

Associated Taxa: *Lythrum maritimum, Myoporum sandwicensis, Styphelia tameiameiae*

Comments: The Dense *Dodonaea* Shrubland is a small community restricted to Kipuka Alala in the western part of the installation. Total woody plant density in this area is 13,683 plants/ha. The overstory is dominated by a dense stand of tall (3–5 m), multi-stemmed *Dodonaea viscosa* (10,875 plants/ha) individuals. *Myoporum sandwicensis* (1441 plants/ha) and *Sophora chrysophylla* (775 plants/ha) are the next densest shrubs. The alien plants, *Ehrharta stipoides, Pennisetum setaceum,* and *Solanum pseudocapsicum* are the major understory species. Some of the largest and most robust populations of the endangered *Silene lanceolata* are found in this community.



Community 7: Dense *Dodonaea* Shrubland

Dodonaea Mixed Shrubland

8 *Dodonaea* Mixed Shrubland

Map Reference Number: 8

Substrate: Mauna Kea and Mauna Loa aa, pahoehoe, ash and cinder

Area: 1856 ha (4583 ac)

Elevational Range: 1280 –1707 m (4200–5600 ft)

Other Classifications:

Jacobi (1990): D:ns(ng–xg,nh–xh)

Gagne & Cuddihy (1990): Aalii (*Dodonaea)* Montane [Dry] Shrubland

Shaw & Douglas (1991): N/A

Rare Plant Species: *Chamaesyce olowaluana, Eragrostis deflexa, Haplostachys haplostachya, Hesperocnide sandwicensis, Portulaca sclerocarpa, Silene hawaiiensis, S. lanceolata, Stenogyne angustifolia, Tetramolopium consanguineum, Zanthoxylum hawaiiense*

Associated Taxa: *Bidens menziesii, Chamaesyce multifomis, Chenopodium oahuense, Dubautia linearis, Myoporum sandwicensis, Sida fallax*

Comments: The *Dodonaea* Mixed Shrubland has the highest density of shrubs (15,800 plants/ha) of all the communities on the installation. This is the major community type found within Kipuka Kalawamauna, between Puu Keekee and Puu Kapele, and west of Puu Ahi on very old (>10,000 years before present) Mauna Kea lava. Small stature (0.5–1.5 m) *Dodonaea viscosa* plants dominate the community (7181 plants/ha). *Bidens menziesii* (2951 plants/ha), *Chenopodium oahuense* (2593 plants/ha), and *Chamaesyce multiformis* (900 plants/ha) also are common. Interstitial shrub species include *Sida fallax* (597 plants/ha) and *Dubautia linearis* (500 plants/ha). Herbaceous aerial cover is dominated by the native grass *Eragrostis atropioides* (25% relative cover) and the alien grass *Pennisetum setaceum* (25% relative cover). Wildfire has had a major impact on the structure of this community. Burned areas have reduced shrub cover and the herbaceous layer is predominantly *Pennisetum setaceum.* Continued burning of this community leads to a near monoculture of *Pennisetum setaceum.*

Community 8: *Dodonaea* Mixed Shrubland

Styphelia–Dodonaea Shrubland

9 *Styphelia–Dodonaea* Shrubland

Map Reference Number: 9

Substrate: Mauna Loa aa and pahoehoe

Area: 6510 ha (16,070 ac)

Elevational Range: 1800–2713 m (5900–8900 ft)

Other Classifications:

Jacobi (1990): D:ns (xg)

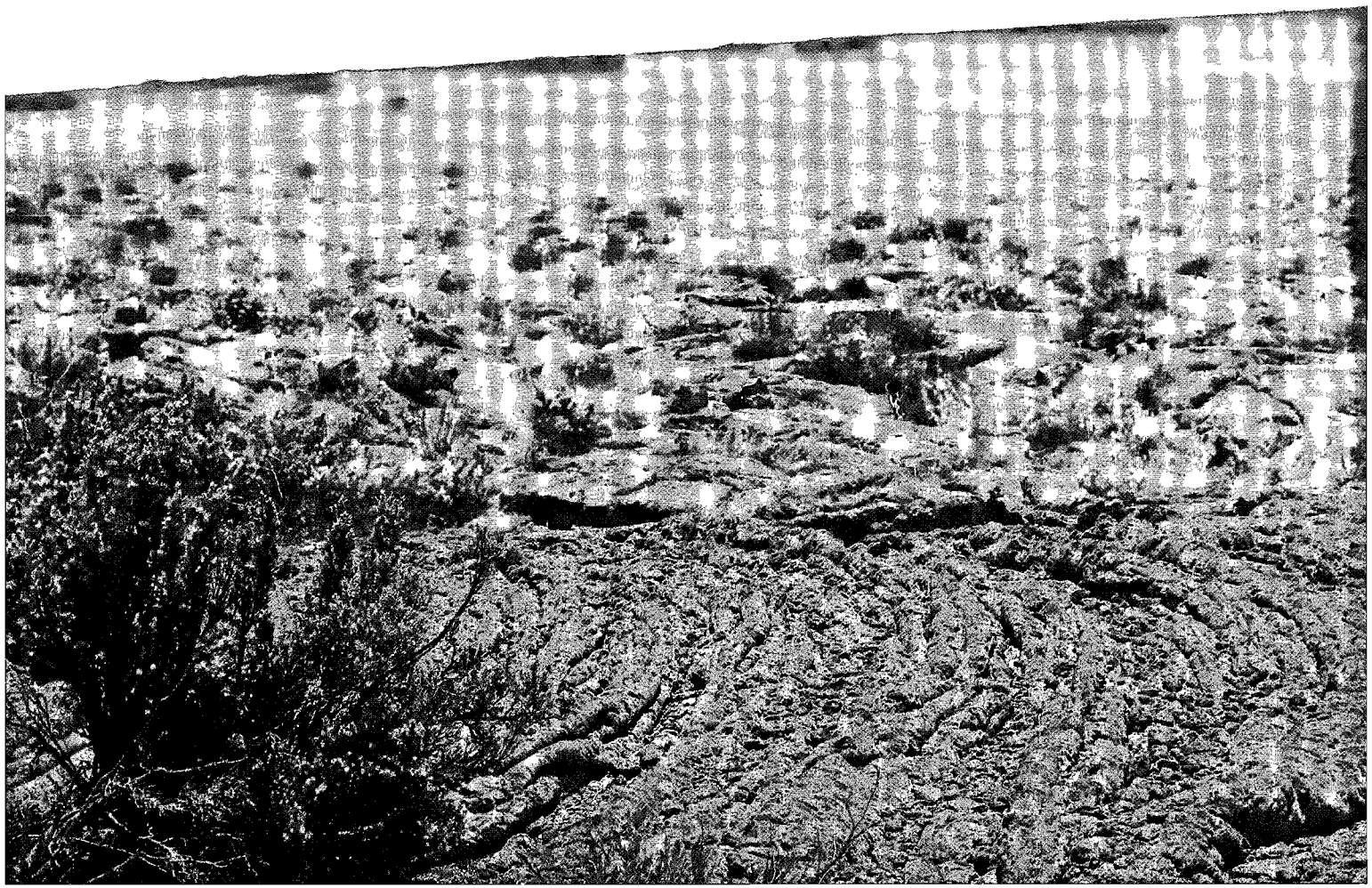
Gagne & Cuddihy (1990): Aalii/Ohelo/Pukiawe (*Dodonaea/Vaccinium/Styphelia*) [Subalpine Dry] Shrubland, Pukiawe/Ohelo (*Styphelia/Vaccinium*) [Subalpine Dry] Shrubland

Shaw & Douglas (1991): N/A

Rare Plant Species: *Asplenium fragile, Hesperocnide sandwicensis, Silene hawaiiensis*

Associated Taxa: *Dubautia ciliota, Deschampsia neubigena, Vaccinium reticulatum*

Comments: The *Styphelia–Dodonaea* Shrubland covers large areas in the southern and eastern part of the installation. It occurs on moderately aged (< 7,500 years before present) Mauna Loa substrate. Total woody plant density in the community is 9130 plants/ha. *Styphelia tameiameiae* (2885 plants/ha) and *Dodonaea viscosa* (1190 plants/ha) are the dominant overstory shrubs. The overstory is generally less than 1 m in height. *Vaccinium reticulatum* (3431 plants/ha) forms a dense, shrubby understory in some areas. The herbaceous layer is poorly developed in this community.



Community 9: *Styphelia–Dodonaea* Shrubland

10 *Styphelia* Mixed Shrubland

Map Reference Number: 10

Substrate: Mauna Loa pahoehoe and ash

Area: 59 ha (146 ac)

Elevational Range: 1495–1560 m (4900–5120 ft)

Other Classifications:

Jacobi (1990): D:ns(ng–xg,nh–xh)

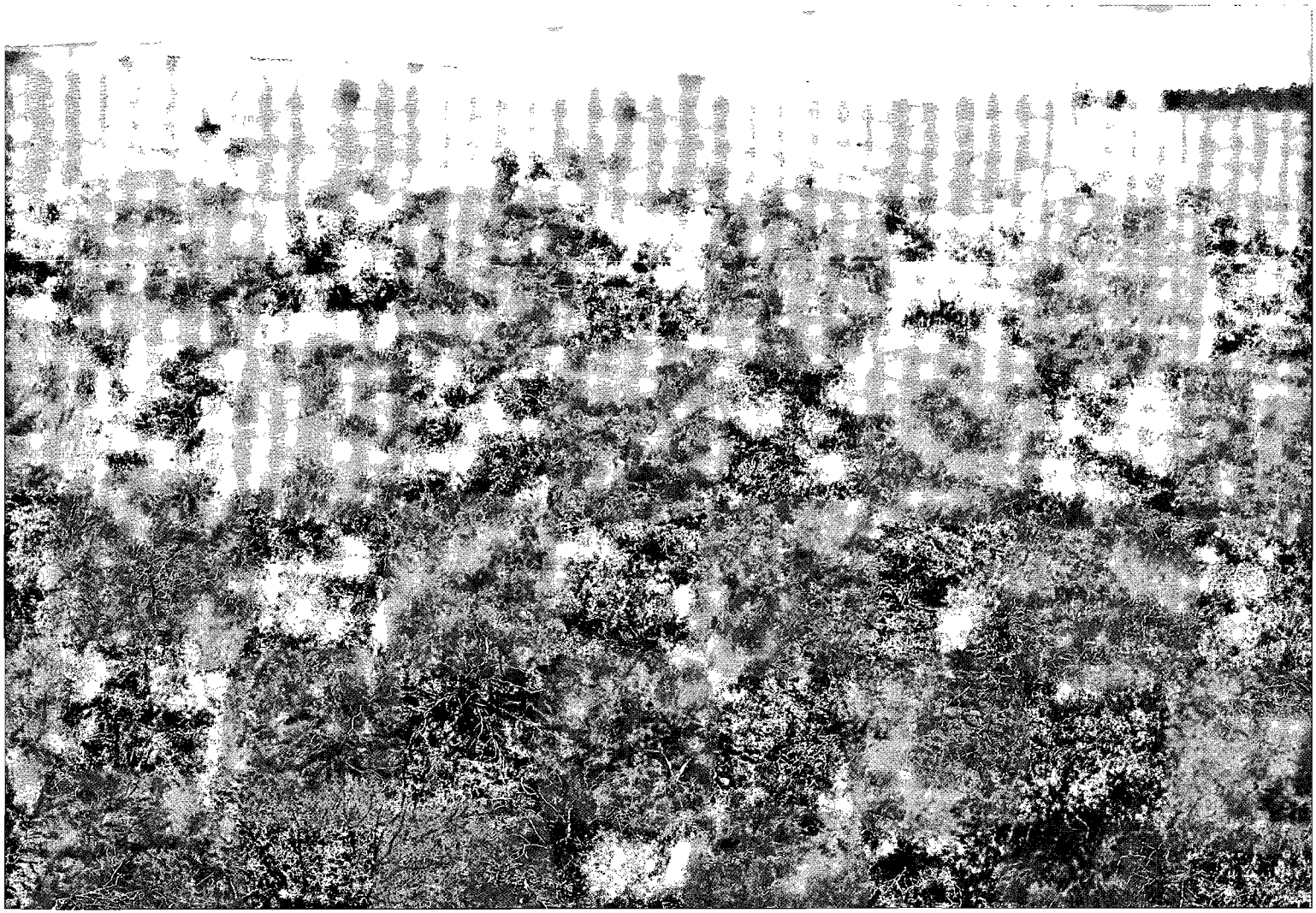
Gagne & Cuddihy (1990): Aalii (*Dodonaea*) Montane [Dry] Shrubland

Shaw & Douglas (1991): Intermediate DOVI/STTA, Open DOVI/STTA, Dense DOVI/STTA w/STAN

Rare Plant Species: *Chamaesyce olowaluana, Eragrostis deflexa, Festuca hawaiiensis, Hesperocnide sandwicensis, Silene lanceolata, Stenogyne angustifolia*

Associated Taxa: *Bidens menziesii, Myoporum sandwicensis, Panicum tenuifolium, Sophora chrysophylla*

Comments: The *Styphelia* Mixed Shrubland is a small area restricted to Kipuka Alala in the western portion of the installation. It occurs on Mauna Loa substrate which flowed about 5000 years before present. Total woody plant density in the community is 4625 plants/ha. Individuals of *Styphelia tameiameiae,* ranging in height from 1 to 3 m, dominate the landscape. *Dodonaea viscosa* (1787 plants/ha), *Sophora chrysophylla* (687 plants/ha), *Coprosma montana* (241 plants/ha), and *Myoporum sandwicensis* (195 plants/ha) also are common. The herbaceous layer is well developed. *Carex wahuensis, Ehrharta stipoides, Malva parvifolia, Panicum tenuifolium,* and *Pennisetum setaceum* constitute the majority of the herbaceous aerial cover.



Community 10: *Styphelia* Mixed Shrubland


Myoporum Shrubland

11 *Myoporum* Shrubland

Map Reference Number: 11

Substrate: Mauna Kea and Mauna Loa aa and pahoehoe

Area: 1614 ha (3984 ac)

Elevational Range: 1340–1860 m (4400–6100 ft)

Other Classifications:

Jacobi (1990): D:ns (ng–xg, nh–xh)

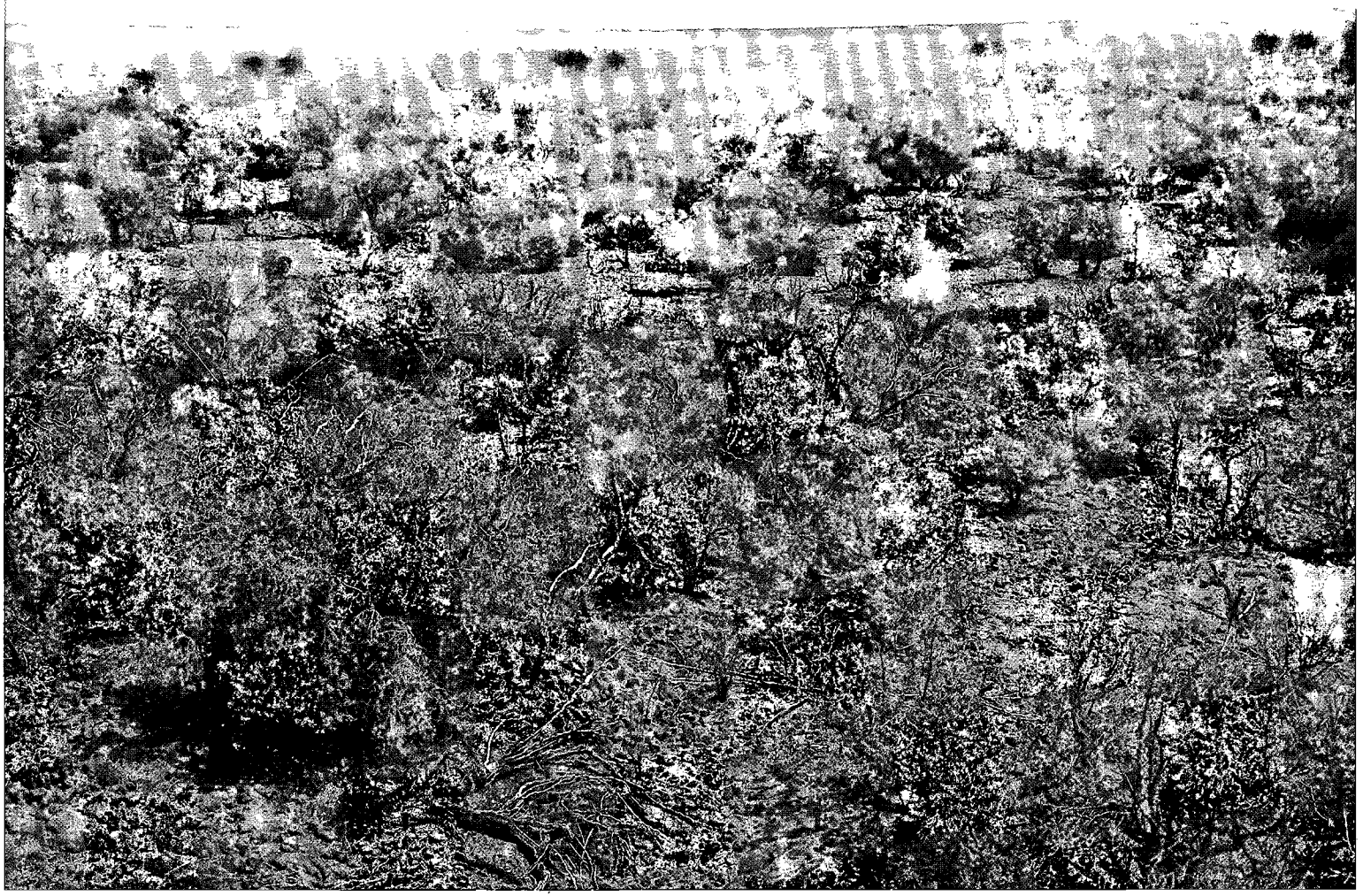
Gagne & Cuddihy (1990): Akoko (*Chamaesyce*) [Montane Dry] Forest, Mamane (*Sophora*) [Subalpine Dry] Forest

Shaw & Douglas (1991): Intermediate SOCH/MYSA, ERAG/PESE3

Rare Plant Species: *Chamaesyce olowaluana, Eragrostis deflexa, Festuca hawaiiensis, Haplostachys haplostachya, Hesperocnide sandwicensis, Portulaca sclerocarpa, Silene lanceolata, Solanum incompletum, Stenogyne angustifolia, Tetramolopium consanguineum, Zanthoxylum hawaiiense*

Associated Taxa: *Chenopodium oahuense, Dodonaea viscosa, Pennisetum setaceum*

Comments: The *Myoporum* Shrubland is scattered across the northern part of the installation, along the margins of Kipuka Kalawamauna, and in isolated kipuka along the western boundary of the installation. Total woody plant density is only 3081 plants/ha in the community. Large (> 3 m tall) *Myoporum sandwicensis* shrubs (473 plants/ha) are the characteristic overstory species. Smaller (0.5–1.5 m tall) *Dodonaea viscosa* (664 plants/ha) and *Chenopodium oahuense* (1504 plants/ha) form an obvious understory shrub layer. Over 50% of the herbaceous aerial cover is composed of *Pennisetum setaceum.* Other common herbaceous species include *Stipa cernua, Tagetes minuta, Bromus willdenowii, Verbascum thapsus,* and *Heterotheca grandiflora.*



Community 11: *Myoporum* Shrubland

Myoporum–Chamaesyce Treeland

12 *Myoporum–Chamaesyce* Treeland

Map Reference Number: 12

Substrate: Mauna Kea and Mauna Loa aa, pahoehoe, and ash

Area: 260 ha (641 ac)

Elevational Range: 1700–1900 m (5840–6240 ft)

Other Classifications:

Jacobi (1990): D:My,Ch (xh)

Gagne & Cuddihy (1990): Akoko (*Chamaesyce*) [Montane Dry] Forest, Mamane (*Sophora*) [Subalpine Dry] Forest

Shaw & Douglas (1991): N/A

Rare Plant Species: *Chamaesyce olowaluana, Haplostachys haplostachya, Hesperocnide sandwicensis*

Associated Taxa: *Chenopodium oahuense, Dodonaea viscosa, Pennisetum setaceum*

Comments: The *Myoporum–Chamaesyce* Treeland occurs in small, scattered pockets across the northern part of the installation on Mauna Kea flows. Total woody density in the community is 11,550 plants/ha. Relatively large (generally > 3 m tall) *Chamaesyce olowaluana* (1167 plants/ha) and *Myoporum sandwicensis* (583 plants/ha) plants dominate the overstory. The understory shrub layer is composed of small (< 1.5 m tall) *Chenopodium oahuense* (9700 plants/ha) plants. The herbaceous layer is sparse and being invaded by the alien grass *Pennisetum setaceum.*

Community 12: *Myoporum–Chamaesyce* Treeland

Myoporum–Dodonaea Shrubland

13 *Myoporum–Dodonaea* Shrubland

Map Reference Number: 13

Substrate: Mauna Kea and Mauna Loa as and pahoehoe

Area: 1036 ha (2559 ac)

Elevational Range: 1460–1860 m (4800–6100 ft)

Other Classifications:

Jacobi (1990): D:My(ns,ng)

Gagne & Cuddihy (1990): Mamane (*Sophora*) [Subalpine Dry] Forest

Shaw & Douglas (1991): N/A

Rare Plant Species: *Chamaesyce olowaluana, Eragrostis deflexa, Haplostachys haplostachya, Hesperocnide sandwicensis, Silene lanceolata, Stenogyne angustifolia, Tetramolopium consanguineum, T. diersingii, Zanthoxylum hawaiiense*

Associated Taxa: *Chenopodium oahuense, Pennisetum setaceum, Sophora chrysophylla*

Comments: The *Myoporum–Dodonaea* Shrubland has a similar distribution to the *Myoporum* Shrubland. The major difference between these two communities is shrub density. Shrubs are nearly three times as great in the former community than in the latter. Total woody plant density in the *Myoporum–Dodonaea* Shrubland is 9226 plants/ha. The overstory is predominantly *Myoporum sandwicensis* (1361 plants/ha) with a few larger *Dodonaea viscosa.* The understory shrub layer is characterized by small *Dodonaea viscosa* (3281 plants/ha) and *Chenopodium oahuense* (4114 plants/ha). The herbaceous layer is dominated by *Pennisetum setaceum* which accounts for nearly 30% of the aerial cover. Other important herbaceous species include *Bidens alba, Bromus rigidus, Crepis capillaris, Dactylis glomerata, Medicago lupulina,* and *Senecio mikanioides.*

Community 13: *Myoporum–Dodonaea* Shrubland

Myoporum–Sophora Mixed Shrubland

14 *Myoporum–Sophora* Mixed Shrubland

Map Reference Number: 14

Substrate: Mauna Loa aa, pahoehoe, and ash.

Area: 370 ha (913 ac)

Elevational Range: 1585 –1880 m (5200–6160 ft)

Other Classifications:

Jacobi (1990): D:My,So(ns,ng–xg)

Gagne & Cuddihy (1990): Mamane (*Sophora*) [Subalpine Dry] Forest

Shaw & Douglas (1991): DOVI/STTA, Intermediate DOVI/STTA, Dense DOVI/STTA, Dense DOVI/STTA w/STAN, Dense DOVI/STTA w/SILA, Dense DOVI/STTA w/MYSA, Dense SOCH/MYSA

Rare Plant Species: *Asplenium fragile, Chamaesyce olowaluana, Eragrostis deflexa, Festuca hawaiiensis, Hesperocnide sandwicensis, Silene lanceolata, Stenogyne angustifolia, Tetramolopium consanguineum*

Associated Taxa: *Dodonaea viscosa, Panicum tenuifolium, Styphelia tameiameiae, Trisetum glomeratum*

Comments: The *Myoporum–Sophora* Mixed Shrubland is one of the dominant plant communities within Kipuka Alala. Total woody plant density within this community is 6052 plants/ha. Overstory is primarily *Myoporum sandwicensis* (1206 plants/ha) and *Sophora chrysophylla* (143 plants/ha). Understory is composed of *Dodonaea viscosa* (3132 plants/ha), *Styphelia tameiameiae* (820 plants/ha), and *Coprosma montana* (617 plants/ha). Absolute aerial cover averages about 50% in this community. *Ehrharta stipoides* is the major herbaceous species. *Eragrostis brownii, Panicum tenuifolium,* and *Pennisetum setaceum* are the other characteristic grass species found in the community. *Lythrum maritimum, Solanum pseudocapsicum, Senecio mikanioides,* and *Carex wahuensis* are common herbaceous forbs found in the understory. This community is more dense and has a more diverse herbaceous layer than the other two *Myoporum–Sophora* communities in Kipuka Alala. This community has been heavily impacted by feral sheep and goats.

Community 14: *Myoporum–Sophora* Mixed Shrubland

Myoporum–Sophora Shrubland with forb understory

15 *Myoporum–Sophora* Shrubland with forb understory

Map Reference Number: 15

Substrate: Mauna Loa aa, pahoehoe, and ash

Area: 937 ha (2313 ac)

Elevational Range: 1660–2350 m (5440–7700 ft)

Other Classifications:

Jacobi (1990): D:My,So (xh)

Gagne & Cuddihy (1990): Mamane (*Sophora*) [Subalpine Dry] Forest

Shaw & Douglas (1991): Intermediate SOCH/MYSA, Dense SOCH/MYSA, Intermediate SOCH/MYSA w/CHOL, Dense SOCH/MYSA w/CHOL

Rare Plant Species: *Asplenium fragile, Chamaesyce olowaluana, Eragrostis deflexa, Festuca hawaiiensis, Hesperocnide sandwicensis, Tetramolopium consanguineum*

Associated Taxa: *Senecio sylvatica, Wahlenbergia gracilis*

Comments: The *Myoporum–Sophora* Shrubland with forb understory only occurs in the Kipuka Alala region of the installation on Mauna Loa substrate (>5,000 years before present). Total woody plant density is 2143 plants/ha within this community. *Myoporum sandwicensis* (1685 plants/ha) and *Sophora chrysophylla* (133 plants/ha) are the dominant woody species. The shrub understory layer is very sparse (*Dodonaea viscosa* [231 plants/ha] and *Styphelia tameiameiae* [33 plants/ha]). Total aerial cover is only 13%, and weedy forbs dominate the herbaceous layer. *Gnaphalium purpureum, Heterotheca grandiflora, Marrubium vulgare,* and *Solanum pseudocapsicum* are the common herbaceous plants. Feral ungulates have destroyed the herbaceous understory in this community, and a browse line on the woody plants is evident.

Community 15: *Myoporum–Sophora* Shrubland with forb understory

Myoporum–Sophora Shrubland with grass understory

16 *Myoporum–Sophora* Shrubland with grass understory

Map Reference Number: 16

Substrate: Mauna Loa aa, pahoehoe, and ash

Area: 284 ha (701 ac)

Elevational Range: 1750 –2195 m (5740–7200 ft)

Other Classifications:

Jacobi (1990): D:My,So(ng–xg)

Gagne & Cuddihy (1990): Mamane (*Sophora*) [Subalpine Dry] Forest

Shaw & Douglas (1991): Open SOCH/MYSA, Intermediate SOCH/MYSA, DOVI/STTA

Rare Plant Species: *Chamaesyce olowaluana, Eragrostis deflexa, Hesperocnide sandwicensis*

Associated Taxa: *Eragrostis* spp., *Wahlenbergia gracilis*

Comments: The *Myoporum–Sophora* Shrubland with grass understory is the smallest of the three communities occurring within Kipuka Alala which are dominated by *Myoporum sandwicensis* and *Sophora chrysophylla.* Total woody plant density within this community is 1331 plants/ha, and *M. sandwicensis* (927 plants/ha) and *S. chrysophylla* (71 plants/ha) are the major overstory species. *Dodonaea viscosa* (240 plants/ha) and *Styphelia tameiameiae* (58 plants/ha) are the most common understory shrub species. Total absolute aerial cover is about 36%. Nearly 80% of the aerial cover is composed of grasses, and *Ehrharta stipoides, Eragrostis brownii,* and *Pennisetum setaceum* are the major grasses in the herbaceous layer. Common forbs are *Heterotheca grandiflora, Solanum pseudocapsicum, Senecio vulgare,* and *Crepis capillaris.* Feral ungulates have significantly altered the herbaceous layer of this community. Also, almost no regeneration of woody plants has been observed, and presumably the sheep and goats consume the woody seedling.

Community 16: *Myoporum–Sophora* Shrubland with grass understory

Sophora–Myoporum–Chamaesyce Shrubland

17 *Sophora–Myoporum–Chamaesyce* Shrubland

Map Reference Number: 17

Substrate: Mauna Kea and Mauna Loa aa, pahoehoe, cinder, and ash

Area: 255 ha (630 ac)

Elevational Range: 2000–2120 m (6600–7000 ft)

Other Classifications:

Jacobi (1990): D:So,My,Ch (ns,xg)

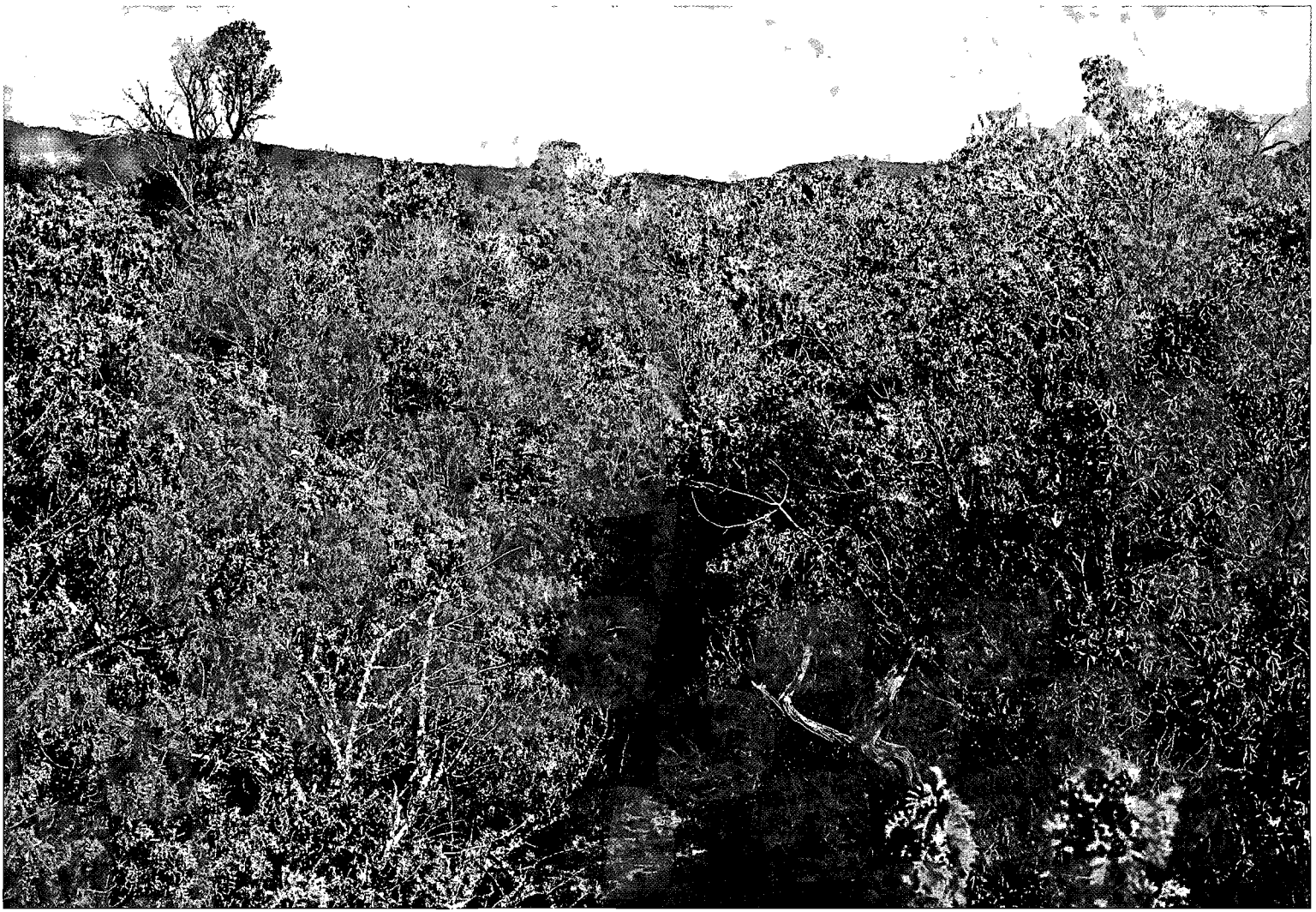
Gagne & Cuddihy (1990): Akoko (*Chamaesyce*) [Montane Dry] Forest, Mamane (*Sophora*) [Subalpine Dry] Forest

Shaw & Douglas (1991): N/A

Rare Plant Species: *Asplenium fragile, Chamaesyce olowaluana, Hesperocnide sandwicensis*

Associated Taxa: *Bromus willdenowii, Chenopodium oahuense, Dactylis glomerata, Vulpia myuros*

Comments: The *Sophora–Myoporum–Chamaesyce* Shrubland is the smallest of the three woody plant communities that dominate the northeastern corner of the installation. Total woody plant density is 4983 plants/ha. *Sophora chrysophylla* is the major overstory species (517 plants/ha), while *Myoporum sandwicensis* (216 plants/ha) and *Chamaesyce olowaluana* (100 plants/ha) are co-dominants. *Chenopodium oahuense* (4150 plants/ha) is the characteristic understory shrub species. Total absolute aerial cover is 58%. *Bromus rigidus, Danthonia pilosa, Ehrharta calycina,* and *Eragrostis atropioides* are the dominant grass species. Characteristic forbs include *Brassica nigra, Lepidium hyssopifolium,* and *Urtica urens.*



Community 17: *Sophora–Myoporum–Chamaesyce* Shrubland

Sophora–Myoporum Shrubland with forb understory

18 *Sophora–Myoporum* Shrubland with forb understory

Map Reference Number: 18

Substrate: Mauna Kea aa and cinder

Area: 467 ha (1153 ac)

Elevational Range: 1875–2380 m (6200–7800 ft)

Other Classifications:

Jacobi (1990): D:So,My(ns,xg)

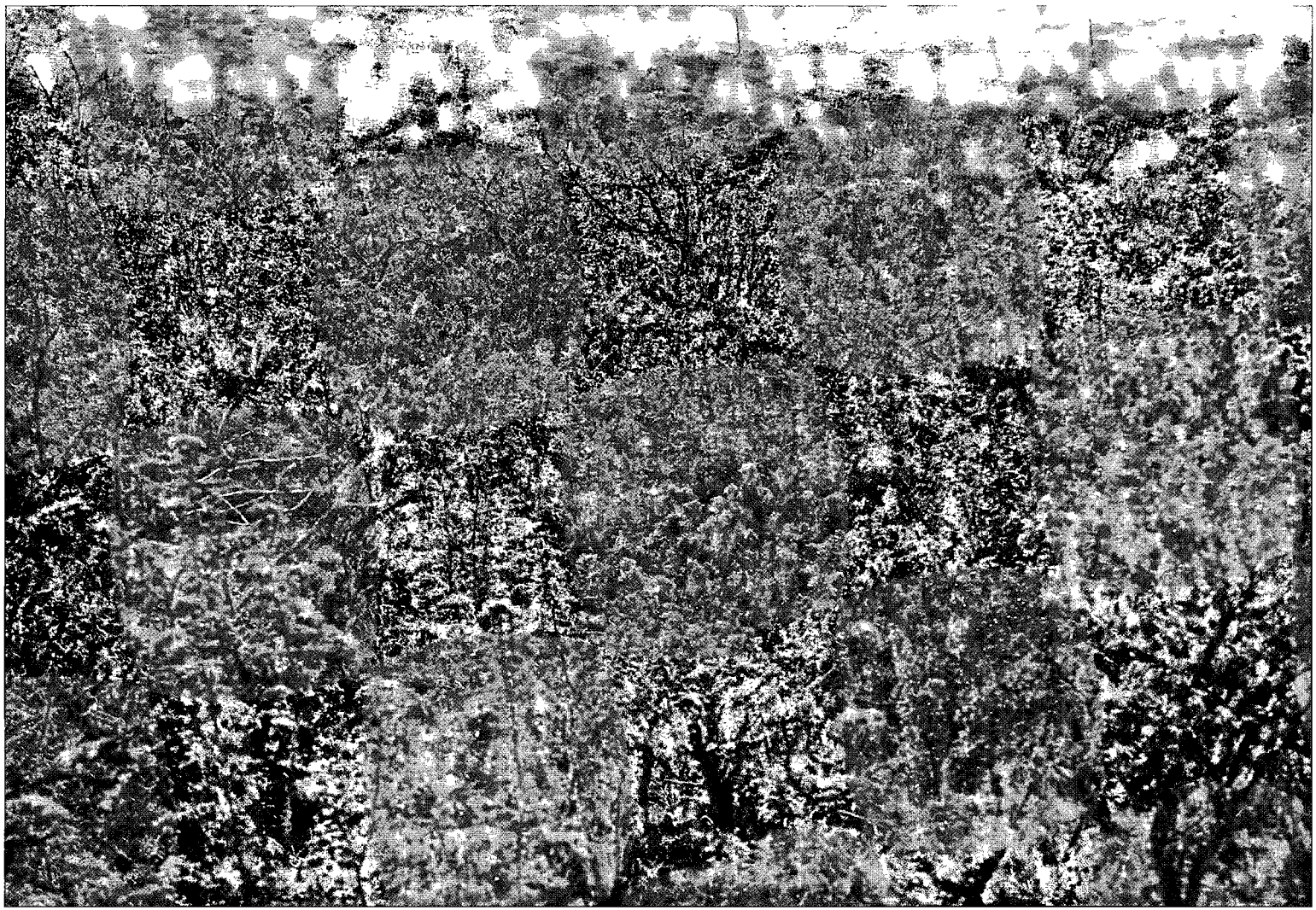
Gagne & Cuddihy (1990): Mamane (*Sophora*) [Subalpine Dry] Forest

Shaw & Douglas (1991): N/A

Rare Plant Species: *Chamaesyce olowaluana, Hesperocnide sandwicensis, Silene hawaiiensis*

Associated Taxa: *Bromus willdenowii, Chenopodium oahuense, Dactylis glomerata, Ehrharta calycina*

Comments: The *Sophora–Myoporum* Shrubland with forb understory is characteristic of drainage areas and cinder cones (puu) on the northern part of the installation; as well as small kipuka along Redleg Trail and the Hilo–Kona Road. Total woody plant density is 10,817 plants/ha, with *Sophora chrysophylla* (400 plants/ha) and *Myoporum sandwicensis* (133 plants/ha) as the major overstory species. *Dodonaea viscosa* (6500 plants/ha) and *Chenopodium oahuense* (1683 plants/ha) are the principal understory shrubs. Total aerial cover is 23% and is composed of predominantly weedy forbs. *Brassica campestris, B. nigra, Chenopodium album, Gnaphalium purpureum, Heterotheca grandiflora, Marrubium vulgare, Urtica urens,* and *Verbascum thapsus* are the most common weedy forbs in this community. This community is heavily disturbed. Most damage is caused by feral ungulates.



Community 18: *Sophora–Myoporum* Shrubland with forb understory

Sophora–Myoporum Shrubland with grass understory

19 *Sophora–Myoporum* Shrubland with grass understory

Map Reference Number: 19

Substrate: Mauna Loa and Mauna Kea aa and ash

Area: 315 ha (630 ac)

Elevational Range: 2045–2160 m (6700–7080 ft)

Other Classifications:

Jacobi (1990): D:So,My(ng–xg)

Gagne & Cuddihy (1990): Mamane (*Sophora*) [Subalpine Dry] Forest

Shaw & Douglas (1991): N/A

Rare Plant Species: *Chamaesyce olowaluana, Hesperocnide sandwicensis*

Associated Taxa: *Bromus willdenowii, Chenopodium oahuense, Dactylis glomerata, Vulpia myuros*

Comments: The *Sophora–Myoporum* Shrubland with grass understory is the common plant community in the northeastern corner of the installation. Total woody plant density is 4499 plants/ha, and *Sophora chrysophylla* (422 plants/ha) and *Myoporum sandwicensis* (172 plants/ha) are the major overstory species. *Chenopodium oahuense* (3805 plants/ha) and *Bidens menziesii* (42 plants/ha) are the common understory species. Total aerial cover averages about 45%. Grasses dominate the herbaceous understory. Characteristic grasses of this community are *Bromus rigidus, Danthonia pilosa, Eragrostis leptophylla, Ehrharta calycina,* and *Stipa cernua.* Common weedy species (*Heterotheca grandiflora, Marrubium vulgare, Urtica urens, Verbascum thapsus)* constitute the herbaceous forbs. Military training and feral ungulates have negatively impacted this community.

Community 19: *Sophora–Myoporum* Shrubland with grass understory

Chamaesyce Treeland

20 *Chamaesyce* Treeland

Map Reference Number: 20

Substrate: Mauna Kea aa, pahoehoe, and ash

Area: 16 ha (39 ac)

Elevational Range: 1515–1585 m (4960–5200 ft)

Other Classifications:

Jacobi (1990): D:Ch(ns,ng–xg)

Gagne & Cuddihy (1990): Akoko (*Chamaesyce*) [Montane Dry] Forest

Shaw & Douglas (1991): N/A

Rare Plant Species: *Chamaesyce olowaluana, Eragrostis deflexa, Haplostachys haplostachya, Silene lanceolata, Stenogyne angustifolia*

Associated Taxa: *Chenopodium oahuense, Eragrostis atropioides, Lipochaeta subcordata, Myoporum sandwicensis, Sida fallax*

Comments: The *Chamaesyce* Treeland is a small community found along the southern boundary of Kipuka Kalawamauna. This community was probably much larger at one time; however, wildfire and feral ungulates have drastically impacted the vegetation and reduced the community's size. Total woody plant density is 15,616 plants/ha. *Chamaesyce olowaluana* is the major overstory tree species (100 plants/ha). *Chenopodium oahuense* (10,800 plants/ha), *Dodonaea viscosa* (2200 plants/ha), and *Sida fallax* (2100 plants/ha) are the dominant understory shrubs. Total absolute aerial cover is 87%. *Pennisetum setaceum* accounts for over 45% of cover. Other important herbaceous species include *Eragrostis atropioides, Bromus rigidus, Lythrum maritimum, Lipochaeta subcordata,* and *Solanum pseudocapsicum.*

Community 20: *Chamaesyce* Treeland

Chenopodium Shrubland

21 *Chenopodium* Shrubland

Map Reference Number: 21

Substrate: Mauna Kea aa, pahoehoe, and ash

Area: 355 ha (876 ac)

Elevational Range: 1675–1890 m (5500–6200 ft)

Other Classifications:

Jacobi (1990): D:ns(ng–xg,xh)

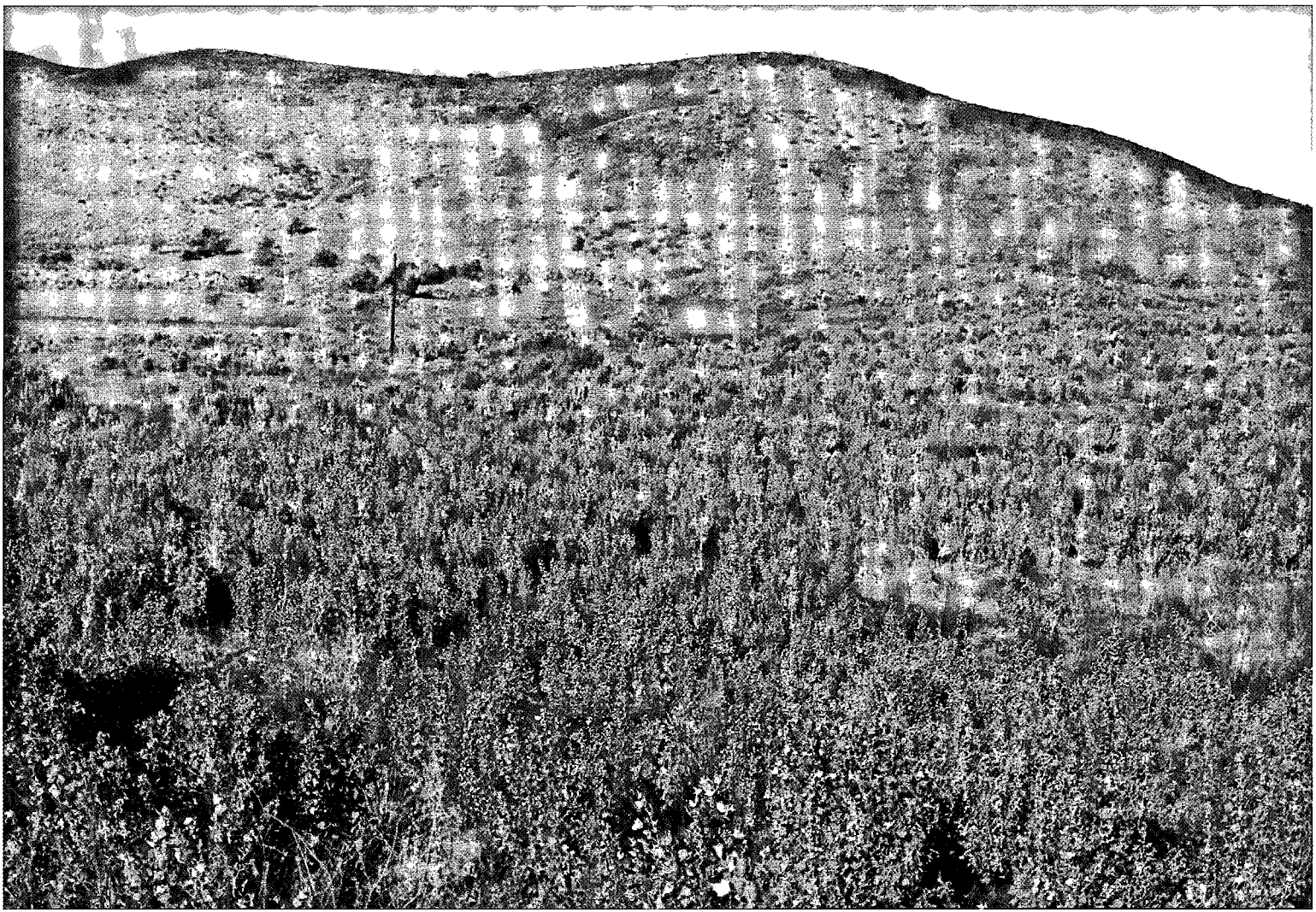
Gagne & Cuddihy (1990): Aweoweo (*Chenopodium*) Subalpine [Dry] Shrubland

Shaw & Douglas (1991): N/A

Rare Plant Species: *Chamaesyce olowaluana, Silene hawaiiensis*

Associated Taxa: *Brassica nigra, Bromus willdenowii, Lepidium hyssopifolium*

Comments: The *Chenopodium* Shrubland occurs along portions of Saddle Road in the northern portion of the installation. It primarily is found on Mauna Kea ash substrate but can extend on to aa and pahoehoe. Total woody plant density is 13,233 plants/ha, and *Chenopodium oahuense* is the only shrub encountered on the transects. A few scattered *Myoporum sandwicensis, Sophora chrysophylla,* and *Dodonaea viscosa* occur on the rougher substrates. Absolute aerial cover averages about 55%. *Eragrostis atropioides* is the dominant native grass species. Many weedy herbaceous species have invaded the community. Common weeds are *Erodium cicutarium, Lepidium hyssopifolium, Melilotus indica, Bromus rigidus,* and *Brassica campestris.* This area is heavily used for military training and many of the Disturbed Sites (Community 24) were once *Chenopodium* Shrubland.



Community 21: *Chenopodium* Shrubland

Eragrostis Grassland

22 *Eragrostis* Grassland

Map Reference Number: 22

Substrate: Mauna Kea aa, pahoehoe, ash, and cinder

Area: 1166 ha (2879 ac)

Elevational Range: 1615–1950 m (5300–6400 ft)

Other Classifications:

Jacobi (1990): D:ng

Gagne & Cuddihy (1990): Lovegrass/Mountain Pili (*Eragrostis/Panicum*) [Montana Dry] Grassland

Shaw & Douglas (1991): N/A

Rare Plant Species: *Chenopodium olowaluana, Eragrostis deflexa, Hesperocnide sandwicensis, Silene hawaiiensis*

Associated Taxa: *Brassica nigra, Dodonaea viscosa, Lepidium virginicum, Panicum tenuifolium*

Comments: The *Eragrostis* Grassland community is found across the northern part of the installation. It primarily occurs on Mauna Kea ash substrate; but occasionally is found on aa, broken pahoehoe, and cinder. Successionally, this community might represent the "climax" community for the saddle region, and fire may help maintain the grassland and prevent the establishment of shrubs. Woody plant density is only 5607 plants/ha, and the majority of these shrubs are *Chenopodium oahuense* (5502 plants/ha). The woody vegetation typically only occurs along the ecotone between the grassland and the adjoining *Chenopodium* Shrubland. Total aerial cover is over 60%. Native grasses predominate, and the most common species are *Eragrostis atropioides, Stipa cernua, Trisetum glomeratum* and *Panicum tenuifolium.* The alien grass species, *Pennisetum setaceum* has not been able to establish and dominate this community. It is only occasionally encountered. Weedy forbs (*Erodium cicutarium, Heterotheca grandiflora, Lepidium hyssopifolium, Tagetes minuta, Tribulus terrestris, Verbascum thapsus, Verbesina encelioides)* have invaded much of the area. Military training has negatively impacted the structure of this community.

Community 22: *Eragrostis* Grassland

Pennisetum Grassland

23 *Pennisetum* Grassland

Map Reference Number: 23

Substrate: Mauna Kea and Mauna Loa aa, pahoehoe, cinder, and ash

Area: 610 ha (1507 ac)

Elevational Range: 1265–1855 m (4160–6080 ft)

Other Classifications:

Jacobi (1990): D:xg

Gagne & Cuddihy (1990): Fountain Grass (*Pennisetum*) [Lowland Dry] Grassland

Shaw & Douglas (1991): N/A

Rare Plant Species: *Asplenium fragile, Eragrostis deflexa, Silene lanceolata, Stenogyne angustifolia, Tetramolopium consanguineum*

Associated Taxa: *Lepidium virginicum, Verbascum thapsus*

Comments: The *Pennisetum* Grassland community occurs in frequently burned areas within the impact area and Kipuka Kalawamauna. Almost no woody vegetation survives (66 plants/ha) in these areas because of fire intensity and frequency. Only occasionally will one encounter an individual of *Dodonaea viscosa* (17 plants/ha), *Myoporum sandwicensis* (33 plants/ha) , or *Sida fallax* (17 plants/ha). Absolute aerial cover exceeds 100% and is dominated by *P. setaceum.* These areas become virtual monocultures of *P. setaceum,* and represent one of the most sterile environments on the installation.

Community 23: *Pennisetum* Grassland

Disturbed

24 Disturbed

Map Reference Number: 24

Substrate: Mauna Kea and Mauna Loa aa, pahoehoe, cinder, and ash

Area: 417 ha (1028 ac)

Elevational Range: 1430–2010 m (4700–6600 ft)

Other Classifications:

Jacobi (1990): N/A

Gagne & Cuddihy (1990): N/A

Shaw & Douglas (1991): Disturbed, Intermediate SOCH/MYSA, Dense SOCH/MYSA

Rare Plant Species: *Chamaesyce olowaluana, Silene hawaiiensis*

Associated Taxa: *Brassica nigra, Pennisetum setaceum, Verbascum thapsus*

Comments: The Disturbed community type is restricted to heavily impacted areas used primarily for military training. These include bivouac sites, staging and refueling areas, firing points, landing zones, etc. These areas are restricted mostly to the northern portion of the installation, around cinder cones (puu) and along Redleg Trail. During periods of heavy use, almost no perennial vegetation is present on these sites with the exception of a few individuals of the *Pennisetum clandestinum* or *Cynodon dactylon.* With rest and some moisture, the sites become a weed patch. Herbaceous plants include *Atriplex semibaccata, Avena fatua, Brassica campestris, B. nigra, Bromus rigidus, Dactylis glomerata, Erodium cicutarium, Gnaphalium* spp., *Heterotheca grandiflora, Hordeum vulgare, Lepidium virginicum, Malva parviflora, Melilotus indica, Medicago lupulina, Plantago lanceolata,* and *Sporobolus indicus.*

Community 24: Disturbed

3 Ecological Checklist

Surveys of the botanical resources at the Pohakuloa Training Area (PTA) have been nearly continuous since November 1988. The following is a list of vascular plant species collected at PTA. This species list is maintained by the Floristics Laboratory at the Center for Ecological Management of Military Lands (CEMML), Colorado State University. Nomenclature and other information concerning the Pteridophyta (ferns) was provided by Alan R. Smith (pers. comm.). Wagner et al. (1990) was the reference for nomenclature concerning the Anthophyta (flowering plants). The species list becomes an ecological checklist when the occurrence of each taxon is reported by plant community. Locations are based on our field observations and others will certainly find taxa in areas we have not visited.

The checklist is arranged alphabetically by family, genus, species, subspecies, and variety within each major category [Pteridophyta, Coniferophyta, Anthophyta, Liliopsida (monocot), and Magnoliopsida (dicot)].

The scientific name and following information is given for each taxa:

L = Life span or longevity: annual (A) or perennial (P).
A = Affinity: endemic (E), indigenous (I), naturalized (N), uncertain (?).
H = Habit: fern and fern allies (F), grass (G), herbaceous (H), parasite (P), shrub (S), tree (T), vine (V).
S = Status under the Endangered Species Act: endangered (E); threatened (T), species of concern (S), none (–).
1 = Barren Lava
2 = Sparse *Metrosideros* Treeland
3 = Open *Metrosideros* Treeland with sparse shrub understory
4 = Open *Metrosideros* Treeland with dense shrub understory
5 = Intermediate *Metrosideros* Mixed Treeland
6 = Open *Dodonaea* Shrubland
7 = Dense *Dodonaea* Shrubland
8 = *Dodonaea* Mixed Shrubland
9 = *Styphelia–Dodonaea* Shrubland
10 = *Styphelia* Mixed Shrubland
11 = *Myoporum* Shrubland
12 = *Myoporum–Chamaesyce* Treeland
13 = *Myoporum–Dodonaea* Shrubland
14 = *Myoporum–Sophora* Mixed Shrubland
15 = *Myoporum–Sophora* Shrubland with forb understory
16 = *Myoporum–Sophora* Shrubland with grass understory
17 = *Sophora–Myoporum–Chamaesyce* Shrubland
18 = *Sophora–Myoporum* Shrubland with forb understory
19 = *Sophora–Myoporum* Shrubland with grass understory
20 = *Chamaesyce* Treeland
21 = *Chenopodium* Shrubland
22 = *Eragrostis* Grassland
23 = *Pennisetum* Grassland
24 = Disturbed

Scientific Name	D	A	L	S	Communities
PTERIDOPHYTA					
ASPLENIACEAE					
Asplenium adiantum-nigrum L.	P	I	F	-	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 23
Asplenium fragile K. Presl var. *insulare* C. Morton (SYN=*A. rhomboideum* Brack.)	P	E	F	E	1 2 3 4 14 17
Asplenium praemorsum Sw. (SYN=*A. rhipidoneuron* B. L. Robins.)	P	I	F	-	23
Asplenium trichomanes L.	P	I	F	-	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Cheilanthes decora (Brack.) R. M. & A. F. Tryon (SYN=*Dryopteris decora* Brack.)	P	E	F	-	
BLECHNACEAE					
Sadleria cyatheoides Kaulf.	P	E	F	-	1 2 3 4 5 7 9 10 11 13 14 15 16 18 19
DENNSTAEDTIACEAE					
Lindsaea repens (Bory) Thwaites var. *macaraeana* (Hook. & Arnott) Mett. ex Kuhn	P	E	F	-	
Pteridium aquilinum (L.) Kuhn var. *decompositum* (Gaud.) R. Tryon	P	E	F	-	2 3 4 6 9 13 14 18
DRYOPTERIDACEAE					
Cyrtomium falcatum (L. f.) K. Presl	P	N	F	-	1 2 3 4 12 13
Cystopteris douglasii Hook.	P	E	F	-	2 3 9 14 18 19
Dryopteris wallichiana (Spreng.) Hyl.	P	I	F	-	9 14 18
Nephrolepis exaltata (L.) Schott ssp. *hawaiiensis* W. H. Wagner, ined.	P	E	F	-	2 3 4

Scientific Name	D	A	L	S	Communities
					1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
POLYPODIACEAE					
Lepisorus thunbergianus (Kaulf.) Ching (SYN=*Pleopeltis thunbergiana* Kaulf.)	P	I	F	-	1 2 3 4 5 9 13
Polypodium pellucidum Kaulf. var. *vulcanicum* Skottsb.	P	E	F	-	1 2 3 4 9
PSILOTACEAE					
Psilotum nudum (L.) P. Beauv.	P	I	F	-	1 2 3 4 5 9 13
PTERIDACEAE					
Adiantum raddianum K. Presl	P	N	F	-	1 4 12 13
Pellaea ternifolia (Cav.) Link	P	I	F	-	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Pteris cretica L.	P	N	F	-	1 2 3 9 11 14 18 19
THELYPTERIDACEAE					
Christella parasitica (L.) H. Lév.	P	N	F	-	8 11
CONIFEROPHYTA					
PINACEAE					
Pinus coulteri D. Don	P	N	T	-	19 24
Pinus radiata D. Don	P	N	T	-	18 19 24
ANTHOPHYTA					
LILIOPSIDA					
AGAVACEAE					
Cordyline fruticosa (L.) A. Chev.	P	N	S	-	4

Scientific Name	D	A	L	S	Communities
CYPERACEAE					
Bulbostylis capillaris (L.) C. B. Clarke	A	N	H	-	1 2 3 4 5 7 9 10 11 14 18 24
Carex inversa R. Br.	P	N	H	-	10 14
Carex wahuensis C. A. Mey. ssp. *rubiginosa* (R. Krauss) T. Koyama	P	E	H	-	3 4 5
Carex wahuensis C. A. Mey. ssp. *wahuensis*	P	E	H	-	2 3 4 5 7 8 9 10 11 14 15 16
Gahnia gahniiformis (Gaud.) A. Heller	P	I	H	-	2 3 4 5 7 8 9 10
Mariscus hillebrandii (Boeck.) T. Koyama ssp. *hillebrandii*	P	E	H	-	2 3 4 5 6 7 8 9 10 11 13 14 18 19 20
JUNCACEAE					
Luzula hawaiiensis Buchenau var. *hawaiiensis*	P	E	H	-	2 3 4 7 10 11 14 18 19
LILIACEAE					
Dianella sandwicensis Hook. & Arnott	P	I	H	-	2 3 4 7 17 18
POACEAE					
Agrostis avenacea J. G. Gmelin	P	I	G	-	2 3 4 6 7 8 9 10 11 13 14 15 18 19 20 24
Agrostis sandwicensis Hillebr.	P	E	G	-	1 2 9
Anthoxanthum odoratum L.	P	N	G	-	15 18 19
Avena fatua L.	A	N	G	-	6 7 8 11 12 13 14 21 22 23 24
Briza minor L.	A	N	G	-	8 14 21 22 23 24
Bromus rigidus Roth (SYN = *Bromus diandrus* Roth)	A	N	G	-	5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Bromus willdenowii Kunth (SYN = *Bromus catharticus* Vahl)	A/P	N	G	-	6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Chloris gayana Kunth	A	N	G	-	8 14 22 24
Cynodon dactylon (L.) Pers.	P	N	G	-	8 18 22

Scientific Name	D	A	L	S	Communities
POACEAE cont.					
Dactylis glomerata L.	P	N	G	-	6 7 8 9 10 14 16 18 19 21 22 23 24
Danthonia pilosa R. Br.	P	N	G	-	2 3 4 7 8 9 11 14 17 18 19
Deschampsia nubigena Hillebr.	P	E	G	-	9 17 18 19
Ehrharta calycina Smith	P	N	G	-	17 18 19
Ehrharta stipoides Labill. [SYN=*Microlaena stipoides* (Labill.) R. Br.]	P	N	G	-	3 4 5 7 8 9 10 11 12 13 14 15 18 19 24
Eragrostis atropioides Hillebr.	P	E	G	-	5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Eragrostis brownei (Kunth) Nees ex Steud.	P	N	G	-	5 7 9 10 11 13 14 15 16
Eragrostis deflexa Hitchc.	P	E	G	S	2 3 4 5 6 7 8 9 10 11 13 14 15 19
Eragrostis leptophylla Hitchc.	P	E	G	-	7 9 10 11 14 17 18 19 22 23
Festuca hawaiiensis Hitchc.	P	E	G	S	2 3 4 5 7 10 11 14
Gastridium ventricosum (Gouan) Schinz & Thell.	A	N	G	-	19
Holcus lanatus L.	P	N	G	-	8 18 19 22 23 24
Hordeum leporinum Link [SYN=*Hordeum murinum* L. ssp. *leporinum* (Link) Arcang.]	A	N	G	-	6 8 13 22
Koeleria nitida Nutt. [SYN=*Koeleria macrantha* (Ledeb.) Schutes]	P	N	G	-	6 8 13 21 22
Lolium perenne L.	P	N	G	-	6 8 19 22 23 24
Melinis minutiflora P. Beauv.	P	N	G	-	3 4 5 19 21 22 24
Panicum konaense Whitney & Hosaka	A	E	G	-	2 3 4 5 7 10 11 14 17 20
Panicum pellitum Trin.	A	E	G	-	7 10 11 14 15 19
Panicum tenuifolium Hook. & Arnott	P	E	G	-	7 10 11 14 15 16 17 18 19 20 22 24
Paspalum dilatatum Poir.	P	N	G	-	6
Paspalum notatum Flugge	P	N	G	-	6 24
Pennisetum clandestinum Chiov.	P	N	G	-	15 17 18 19 22 23 24
Pennisetum setaceum (Forssk.) Chiov.	P	N	G	-	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Poa annua L.	A	N	G	-	7 10 11 14 15 16

Scientific Name	D	A	L	S	Communities
					1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
POACEAE cont.					
Poa pratensis L.	P	N	G	-	14 18 19 24
Polypogon interruptus Kunth	P	N	G	-	2 3 7 9 10 11 14 15 16 18
Polypogon monspeliensis (L.) Desf.	A	N	G	-	7 10 11 14 18 19
Rhynchelytrum repens (Willd.) Hubb.	A/P	N	G	-	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Sporobolus africanus (Poir.) Robyns & Tourney	P	N	G	-	6 8 22 23 24
Sporobolus indicus (L.) R. Br.	P	N	G	-	5 6 7 8 10 11 14 18 19 20 21 22 23 24
Stipa cernua Stebb. & A. Love [SYN=*Nassella cernua* (Stebb. & A. Love) Barkworth]	P	N	G	-	6 8 17 18 19 21 22 24
Trisetum glomeratum (Kunth) Trin.	P	E	G	-	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Vulpia bromoides (L.) S. F. Gray	A	N	G	-	2 3 4 5 7 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Vulpia myuros (L.) C. C. Gmelin	A	N	G	-	2 3 4 8 9 11 12 13 14 15 16 17 18 19 20 21 22 23 24
SMILACACEAE					
Smilax melastomifolia Sm.	P	E	V	-	3
MAGNOLIOPSIDA					
AIZOACEAE					
Lampranthus glomerata (L.) N. E. Br.	P	N	S	-	24
AMARANTHACEAE					
Nototrichium sandwicense (A. Gray) Hillebr.	P	E	S/T	-	11
APIACEAE					
Ciclospermum leptophyllum (Pers.) Sprague	A	N	H	-	11 14 15 16 17 18 19
Daucus pusillus Michx.	A	N	H	-	2 3 4 5 6 7 8 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Foeniculum vulgare Mill.	P	N	H	-	6 8 13 22
Petroselinum crispum (Mill.) A. W. Hill	P	N	H	-	6 22
Spermolepis hawaiiensis Wolff	A	E	H	E	2 3 4 5 14 15 16

Scientific Name	D	A	L	S	Communities
					1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
APOCYNACEAE					
Alyxia oliviformis Gaud.	P	E	S/V	-	4 5
ASCLEPIADACEAE					
Asclepias curassavica L.	P	N	H	-	2 3
Asclepias physocarpa (E. Mey.) Schlecter	P	N	H	-	2 3 11 14 15 17 18 19
ASTERACEAE					
Achillea millefolium L.	P	N	H	-	2 3 15 16 18 19 21 22 23 24
Ageratina riparia (Regel) R. King & H. Robinson	P	N	S	-	3 7 8 14 24
Ageratum conyzoides L.	A/P	N	H	-	2 3 4
Ambrosia pumila (Nutt.) A. Gray	P	N	H	-	24
Anthemis cotula L.	A	N	H	-	11 13 17 18 19 24
Bidens alba (L.) DC var. *radiata* (Schultz-Bip.) Ballard ex Melchert	A/P	N	H	-	1 2 3 4 5 6 7 8 10 11 12 13 14 15 18 19 20 21 22 23 24
Bidens menziesii (A. Gray) Sherff ssp. *filiformis* (Sherff) Ganders & Nagata	P	E	S	-	6 7 8 10 11 14 18 22
Bidens pilosa L.	A	N	H	-	2 3 4 5 6 7 8 9 10 11 12 13 17 18 19 20 21 22 23 24
Centaurea melitensis L.	A	N	H	-	6 7 8 11 15 21 22 24
Cirsium vulgare (Savi) Ten.	P	N	H	-	3 6 8 9 10 11 14 15 16 18 19 20 21 22 23 24
Conyza bonariensis (L.) Cronq.	A	N	H	-	6 8 18 19 20 21 22 23 24
Conyza canadensis (L.) Cronq. var. *canadensis*	A	N	H	-	11 19 21 22 23 24
Conyza canadensis (L.) Cronq. var. *pusilla* (Nutt.) Cronq.	A	N	H	-	5 9 18 19 20
Crassocephalum crepidioides (Benth.) S. Moore	A	N	H	-	5 6 8 11 22 24
Crepis capillaris (L.) Wallr.	A/P	N	H	-	7 8 10 11 14 15 16 18 19 20 21
Dubautia ciliolata (DC) D. Keck ssp. *ciliolata*	P	E	S	-	2 3 4 8 9

Scientific Name	D	A	L	S	Communities
ASTERACEAE cont.					
Dubautia linearis (Gaud.) D. Keck ssp. *hillebrandii* (H. Mann) G. Carr	P	E	S	-	2 3 4 5 6 8 9 10 20 22 23
Dubautia scabra (DC) D. Keck	P	E	S	-	2 9
Emilia fosbergii Nicolson	A	N	H	-	2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 18 19 20 21 22 23 24
Galinsoga parviflora Cav.	A	N	H	-	2 3 4 5 6 8 11 12 13 14 15 16 17 18 19 20 22 23 24
Galinsoga quadriradiata Ruiz & Pav.	A	N	H	-	5 6 8 11 12 13
Gnaphalium japonicum Thunb.	A	N	H	-	2 3 4 5 7 10 14 19 22 24
Gnaphalium purpureum L. [SYN=*Gamochaeta purpurea* (L.) Cabrera]	A/P	N	H	-	2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Gnaphalium sandwicensium Gaud. var. *hawaiiense* (Degener & Sherff) W. L. Wagner, Herbst & Sohmer	P	E	H	-	9 11 13
Gnaphalium sandwicensium Gaud. var. *kilaueanum* Degener & Sherff	P	E	H	-	2 3 4 5 6 7 8 9 10 11 13 14 15 16 18 19 20 21 22
Gnaphalium sandwicensium Gaud. var. *sandwicensium*	P	E	H	-	8 13
Helichrysum foetidum (L.) Cass.	P	N	H	-	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Heterotheca grandiflora Nutt.	A/P	N	H	-	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hypochoeris radicata L.	P	N	H	-	2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Lactuca serriola L.	P	N	H	-	2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Lipochaeta subcordata A. Gray	P	E	H	-	6 8 11 13 20
Picris hieracioides L.	P	N	H	-	1 2 3 4 5 6 7 8 9 10 14 15 16 18 19 20 21 22 23 24
Pluchea symphytifolia (Mill.) Gillis	P	N	S	-	1 24
Reichardia tingitana (L.) Roth	A/P	N	H	-	6 22
Senecio mikanioides Otto ex Walp.	P	N	V	-	7 8 11 12 13 14 15 16 17 18 19 20 23 24
Senecio sylvaticus L.	A	N	H	-	2 3 4 5 7 10 11 13 14 15 16 18 19 23 24
Senecio vulgaris L.	A	N	H	-	2 3 4 5 14 15 16 17 18 19
Sigesbeckia orientalis L.	A	N	H	-	2 3 4 5 6 8 11 14 19 20 21 22 23 24

Scientific Name	D	A	L	S	Communities
					1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
ASTERACEAE cont.					
Sonchus asper (L.) J. Hill	A	N	H	-	2 3 4 5 6 7 8 14 15 16 17 18 19 20 21 22 23 24
Sonchus oleraceus L.	A	N	H	-	2 3 4 5 6 8 18 19 20 21 22 23 24
Tagetes minuta L.	A	N	H	-	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Tetramolopium arenarium (A. Gray) Hillebr.	P	E	S	E	8
Tetramolopium consanguineum (A. Gray) Hillebr. ssp. *leptophyllum* (Sherff) Lowrey var. *leptophyllum*	P	E	S	S	2 3 4 5 11 13 14
Tetramolopium diersingii Shaw & Lowrey 1	P	E	S	-	13 14
Tetramolopium humile (A. Gray) Hillebr. ssp. *humile* var. *humile*	P	E	S	-	1 2 3 4 9
Tetramolopium humile (A. Gray) Hillebr. ssp. *humile* var. *sublaeve* Sherff	P	E	S	S	1 2 9
Verbesina encelioides (Cav.) Benth. & Hook.	A	N	H	-	2 3 4 5 6 7 8 9 10 11 14 15 16 18 19 20 21 22 23 24
Xanthium strumarium L. var. *candense* (Mill.) Torr. & A. Gray	A	N	H	-	15 18 24
Youngia japonica (L.) DC	A	N	H	-	2 3 4 5 6 7 8 9 10 11 13 14 20 22 23 24
Zinnia peruviana (L.) L.	A	N	H	-	1 19
BRASSICACEAE					
Brassica juncea (L.) Czernj.	A	N	H	-	
Brassica nigra (L.) W. Koch	A	N	H	-	2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Capsella rubella Reut.	A	N	H	-	6 8 21 22 23 24
Cardamine flexuosa With.	A/P	N	H	-	15 17 18 19
Coronopus didymus (L.) Sm.	A	N	H	-	6 8 20 21 22 24
Lepidium africanum (Burm. f.) DC	P	N	H	-	2 3 4 5 6 7 8 9 10 11 12 13 14 15 17 18 20 21 22 23 24
Lepidium hyssopifolium Desv.	P	N	H	-	
Lepidium virginicum L.	A/P	N	H	-	2 3 4 8 9 13 14 15 16 17 18 19 20

Scientific Name	D	A	L	S	Communities
					1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
BRASSICACEAE cont.					
Sisymbrium altissimum L.	A	N	H	-	22 24
Sisymbrium irio L.	A	N	H	-	22 24
Sisymbrium officinale (L.) Scop.	A	N	H	-	8 22 23 24
CACTACEA					
Opuntia ficus-indica (L.) Mill.	P	N	T	-	2 3 9 12 14 18 19 24
CAMPANULACEAE					
Triodanis biflora (Ruiz & Pav.) Greene [SYN = *Triodanis perfoliata* (C.) Nieuwl. var. *biflora* (Ruiz & Pav.) Bradley]	A	N	H	-	7 11 14
Wahlenbergia gracilis (G. Forster) A. DC [SYN = *Wahlenbergia marginata* (Thunb.) A. DC]	P	N	H	-	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
CAPRIFOLIACEAE					
Sambucus mexicana K. Presl. ex A. DC	P	N	S/T	-	19
CARYOPHYLLACEAE					
Arenaria serpyllifolia L.	A	N	H	-	7 11 14
Cerastium fontanum Baumg. ssp. *triviale* (Link) Jalas [SYN = *Cerastium fontanum* Baumg. ssp. *vulgare* (Hartman) Greuter & Burdet]	P	N	H	-	3 4 6 8 9 18 19
Petrorhagia velutina (Guss.) P. Ball & Heyw. [SYN = *Petrorhagia dubia* (Raf.) G. Lopez & Romo]	A	N	H	-	6 8 18
Polycarpon tetraphyllum (L.) L.	A	N	H	-	22
Schiedea pubescens Hillbr.	P	E	V	S	
Silene gallica L.	A/P	N	H	-	6 8
Silene hawaiiensis Sherff	P	E	S	T	2 3 4 6 8
Silene lanceolata A. Gray	P	E	S	E	3 4 5 6 7 8 10 11 14
Stellaria media (L.) Vill.	A/P	N	H	-	14 15 16 18 19

Scientific Name	D	A	L	S	Communities
					1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
CHENOPODIACEAE					
Atriplex semibaccata R. Br.	P	N	H	-	5 22
Atriplex suberecta Verd.	A	N	H	-	2 3
Chenopodium album L.	A	N	H	-	3 6 8 22 24
Chenopodium ambrosioides L.	A/P	N	H	-	2 3 4 8 9
Chenopodium carinatum R. Br.	A	N	H	-	2 3 4
Chenopodium murale L.	A	N	H	-	2 8 14 15 16 18 19 20 21 22
Chenopodium oahuense (Meyen) Aellen	P	E	S	-	6 8 9 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Salsola kali L.	A	N	H	-	8 13 21 22
CONVOLVULACEAE					
Ipomoea tuboides Degener & Ooststr.	P	E	V	-	8 23
Ipomoea violacea L.	P	N	V	-	23
CRASSULACEAE					
Crassula sieberiana (Schult.) Druce	A	N	H	-	2 3 4 5 6 7 8 9 10 11 12 13 14 15
Kalanchoe tubiflora (Harv.) Raym.- Hamet	P	N	H	-	3 11 13
CUCURBITACEAE					
Sicyos anunu (St. John) Telford	A	E	V	-	3 4 5 7 8 11 12 13 14 17 18 19 20
Sicyos lasiocephalus Skottsb.	A	E	V	-	3 5 7 10 11 13 14 20
EPACRIDACEAE					
Styphelia tameiameiae (Cham. & Schlechtend.) F. v. Muell.	P	I	S	-	1 2 3 4 5 6 7 8 9 10 11 13 14
ERICACEAE					
Vaccinium reticulatum Sm.	P	E	S	-	1 2 3 9

Scientific Name	D	A	L	S	Communities
					1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
EUPHORBIACEAE					
Chamaesyce albomarginata (Torr. & A. Gray) Small	P	N	H	-	11
Chamaesyce multiformis (Hook. & Arnott) Croizat & Degener var. *microphylla* (Boiss.) Degener & I. Degener	P	E	S	-	6 8 11 12 13 23
Chamaesyce olowaluana (Sherff) Croizat & Degener	P	E	T	S	3 5 6 8 10 11 12 13 14 15 16 17 18 19 20 21 22 24
Euphorbia peplus L.	A	N	H	-	8 11 15 16 22
Ricinus communis L.	P	N	S	-	21
FABACEAE					
Indigofera suffruticosa Mill.	P	N	S	-	18 19 22 23 24
Lupinus arboreus Sims.	P	N	S	-	18 19 22 23 24
Medicago lupulina L.	A/P	N	H	-	7 8 10 11 22 23 24
Medicago polymorpha L.	A	N	H	-	6 7 8 10 11 14 15 16 20 21 22 23 24
Melilotus indica (L.) All.	A	N	H	-	6 7 8 11 14 22 23 24
Sophora chrysophylla (Salisb.) Seem.	P	E	S/T	-	6 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Trifolium arvense L. var. *arvense*	A	N	H	-	6 8 18 19 24
Trifolium hybridum L. var. *hybridum*	P	N	H	-	
Trifolium pratense L. var. *sativum* Schreb.	P	N	H	-	9 18 24
Trifolium repens L. var. *repens*	P	N	H	-	8 11 24
Vicia sativa L. ssp. *nigra* (L.) Ehrh.	A	N	H	-	7 8 11 14 19 22 23
Vicia villosa Roth	A/P	N	H	-	8 11 22 23
FAGACEAE					
Quercus suber L.	P	N	T	-	18
GENTIANACEAE					
Centaurium erythraea Raf. ssp. *erythraea*	P	N	H	-	2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Scientific Name	D	A	L	S	Communities
					1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
GERANIACEAE					
Erodium cicutarium (L.) L'Hér.	A	N	H	-	2 3 4 8 9 15 16 18 19 20 21 24
Geranium cuneatum Hook. ssp. *hololeucum* (A. Gray) Carlq. & Bissing	P	E	S	-	19
Geranium homeanum Turcz.	P	N	H	-	2 3 4 14 15 16 18 19 24
Geranium retrorsum L'Hér. ex DC	P	N	H	-	
LAMIACEAE					
Haplostachys haplostachya (A. Gray) St. John	P	E	H	E	2 6 8 11 13 20
Marrubium vulgare L.	P	N	H	-	7 8 9 10 11 12 13 14 18 19 20 21 24
Plectranthus parviflorus Willd.	P	I	H	-	1 2 3 4 5 6 8 9 11 12 13 18 20 23
Stenogyne angustifolia A. Gray	P	E	V	E	2 3 4 5 6 8 10 11 14 20 23
Stenogyne microphylla Benth.	P	E	V	-	2 3 4 5 9 17 18
Stenogyne rugosa Benth.	P	E	V	-	5 15
LYTHRACEAE					
Lythrum maritimum Kunth	P	I?	S	-	6 7 8 10 11 12 13 14 15 16 20 22 23 24
MALVACEAE					
Malva parviflora L.	A/P	N	H	-	6 8 12 14 17 18 19 21 22 23 24
Sida fallax Walp.	P	I	S	-	6 8 12 13 14 18 19 20 21 22 23 24
MENISPERMACEAE					
Cocculus trilobus (Thunb.) DC	P	I	V	-	4 5 6 7 14
MYOPORACEAE					
Myoporum sandwicense A. Gray	P	I	S/T	-	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
MYRSINACEAE					
Myrsine lanaiensis Hillebr.	P	E	T	-	1 2 3 4 5 8 11 13 14 15 20 23

Scientific Name	D	A	L	S	Communities 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
MYRTACEAE					
Eucalyptus citriodora Hook.	P	N	T	-	19 22 24
Metrosideros polymorpha Gaud. var. *glaberrima* (H. Lév.) St. John	P	E	S/T	-	1 2 3 4 5
Metrosideros polymorpha Gaud. var. *polymorpha*	P	E	S/T	-	1 2 3 4 5
OLEACEAE					
Ligustrum lucidum Ait.	P	N	S/T	-	19
Olea europaea L. ssp. *europaea*	P	N	T	-	8 11 13
ONAGRACEAE					
Epilobium billardierianum Ser. ssp. *cinereum* (A. Rich.) Raven & Engelhorn	P	N	H	-	2 3 4 5 6 8 14 18 19 21 22 23 24
Oenothera stricta Ledeb. ex Link ssp. *stricta*	A/P	N	H	-	19
OXALIDACEAE					
Oxalis corniculata L.	P	N	H	-	2 3 4 5 13 14 15 16 18 19
PAPAVERACEAE					
Argemone glauca (Nutt. ex Prain) Pope var. *decipiens* Ownbey	P	E	H	-	6 8 11 14 18 19 20 21 22 23
PASSIFLORACEAE					
Passiflora mollissima (Kunth) L. H. Bailey	P	N	V	-	3 7 11 12 13 14 15 18 19 20
PIPERACEAE					
Peperomia tetraphylla (G. Forster) Hook. & Arnott	P	I	H	-	2 3 4 5 14 18

Scientific Name	D	A	L	S	Communities
					1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
PITTOSPORACEAE					
Pittosporum confertiflorum A. Gray	P	E	S/T	-	5
Pittosporum terminalioides Planch. ex A. Gray	P	E	T	-	4 5
PLANTAGINACEAE					
Plantago lanceolata L.	P	N	H	-	6 8 20 23
POLYGONACEAE					
Emex spinosa (L.) Campd.	A	N	H	-	6 8 11 20 21 22 23 24
Polygonum capitatum F. Ham.	P	N	H	-	19 24
Rumex acetosella L.	P	N	H	-	6 8
Rumex brownei Campd.	P	N	H	-	2 3 4
Rumex giganteus W. T. Aiton	P	E	S/V	-	3 4 5 7 8
Rumex skottsbergii Degener & I. Degener	P	E	S	-	2 3 4 5 6 7 8 9 10 14 18 19 20 21
PORTULACACEAE					
Portulaca oleracea L.	A	N	H	-	3 4
Portulaca sclerocarpa A. Gray	P	E	H	E	1 3 4 5 6
Portulaca villosa Cham.	P	E	H	-	6
PRIMULACEAE					
Anagallis arvensis L.	A/P	N	H	-	2 3 4
PROTEACEAE					
Grevillea robusta A. Cunn. ex R. Br.	P	N	T	-	5 6
RHAMNACEAE					
Alphitonia ponderosa Hillebr. 2	P	E	T	-	3
Rhamnus californica Eschsch. var. *californica*	P	N	S	-	18

Scientific Name	D	A	L	S	Communities
					1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
ROSACEAE					
Heteromeles arbutifolia Roem.	P	N	S	-	18
Osteomeles anthyllidifolia (Sm.) Lindl.	P	I	S	-	2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Rubus rosifolius Sm.	P	N	S	-	15
RUBIACEAE					
Coprosma ernodeoides A. Gray	P	E	S	-	1 2 3 9
Coprosma montana Hillebr.	P	E	S/T	-	2 3 4 5 10 11 13 14 15
Hedyotis coriacea Sm.	P	E	S	E	2 3 4
RUTACEAE					
Melicope hawaiensis (Wawra) T. G. Hartley & B. C. Stone (SYN=*Pelea hawaiensis* Wawra)	P	E	S/T	S	4 5 13
Zanthoxylum hawaiiense Hillebr.	P	E	T	E	3 4 5 13
SANTALACEAE					
Exocarpos gaudichaudii A. DC	P	E	S/T	S	2 3 4 5
Exocarpos menziesii Stauffer	P	E	S	-	2 3 9
Santalum ellipticum Gaud.	P	E	S/T	-	8 11
Santalum paniculatum Hook. & Arnott var. *paniculatum*	P	E	S/T	-	2 3 4 5 6 8 13 14 15 16 18 19 20 21 22 23
Santalum paniculatum Hook. & Arnott var. *pilgeri* (Rock) Stemmermann	P	E	S/T	-	19
SAPINDACEAE					
Dodonaea viscosa Jacq.	P	I	S/T	-	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Scientific Name	D	A	L	S	Communities
					1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
SCROPHULARIACEAE					
Lophospermum erubescens D. Don	P	N	V	-	3
Verbascum thapsus L.	P	N	H	-	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Verbascum virgatum Stokes	P	N	H	-	19
Veronica plebeia R. Br.	A/P	N	H	-	19
Veronica serpyllifolia L.	P	N	H	-	19 24
SOLANACEAE					
Datura stramonium L.	A	N	H	-	14
Nicotiana tabacum L.	P	N	H	-	2
Physalis peruviana L.	P	N	S	-	2 3 4 15 16 17 18 19
Solanum americanum Mill.	A/P	I?	H/S	-	2 3 4 5 6 8 10
Solanum incompletum Dunal	P	E	S	E	3 11
Solanum nigrescens Mart. & Galeotti	P	N	H/S	-	3 4 5 6 8 10 14 15 17 18 19 20
Solanum pseudocapsicum L.	P	N	S	-	2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
THYMELAEACEAE					
Wikstroemia phillyreifolia A. Gray	P	E	S/T	-	2 3 4 5 8 9
URTICACEAE					
Hesperocnide sandwicensis (Wedd.) Wedd.	A	E	H	-	2 3 4 5 6 8 11 12 13 14 15 16 17 18 19 20
Neraudia ovata Gaud.	P	E	S	E	3
Urtica urens L.	A	N	H	-	2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
VERBENACEAE					
Verbena litoralis Kunth	P	N	H	-	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Scientific Name	D	A	L	S	Communities
					1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
VISCACEAE					
Korthalsella complanata (Tiegh.) Engl.	P	I	P	-	3 4 15 18 19
Korthalsella latissima (Tiegh.) Danser	P	E	P	-	11 15 18 19
ZYGOPHYLLACEAE					
Tribulus terrestris L.	A	N	H	-	9 21 22 23 24

[1] Unpublished
[2] Personal communication, Joel Lau 1996.

LITERATURE CITED

Bern, C. M. 1995. Land Condition-Trend Analysis Summary of Vegetation Monitoring, Pohakuloa Training Area, Hawaii. 1989–1993. Center for Ecological Management of Military Lands, Department of Forest Sciences, Colorado State University, Fort Collins, CO. CEMML TPS 95-4

Bruegmann, M. M. 1995. Endangered and threatened wildlife and plants; proposed endangered status for thirteen plants from the Island of Hawaii, State of Hawaii. Fed. Reg. 60: 49377-49392.

Bruegmann, M. M., J. E. Canfield and D. R. Herbst. 1994. Endangered and threatened wildlife and plants; endangered status for four ferns from the Hawaiian Islands. Fed. Reg. 59: 49025-49032.

Canfield, J. E., D. R. Herbst and A. Asquith. 1994. Endangered and threatened wildlife and plants; endangered status for 12 plants from the Hawaiian Islands. Fed. Reg. 59:56333-56351.

Castillo, J. M., T. Tierney, and R. B. Shaw. 1997. Plant Community Types of Pohakuloa Training Area, Hawaii. Center for Ecological Management of Military Lands, Colorado State University, Fort Collins, CO. Map.

Diersing, V. E., R. B. Shaw, and D. J. Tazik. 1992. US Army Land Condition-Trend Analysis (LCTA) Program. Envir. Manage. 16:405-414.

Gagne, W. C. and L. W. Cuddihy. 1990. Vegetation. *In*: Wagner, W. L., D. R. Herbst and S. H. Sohmer. 1990. Manual of the Flowering Plants of Hawaii. University of Hawaii Press and Bishop Museum Press, Honolulu, Hawaii.

Herbst, D. R., J. E. Canfield, J. M. Yoshioka, and Z. E. Ellshoff. 1992a. Endangered and threatened wildlife and plants; determination of endangered and threatened status for 15 plants from the island of Maui. Fed. Reg. 57:20772-20878.

Herbst, D. R., J. E. Canfield, J. M. Yoshioka, and Z. E. Ellshoff. 1992b. Endangered and threatened wildlife and plants; determination of endangered and threatened status for 16 plants from the island of Molokai. Fed. Reg. 57:46325-46340.

Herbst, D. R. and J. J. Fay 1979. Endangered and threatened wildlife and plants; determination that three Hawaiian plants are endangered species. Fed. Reg. 44:62468-62469.

Jacobi, J. D. 1990. Distribution maps, ecological relationships, and current status of native plant communities on the island of Hawaii, Ph.D. diss., Univ. of Hawaii, Honolulu, Hawaii.

Langeheim, V. A. and D. A. Clauge. 1987. The Hawaiian Emperor Volcanic Chain. Part II. Stratigraphic framework of volcanic rocks of the Hawaiian Islands. IN: R. W. Decker, T. L. Wright and P. H. Stauffer (eds.). Vol. 1. U. S. Geological Survey Professional Paper 1350.

Loope, L. L. and P. G. Scowcroft. 1985. Vegetation response within exclosures in Hawaii: A review. IN: C. P. Stone and J. M. Scott (eds.). Hawaii's Terrestrial Ecosystems: preservation and management. University of Hawaii Press, Honolulu, HI.

MacDonald, G. A. 1949. Petrography of the Island of Hawaii. U.S. Geological Survey Professional Paper 214D. Map.

Mehrhoff, L. A. 1994. Endangered and threatened wildlife and plants; determination of endangered or threatened status for 21 plants from the Island of Hawaii, State of Hawaii. Fed. Reg. 59: 10305-10325.

Sato, H. H., W. Ikeda, R. Paeth, R. Smyth and M. Takehiro. 1973. Soil survey of the island of Hawaii. USDA Soil Conservation Service in cooperation with the University of Hawaii.

Shaw, R. B. 1997. Rare Plants of Pohakuloa Training Area, Hawaii. Center for Ecological Management of Military Lands, Department of Forest Sciences, Colorado State University, Fort Collins, CO

Shaw, R. B., S. L. Anderson, K. A. Schulz, and V. E. Diersing. 1989. Plant Communities, Ecological Checklist and Species List for the U.S. Army Pinon Canyon Maneuver Site, Colorado. Department of Range Science, Colorado State University, Fort Collins, CO. Science Series No. 37.

Shaw, R. B., C. M. Bern, K. A. Schulz, V. E. Diersing, and D. J. Tazik. 1990. U. S. Army Land Condition/Trend Analysis of the Pohakuloa Training Area, Hawaii. Proceedings of the International Symposium on Tropical Hydrology and Caribbean Islands Water Resources Congress. American Water Resources Association. San Juan, PR.

Shaw, R. B. and P. P. Douglas. 1991. Botanical Survey of the Multipurpose Range Complex, Pohakuloa Training, Area, Hawaii, Hawaii, USA. Unpublished Report. Department of Range Science, Colorado State University, Fort Collins, CO.

Stearns, H. T. and G. A. MacDonald. 1946. Geology and ground-water resources of the Island of Hawaii. Hawaii Division of Hydrology Bulletin 7.

U.S. Fish and Wildlife Service. 1997. Species List for the State of Hawaii, May. U.S.D.I. Fish and Wildlife Service, Pacific Islands Ecoregion, Honolulu, Hawaii.

Wagner, W. L., D. R. Herbst and S. H. Sohmer. 1990. Manual of the Flowering Plants of Hawaii. University of Hawaii Press and Bishop Museum Press, Honolulu, Hawaii.

Wolfe, E. W. and J. Morris. 1996. Geologic Map of the Island of Hawaii. U.S. Geologic Survey. Miscellaneous Investigations Series. Map 1-2524-A.