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Recent Observations on the Plants of Nihoa Island, Northwestern Hawaiian Islands[1]

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ABSTRACT: Terrestrial plants on Nihoa Island were censused, mapped, and collected during four expeditions to the island between May 1980 and May 1983. Distribution, abundance, and phenology of the vascular plants are reported, including maps and population estimates for the rarer species. With the possible exception of the exceedingly rare *Amaranthus brownii*, the island's endemic plants are present in small but stable populations. A total of 7 months of field work, including the first extended winter expedition to the island, permitted exhaustive searches for rare species and opportunities to estimate populations of winter annuals. Apparently, only one alien plant, *Portulaca oleracea*, is abundant on the island. A second alien species, *Nephrolepis multiflora*, probably reached the island naturally via wind or bird dispersal and occurs in very limited numbers.

NIHOA IS THE SOUTHERNMOST of those islands referred to as the Northwestern Hawaiian Islands (NWHI) or leeward Hawaiian Islands. It is about 250 statute miles northwest of Honolulu and about 155 statute miles southeast of Necker Island. Nihoa is about 63 ha in area, rising to 273 m at its highest point (Miller Peak), with an average southward facing slope of 45° (Palmer 1927). There is one nearly inaccessible beach on the south shore, most of which consists of low (10–20 m) cliffs, while the east, north, and west coasts are sheer cliffs, sometimes as high as 250 m. The island is part of the Hawaiian Islands National Wildlife Refuge (HINWR), which includes all of the NWHI except Midway and Kure. This refuge is managed by the U.S. Fish and Wildlife Service (FWS).

Nihoa has two endemic species of birds, both of which are considered endangered: the Nihoa millerbird (Muscicapidae: *Acrocephalus familiaris*) and the Nihoa finch (Drepanidinae: *Telespyza ultima*). In addition, there are 17 species of breeding seabirds and a number of migratory shore birds and accidental or vagrant bird species (Conant 1983). A small population of the endangered Hawaiian monk seal (*Monachus schauinslandi*) is resident, and individuals of the threatened green sea turtle (*Chelonia mydas*) may be seen foraging on marine algae near the rocky shorelines. There are also over 35 endemic arthropods, including a number of newly discovered, undescribed species (Conant et al. 1983).

Nihoa has the most diverse biota, and probably the most intact biota, of any of the islands in the northwestern group (Conant et al. 1983). It may also be one of the only places remaining in the entire Hawaiian archipelago where there is a diverse and relatively intact low-elevation dry-land ecosystem, with its complement of native terrestrial plants, arthropods, and birds. Emory (1928) conjectured that 170 to 200 people occupied Nihoa for an undetermined period of time. He also noted that the character of the archaeological sites suggested that the main occupation took place early in the Hawaiian sequence, rather than during the last several hundred years before contact. The fact that there was a period of human occupation could mean that enough disturbance took place to have caused some extinctions of native organisms (Olson and

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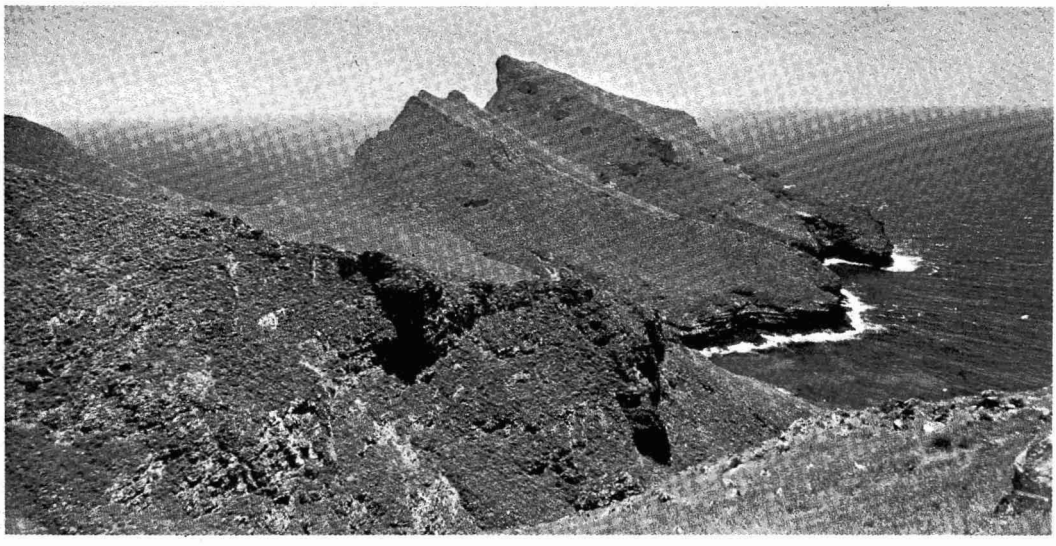

FIGURE 1. View of Nihoa Island from the summit of Dog's Head.

James 1982). Nevertheless, Nihoa remains biotically the "gem" of the northwestern islands of the Hawaiian archipelago.

Of the 26 vascular plant species that have been recorded from the island (Christophersen and Caum 1931, Conant and Herbst 1983, Herbst 1977), 5 are alien, 17 are indigenous, and 4 are endemic to the island. The objective of this paper is to update information on the status and distribution of the vascular plants of Nihoa, providing distribution maps and population estimates for the rarer species. Herbst's (1977) discussion of the vegetation of Nihoa provides the starting point from which I began assembling new information. I also have included some notes on my collections and brief observations of lichens and algae. Figure 1 is a photograph of the island, showing the terrain and major topographic features.

METHODS

The majority of the information reported in this paper is based on observations made during reconnaissance of vegetation or during the course of my studies of birds and invertebrates on four different expeditions to the island. Although I collected a few plants during the first three expeditions, I made systematic collections of all species present on the fourth, depositing all specimens in the Herbarium Pacificum of the Bernice P. Bishop Museum (BISH). During the third and fourth expeditions, some seeds and live plant materials were collected and subsequently deposited at the Waimea Arboretum.

The dates of my four expeditions and the names of my co-workers on these expeditions are as follows: 31 May to 6 July 1980 (Mark S. Collins), 31 January to 22 February 1981 (Mark J. Rauzon), 18 May to 23 August 1981 (Audrey L. Newman through 19 July and David P. McCauley thereafter), and 19 April to 3 May 1983 (Wayne C. Gagné).

In the summer of 1981, I estimated the percent cover of the various plant species in each of 74 sample plots (76 × 76 m). In 1980, Mark Collins of the U.S. Forest Service and I had marked off all the accessible parts of the island into plots that were approximately the same size (250 × 250 ft) and location as those sampled by FWS biologist John Sincock (unpublished data), who also estimated the percent cover of the species in these plots in May of 1969. My objective was to determine the relative abundance of the various plant species present. Values for total cover of the various species are reported in Table 4.

TABLE 1

RAINFALL DATA FROM FRENCH FRIGATE SHOALS (TERN ISLAND) AND MĀNĀ, KAUA 'I, FOR THE PERIODS PRECEDING EXPEDITIONS DESCRIBED IN THIS PAPER

MONTH AND YEAR		RAINFALL (in.) FRENCH FRIGATE SHOALS	MĀNĀ
December	1979	na	1.52
January	1980	na	4.60
February	1980	na	1.70
March	1980	na	0.42
April	1980	na	0.36
May	1980	na	6.63
June	1980	na	1.38
August	1980	1.46	0.64
September	1980	3.84	0.29
October	1980	na	0.27
November	1980	na	0.38
December	1980	5.18	5.27
January	1981	2.67	1.45
February	1981	3.56	2.53
March*	1981	0.36	0.29
April*	1981	0.83	1.01
May*	1981	0.39	0.26
June*	1981	1.18	1.16
July*	1981	0.92	0.91
August*	1981	1.64	1.39
September	1982	2.56	0.30
October	1982	4.69	14.14
November	1982	6.17	5.51
December	1982	1.86	5.22
January	1983	0.61	0.35
February	1983	0.49	0.15
March	1983	0.56	1.33
April	1983	0.85	0.07
May	1983	1.19	—

NOTE: na = data not available.

*Rainfall data for these periods were actually recorded from mid-month to mid-month, such that the data for March were recorded from 15 March to 15 April, for April from 15 April to 15 May, and so on.

PHENOLOGY

During the several expeditions I kept anecdotal notes on phenology of the various plant species. Because plant phenology on Nihoa is probably influenced by the temporal distribution and amount of rainfall, I acquired rainfall data from the FWS field station on Tern Island, French Frigate Shoals, about 300 mi northwest of Nihoa Island, and from the National Weather Service station at Mānā, on the northwestern, leeward coast of Kaua'i (Table 1). For the most part, rainfall amounts from French Frigate Shoals and Mānā correspond, but there are a few months where data are markedly different (e.g., October 1982). Rainfall was greatest in the months of December, January, and February in 1979–1980 and 1980–1981, but heavy rainfall occurred earlier (i.e., October, November, December) in 1982–1983. Other patterns of rainfall do not clearly emerge from the data in Table 1, though they may exist.

Table 2 summarizes my notes on the phenology of the various plant species on Nihoa. It appears that most Nihoa plant species flower during the spring months. Fewer species were observed flowering in winter and summer months. Most species had mature fruits at some point during the spring and summer, fewer in the winter observation period. Observations indicate that flowering and fruit production follow an initial period of growth (germination and early development for the annual plants) that may be stimulated by rainfall in the winter months.

A visit to Nihoa during the September–November period would be helpful in assessing which plants have distinctive phenological fluctuations. The present data indicate that only a few of the species show distinctive patterns. These are the annuals *Panicum torridum*, *Amaranthus brownii*, and *Sicyos nihoaensis*; and at least one perennial, *Eragrostis variabilis*. More complete observations are needed, as there were some species (e.g., *Euphorbia celastroides*, *Ipomoea indica*, *Sida fallax*) for which I did not make specific searches for fruits or seeds. Additional comments on phenology are given in the species accounts.

SPECIES ACCOUNTS

In the following account, plant families are listed in phylogenetic order and genera in alphabetical order within families. Botanical nomenclature of the flowering plants is based primarily on St. John (1973). I summarized the available historical data on collections and sightings of the vascular plants in Table 3 to provide an overview of the history and present status of the taxa.

TABLE 2

SUMMARY OF PHENOLOGICAL DATA ON NIHOA PLANTS DURING FOUR VISITS FROM MAY 1980 TO MAY 1983

PLANT SPECIES	MAY–JULY 1980	JANUARY–FEBRUARY 1981	MAY–AUGUST 1981	APRIL–MAY 1983
Nephrolepis multiflora	—	—	s	v
Cenchrus echinatus	—	mf, d	—	—
Eragrostis variabilis	v, fl, yf, mf	v, fl	v, fl, yf, mf, sd	v, b, fl, yf, mf
Panicum torridum	d	v, b, fl, yf	d	v, mf
Pritchardia remota	v, b, fl, yf	v	v, b, fl, yf, mf	v, b, fl, yf
Rumex giganteus	v	v	v, mf, d	v, b, fl, yf, mf
Chenopodium oahuense	v, b, fl, yf, mf	v, b, fl, yf, mf	v, b, fl, yf, mf	v, b, fl, yf, mf
Amaranthus brownii	b, fl, yf, mf	slg, v, b, fl	v, mf, sd, d	v, b, fl, yf
Portulaca lutea	—	—	—	b, fl
Portulaca oleracea	v, b, fl	v, b, fl	v, b, fl, mf	v, b, fl, mf
Portulaca villosa	v, fl, mf	v, b, fl, mf	v, b, fl, mf	v, b, fl, mf
Schiedea verticillata	v, b, fl, sd, d	v, fl, mf, sd, d	v, fl, sd, d	slg, v, b, fl, yf, mf, sd, d
Sesbania sp.	v, b, fl, yf, mf	v, b, fl	v, b, fl, yf, mf	v, b, fl, yf, mf
Tribulus cistoides	—	v	—	—
Euphorbia celastroides	v, fl	v, fl	v, fl	v, fl
Sida fallax	v, b, fl, yf, mf	v, b, fl, yf, mf	v, b, fl, yf, mf	v, b, fl, yf, mf
*Ipomoea indica**	v, fl	v, fl	v, fl	v
*Ipomoea pes-caprae**	—	—	v, fl	—
Heliotropium curassavicum	—	—	v, b, fl	v
Solanum nelsoni	v, b, fl, yf, mf	v, b, fl, mf	v, b, fl, yf, mf	v, b, fl, mf
Sicyos nihoaensis	—	slg, v, fl	—	slg, v, b, fl, yr, mf, sd, d

NOTE: s = sori, slg = seedling, v = vegetative, b = flower buds, fl = open flowers, yf = young fruit, mf = mature fruit, sd = seeds dropped, d = plants dead.

* Plants were inaccessible so that I could not search for fruits and seeds.

Algae

Algae growing on moist surfaces and in pools formed from fresh water seeps are a relatively inconspicuous form of plant life on Nihoa. During the 1983 expedition I collected alcoholic specimens of algae from a variety of habitats (*Conant 201–209, 212–215, 217, 218*). K. Schlech (personal communication) examined the material, concluding that there probably were three species of blue-green algae (Cyanophyta) and one species of green (Chlorophyta) alga. The blue-green algae appeared to be in the order Oscillatoriales, the most common of the three species probably in the genus *Oscillatoria*. Further identification of the specimens awaits the attention of a specialist.

Lichens

Magnusson (1942) published a list of the lichens of Nihoa and Necker islands. I made exhaustive collections of lichens on Nihoa in 1981 and collected additional materials in 1983. These specimens will be deposited in the Bernice P. Bishop Museum after being identified by C. W. Smith of the University of Hawaii's Department of Botany.

Ferns

Davalliaceae—sword fern family

Nephrolepis multiflora (Roxb.) Jarret ex Morton (sword fern)

This fern was collected (*Conant, s.n.*) on Nihoa for the first time in June 1981 (Conant and Herbst 1983). Identification of these fertile specimens was made by D. Herbst and C. H. Lamoureux. Although this fern is an alien species in Hawai'i (Lamoureux 1982), it probably arrived on Nihoa by wind dispersal rather than by intentional or accidental human introduction. This is suggested by the location of the first colony (about 1 m^2 in

TABLE 3

OBSERVATIONS OF PLANT SPECIES ON VARIOUS EXPEDITIONS TO NIHOA ISLAND

PLANT SPECIES	STATUS	1920s*	1961–1962†	1964–1968‡	1969**	1981–1983††
Nephrolepis multiflora	A	–	–	–	–	+
Cenchrus echinatus	A	–	+	+	+	+
Eragrostis variabilis	I	+	+	+	+	+
Panicum torridum	I	+	+	+	+	+
Paspalum sp.	A	–	+	–	–	–
Setaria verticillata	A	–	–	–	+	–
Pritchardia remota	E	+	+	+	+	+
Rumex giganteus	I	+	–	+	+	+
Chenopodium oahuense	I	+	+	+	+	+
Amaranthus brownii	E	+	–	–	+	+
Boerhavia diffusa	I	+	–	–	–	–
Tetragonia tetragonioides	A	+	–	–	–	–
Portulaca lutea	I	+	+	–	+	+
Portulaca oleracea	A	–	–	+	+	+
Portulaca villosa	I	+	+	+	+	+
Schiedea verticillata	E	+	–	+	+	+
Sesbania sp.	E	+	+	+	+	+
Tribulus cistoides	I	+	+	+	–	+
Euphorbia celastroides	I	+	+	+	+	+
Sida fallax	I	+	+	+	+	+
Ipomoea indica	I	+	+	+	+	+
Ipomoea pes-caprae	I	–	–	–	+	+
Heliotropium curassavicum	I	+	–	+	+	+
Solanum nelsoni	I	+	+	+	+	+
Solanum nigrum	I	+	–	–	–	–
Sicyos nihoaensis	E	+	+	–	+	+

NOTE: A = alien, E = endemic to Nihoa, I = indigenous to Northwestern Hawaiian Island.
* Tanager Expedition (several trips).
† Bureau of Sport Fisheries and Wildlife and Hawaii Division of Fish and Game.
‡ Bureau of Sport Fisheries and Wildlife, Hawaii Division of Fish and Game, University of Hawaii, Pacific Ocean Biological Survey Program.
** Bernice P. Bishop Museum and Bureau of Sport Fisheries and Wildlife.
†† S. Conant, this study.

area) I found at about 213 m elevation on the west ridge of Miller Valley (Figure 2), a site that is some distance from the usual landing site. *Nephrolepis multiflora* probably is the first naturalized fern to be recorded from the NWHI. There is also a record of the species from Midway (Herbst 1981); it is not known whether this represents an accidental, intentional, or natural introduction.

In April 1983, I discovered two additional colonies of this fern growing in cracks of a volcanic dike near the base of Miller Ridge at about 50 m elevation (Figure 2). The two colonies were less than 4 m apart. Neither colony had more than 50 fronds, and neither had any fertile fronds. Material was collected from one of these colonies (*Conant 104*) and identified as *Nephrolepis multiflora* by C. H. Lamoureux. It seems likely that these small colonies were established after August 1981, because I traversed that particular area frequently during the summer of 1981 and probably would have noticed the plants if they had been there. In April 1983, I collected (*Conant 114*) additional material from the original colony, now reduced in size due to crowding by a clump of *Eragrostis variabilis*.

Flowering Plants—Monocots

Gramineae—grass family

Cenchrus echinatus L. (sandbur)

In late May 1981, one small (about 20 cm tall), dead plant with fewer than 10 fruits was collected and destroyed as per the request of FWS personnel. The collection was made at

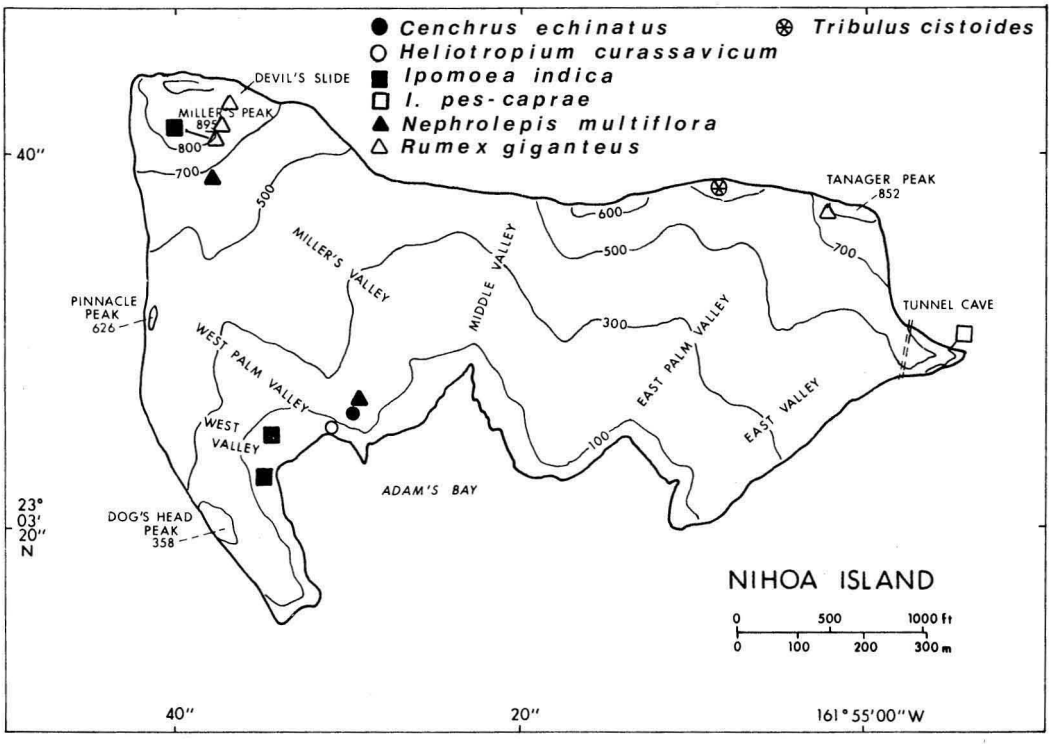

FIGURE 2. Distribution map for seven of the less common plants found on Nihoa Island.

TABLE 4

AVERAGE ESTIMATED PERCENTAGE COVER VALUES FOR COMMON VASCULAR PLANTS, BARE SOIL, AND BARE ROCK IN 74 PLOTS (76 × 76 m EACH) ON NIHOA ISLAND

CATEGORY	AVERAGE PERCENT COVER (%)	FREQUENCY OF OCCURRENCE* (%)
Chenopodium oahuense	27	100
Bare rock	25	100
Solanum nelsoni	22	95
Sida fallax	11	78
Eragrostis variabilis	11	50
Bare soil	10	99
Pritchardia remota	9	11
Sesbania sp.	3	46
Euphorbia celastroides	2	11
Ipomoea indica	2	1
Panicum torridum	1.5	12
Portulacea spp.	1	20
Schiedea verticillata	0.5	3

* Frequency of occurrence was calculated by dividing the number of plots in which the species or category occurred by the total number (74) of plots.

the base of the ridge that divides Miller and West Palm valleys about 50 m upslope from Emory's (1928) Site 10 (Figure 2). Although this species was seen or collected in 1961, 1968, and 1969 (Herbst 1977), it has not been reported between 1969 and 1981. My observation of only one individual during approximately 7 months of work over a 3-year period indicates that the species has failed to become successfully established on the island.

Eragrostis variabilis (Gaud.) Steud. ('emoloa)

This perennial bunch grass is the fourth most abundant plant on Nihoa (11% cover, 50% frequency; Table 4). *Eragrostis* clumps may exceed 1 m in height, and are spaced 20–30 cm apart, often in dense stands. Although it is relatively abundant, it is patchily distributed, being most common on exposed slopes and ridge tops. The most extensive grasslands are on Miller and Tanager peaks and the ridges leading up to them. While these areas are not pure stands, other plant species

tend to be uncommon in extensive stands of *Eragrostis*. Single clumps or small stands are scattered throughout the rest of the island.

Rainfall probably affects the amount and time of flowering and seed set (Tables 2, 4). For example, although flowering was noted in the winter 1981 period, no fruits were observed. Specimens of this species were collected on the 1983 expedition (*Conant 106, 107*).

Eragrostis bunches are the sole habitat for Nihoa's seven land snail species, which include six endemic and one indigenous species (Conant et al. 1983).

Panicum torridum (Gaud.) (kakonakona)

This annual grass is found seasonally (Table 2) throughout the island, though it is much more abundant on the valley floors and other places where moisture may accumulate and persist. Our quantitative estimate of cover by this species was less than 2% (Table 4). This estimate is probably low because it was made in August 1981, when all the plants had died and withered.

It is likely that the abundance of this species varies considerably from year to year. Sincock (unpublished data) estimated the total average cover by this species in June 1969 to be 5%, a much higher estimate than ours. Herbst (1977) noted that the abundance of this species varies considerably on Necker Island. During a 5-day visit to Necker in late June 1982, *Panicum torridum* was very abundant (as high as 25–50% cover in some sample plots), and there were still numerous green clumps that were in flower. However, in late June 1984, very few living plants of this species were observed during a 1-week visit to Necker.

This plant does not appear to provide much habitat for terrestrial invertebrates, although during field work on Necker Island in 1982, P. Conant (unpublished data) collected a few species of insects from it.

Paspalum sp.

A plant was recorded, but not collected, by R. J. Kramer and J. W. Beardsley (unpublished manuscript, FWS) from Albatross Plateau (area immediately north of Miller Peak) in 1962. Although I searched for it there, particularly near the debris left behind by a temporary military installation, I did not find it.

Setaria verticillata (L.) Beauv. (bristly foxtail)

This plant was collected by Yen in 1969 from "near [the] south coast" (Herbst 1977). I did not find it.

Palmae—palm family

Pritchardia remota Becc. (lo'ulu)

Nihoa's endemic lo'ulu palm is certainly the island's most conspicuous plant, though it is restricted to two valleys (East and West Palm), one at each end of the island. The cover estimate for this species was 9%, and the frequency of occurrence (11%) reflects its limited distribution (Table 4). Herbst (1977) reported his careful count of the palms in 1968, noting numbers of plants in different size classes. Herbst's count and the one made by C. R. Long (reported by Herbst 1977) in 1964 were the most exhaustive ever made, including, unlike previous counts, enumeration of seedlings. These counts are included in Herbst's (1977) report, and reveal that there were 500–600 trees.

Long noted that there were 173 trees with fruit or flowers in his September count, and Herbst noted 182 trees with fruit or flowers in his August count. Although I did not count the palms, I took a few notes on their reproductive phenology (Table 2). With the permission of the FWS I collected seeds in August 1981 for distribution to arboreta and horticulturists. At that time I found fewer than ten trees in either valley with mature fruit from which I could make collections. No reproductive structures were observed in the winter of 1981.

The Nihoa lo'ulu provides nesting, loafing, and roosting habitat for red-footed boobies (*Sula sula rubripes*), which nest only in bushes and trees, rather than on the ground. Occasionally, brown noddies (*Anous stolidus pileatus*) perched on or attempted to nest in the lo'ulu trees.

Flowering Plants—Dicots

Polygonaceae—buckwheat family

Rumex giganteus Ait.

This perennial is one of Nihoa's rarest plants, previously recorded only from the

Devil's Slide–Miller Peak area (Herbst 1977). Figure 2 shows the distribution of plants I found on my expeditions. On 3 February 1981, I found two small colonies of sterile *Rumex* plants on Tanager Peak; and on 25 June 1981, I found three colonies, two in flower, in the same area. I suspect that these finds represent a total of just three colonies because the plants are rather obvious and the locality distinctive. The Tanager Peak plants were all on the northwest face of that peak. Seeds were collected from other plants found in June 1981 and sent to D. Herbst of the FWS, who passed them on to the Waimea Arboretum. The seeds were not successfully germinated.

Rumex is one of the few plants that may exhibit some seasonality in reproductive activities, with flowering and seed set being primarily spring and summer phenomena. No reproductive structures were observed in the winter of 1981. Although the same is true of the summer 1980 expedition, it should be noted that only two plants were observed at that time.

On 3 June 1980, I noted two sterile plants 10–15 m apart on the north-facing side of Devil's Slide, which is contiguous with the base of Miller Peak. The following June, I noted a single sterile plant about 25 m above and to the west of the locality of the plants observed in 1980. All the rest of the *Rumex* individuals I observed were on the floor of Devil's Slide growing in deep soil, in contrast to the other plants, which were growing on rocky outcrops in pockets of shallow soil.

On 15 August 1981, I found a *Rumex* colony with three separate groups of plants in Devil's Slide. All the plants were growing next to the northwest wall of the Slide. My count puts this colony at about 22 plants, all of which appeared to have several stems capable of producing flowers and fruit. It was often difficult to distinguish one individual from another when plants were close together, making this count only approximate. Furthermore, the plants have large fleshy roots, and there may have been some dormant individuals with no stems above ground. This colony was adjacent to a large colony of *Schiedea verticillata*, and at some places the two species were intermixed. *Rumex* seeds and rooted shoots collected from this colony and sent to the Waimea Arboretum failed to grow.

Chenopodiaceae—goosefoot family

Chenopodium oahuense (Meyen) Aellen ('aweoweo)

This is the most abundant plant on Nihoa, with an estimated cover of 27% and a sample frequency of 100% (Table 4). This widely distributed species grows in dense, nearly monospecific stands in a few areas—for example, the west slope of Miller Valley. There were nearly always some individuals of this species in flower (Table 2), and my notes on its phenology are insufficient to determine whether there was a peak of flowering or flushing at any particular time.

Chenopodium was one of the plants whose flowers and fruits were most frequently eaten by Nihoa finches. In addition, this plant supports the densest populations of insects (W. C. Gagné, personal communication), making it an important foraging substrate for the insectivorous Nihoa millerbird.

Amaranthaceae—amaranth family

Amaranthus brownii Christophersen and Caum

This plant was collected on the Tanager Expedition in 1923, but it was not seen again until 1969 when D. Yen collected it near Miller Peak (reported by Herbst 1977). Christophersen and Caum (1931) described the species from 1923 collections, noting that Caum and C. J. Judd had found the plant to be "common" on Miller Ridge and "abundant also on ridges to the east." In contrast, my observations indicate that the plant was very rare, at least in recent years.

This plant is the only member of its genus endemic to the Hawaiian Islands, and its distribution is limited to Nihoa Island. It is the island's rarest native plant with the possible exception of *Tribulus cistoides*. The total number of individuals of this annual species I observed during my visits did not exceed 35. Based on phenological observations (Table 2), I estimate that the growing season of this species probably extends from about December through July. Figure 3 shows the distribution of the plants I observed.

The earliest month of the year in which I

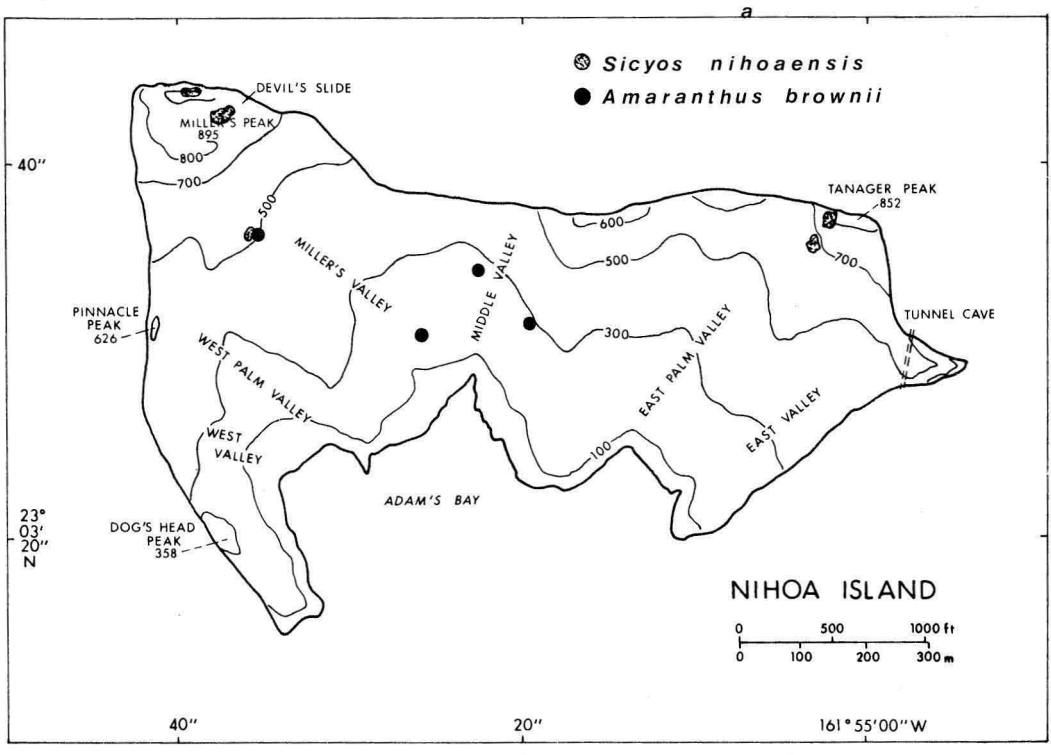

FIGURE 3. Distribution of *Amaranthus brownii* and *Sicyos nihoaensis* on Nihoa Island.

observed plants was February (1981), when I found 22 plants growing at about 175 m elevation on the west ridge of Miller Valley about 5 m below the crest of the ridge on the east side (Figure 3). On 16 February, I noted that 20 plants were less than 10 cm tall, 1 plant was 15 cm tall, and 1 plant was 35 cm tall. The two taller plants were in a very early stage of flowering. On 11 June 1981, I returned to this colony to find 23 plants, all of which had died or were dying. Some were in such deteriorated condition that it was impossible to be sure they had flowered, but most of the plants had actually set seed. I collected seed from 5 standing plants and one inflorescence I found on the soil surface. When I examined this colony area again on 21 August 1981, I found a single plant still standing but apparently dead. All other plants observed were found on the late spring–summer expeditions.

The habitat in which the largest *Amaranthus* colony was found (on Miller Ridge) was characterized by rocky outcrops with shallow soil and scattered *Chenopodium* bushes. Earlier in the seasons of both 1981 and 1983 there had been a colony of *Panicum torridum*, most of which was dead or dying in late April 1983 and entirely dead in June 1981. In February 1981, the *Panicum* was robust and beginning to flower. It is interesting to note that in 1983, numerous *Sicyos* seedlings were present in the same small area occupied by dying *Panicum* and the *Amaranthus* plants. Perhaps *Sicyos* and *Amaranthus* share similar habitat requirements.

The seeds that I collected in 1981 were deposited with the Waimea Arboretum and the Royal Botanic Gardens at Kew in England. Although the seeds at Waimea germinated and grew for a time, none of the plants at Waimea survived beyond the seedling stage. The fate of the seeds that were sent to England is not known.

The extremely low numbers in recent years and the limited distribution of this endemic plant suggest that it should be carefully moni-

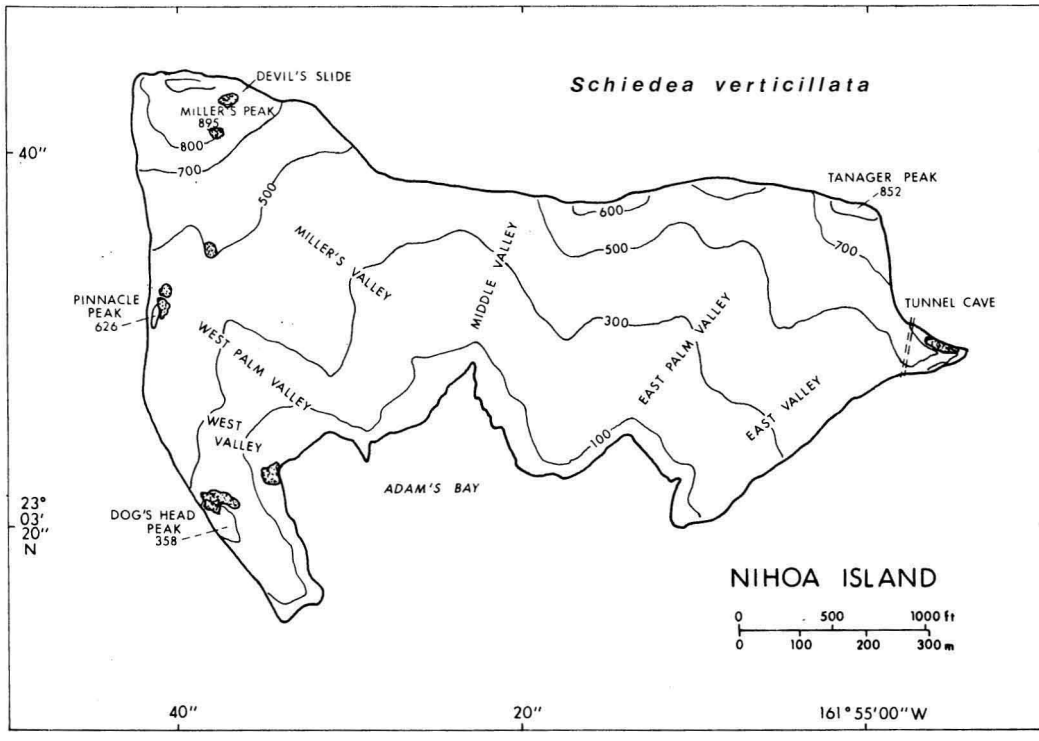

FIGURE 4. Distribution map of *Schiedea verticillata* colonies on Nihoa Island.

tored, as it is one of the rarest endemic Hawaiian plants.

Nyctaginaceae—four o'clock family

Boerhavia diffusa L. (alena)

As Herbst (1977) mentioned, this plant "was found only on the sandy beach in Adams Bay and may have washed away." Numerous scans of the beach with 10 × 40 binoculars revealed no vegetation at all on the beach. In fact, during the 1981 winter expedition, the beach was completely awash during high tides, and high water reached all the way to the base of the cliffs behind the beach during a heavy storm.

Aizoaceae—carpetweed family

Tetragonia tetragonioides (Pallas) Ktze. (New Zealand spinach)

Careful observations of the cliffs above the beach where this plant had been found (Herbst 1977) failed to reveal this species, and I concur with Herbst that it probably has failed to become established on Nihoa.

Portulacaceae—purslane family

Portulaca lutea Forst. f. ('ihi)

Portulaca oleracea L. (common purslane)

Portulaca villosa Cham.

Herbst (1977) wrote that *Portulaca lutea* "grows in shallow, rocky soil and in cracks along the lower south side," and that there was a large colony at the northeast end of Miller Plateau. I searched thoroughly for this species throughout my various expeditions, but was unable to find a single plant. However, W. C. Gagné (personal communication) located and photographed a single flowering plant on the east ridge of Miller Valley at an elevation of about 50 m. The plant was growing on the ridge top in a pocket of soil. Herbst (personal communication), who visited Nihoa in 1980, confirmed my impressions that this plant is rarer now than it was during his visit in 1968.

In contrast to *Portulaca lutea*, *P. oleracea*, which Herbst (1977) found in only two colonies on Miller Plateau and at the mouth of Miller Valley, has spread over the entire island. This species, which produces abundant seed, can be found in pockets of shallow soil

TABLE 5

LOCATION, POPULATION COUNTS, AND PHENOLOGY OF *Schiedea verticillata* ON NIHOA

LOCATION	DATE	NO. OF PLANTS†	PHENOLOGY*	
			NO. OF PLANTS WITH BUDS AND FLOWERS	NO. OF PLANTS WITH SPENT FLOWERS
Devil's Slide	15/8/81	96	20	76
	30/4/83	100±	7	—
Miller Peak	05/2/81	5	—	1
	30/4/83	2	1	—
Upper West Palm	04/7/80	2 or 3	Too far for specific observations	
Pinnacle Peak	04/7/80	15	9	6
	21/6/81	25	5	20
Lower West Palm	14/2/81	30	30	—
	22/6/81	38	No phenology data recorded	
Dog's Head, base‡	04/7/80	43+	13+	Approx. 30
Dog's Head, summit	04/7/80	52	50	3
	21/6/81	29	4	25
East spur colony	25/6/81	148	No phenology data recorded	

* These values are numbers of plants showing the specified conditions. In some cases a plant could have both buds and spent flowers and be counted in two categories.

† Each individual plant may have 1–8 branches capable of producing flowers.

‡ This colony was observed with 10 × 40 binoculars from the cliff above the east side of the beach. The total number of plants is probably considerably greater than the 43 actually counted, as it would have been virtually impossible to count very young plants.

virtually everywhere, though it is most common near ridge tops. It is not clear whether this exotic species is replacing the indigenous *P. lutea*, as there is still abundant suitable habitat for both species, even taking into consideration the tendency of *P. lutea* to be limited to the zone of salt spray (H. St. John, personal communication). *Portulaca oleracea* is the only widespread exotic species on Nihoa, and is apparently the only established exotic plant on the island.

The distribution of *Portulaca villosa* remains as Herbst (1977) described it, i.e., "in pockets of soil and in cracks throughout the island." I saw examples of both the common white-flowered form and the much rarer (on Nihoa) form in which the outer edges of the petals are pink. Though taken collectively the *Portulaca* species are relatively widespread (sampling frequency of 20%), they are not very abundant, their estimated cover being less than 1% (Table 4). Unfortunately, I did not separate the species when estimating cover values.

Caryophyllaceae—pink family

Schiedea verticillata F. Br.

During the four expeditions I located eight different colonies of this endemic Nihoa species ranging in size from 2 to 150 plants. As nearly as I can determine, previous collections were made from at least three of these colonies: Lower Dog's Head, Miller Peak, and Devil's Slide (Figure 4). I collected a single fertile specimen from the Devil's Slide colony (*Conant 115*). I counted the plants in each colony one or two times, usually noting the numbers of plants in various phases of the life cycle. These data are given in Table 5.

Very few plants were found with buds and flowers, but large numbers of postflowering plants were recorded, though none had seeds. Judging from these data, *Schiedea verticillata* plants probably come into flower, set and disperse seed in a short period of time. However, phenological data (Table 2) do not indicate that the reproductive cycle is seasonal. W. C. Gagné (personal communication) noted that

the inflorescences were sticky enough to have trapped small insects.

The plant could be considered locally common on Nihoa, but certainly not abundant, covering less than 1% of the sampling area, and appearing in only 3% of the plots (Table 4). Its population status appears to be stable; nevertheless, it is a relatively rare plant and should be regularly monitored.

Leguminosae—pea family

Sesbania sp. ('ohai)

This attractive legume, whose closest relatives are rare in the main islands (St. John 1981), is relatively common on Nihoa. In the sampling plots it occurred with a frequency of 46%, but it is not abundant, as its estimated total cover was 3% (Table 4). I estimated that there are several thousand plants on Nihoa, but this estimate is based on counts of individuals in only 10 of the 74 sampling plots. Flowers were observed on all visits (Table 2), though they were most abundant in April and May. Mature fruits were observed only in spring and summer months.

In previous publications this plant was called *Sesbania tomentosa*, but recent research by W. Char has revealed it to be an undescribed species which will be described elsewhere.

Zygophyllaceae—tribulus family

Tribulus cistoides L. (nohu)

Earlier reports of this species include records from the back of the west ridge of Miller Valley, the bottom of West Palm Valley, and on the south sides of upper slope cliffs (Herbst 1977). I made only one sight record of this species on 3 February 1981 at the top of the west ridge of East Palm Valley (Figure 2). The cluster of plants was only 1 m from the edge of the cliff. The fact that I observed only one colony in my extensive movements over the island suggests that the species is rare. However, the existence of records from a variety of locations suggests that it may be frequently introduced by seabirds to which its thorny fruits may attach.

Euphorbiaceae—spurge family

Euphorbia celastroides Boiss. var. *celastroides* ('akoko)

This plant is found primarily on windswept ridge tops on Nihoa, and it has a relatively wide distribution on the island (sampling frequency 11%), though its total cover was less than 2% (Table 4). It sometimes grows in dense monospecific stands—for example, on Miller Peak and just above the west end of the sand beach. I found flowering plants on all my expeditions (Table 2), but my observations are insufficient to conclude that flowering is seasonal. Due to my lack of experience with the species and limited observation time, I did not see any fruits or seeds on the species, though they may have been present.

W. C. Gagné (personal communication) noted that the flowers were visited by large numbers of ants, which might have a negative impact on any native insects that are host-specific to this plant or on seed production in the plant itself. Dense stands of this species on Miller Ridge and Miller Peak are an important nesting habitat for Christmas shearwaters (*Puffinis nativitatis*). The major nesting colonies of this bird are in stands of *Euphorbia* and *Eragrostis variabilis* on Nihoa.

Malvaceae—mallow family

Sida fallax Wapl. ('ilima)

Herbst's (1977) description of this plant as "common over the entire island" can hardly be improved upon, and I found it in 78% of my plots. However, it is not as abundant as it is widespread, since its estimated cover was only 11% (Table 4). Flowering was in greatest evidence during May 1981 and April–May 1983, when one could traverse many hectares dotted with the small attractive orange flowers of this plant. I did not make specific searches for seeds and fruits of this species while making phenology notes. In the saddle between Miller and Middle valleys, and on the west side of the head of East Palm Valley, are areas where there are several hectares of nearly pure stands of this species. This plant is attractive to Nihoa finches, which I observed eating its seeds and leaf buds.

Convolvulaceae—morning glory family

Ipomoea indica (Burm. f.) Merr. f. *indica* (koali 'awania)

Herbst (1977) summarized the records of this species as being from two areas: on the north face of Miller's Peak about 10–15 m below the summit and above the sand beach. I observed the species in both locations (Figure

2). The Miller Peak colony was smaller, 20 m^2 at best. However, there are two large colonies above the beach. One is on the steep cliff above the west end of the beach, where there are at least ten small (5–10 m^2) colonies or plants. The other is a single large colony (about 100 m^2) at the base of the tall stony face at the west side of the mouth of West Palm Valley. Due to the inaccessible nature of the colonies, I could not search for fruits and seeds, and I collected no specimens of this species.

Ipomoea pes-caprae subsp. *brasiliensis* (L.) v. Ooststr. (pohuehue)

I found no trace of the colony reported by Yen (Herbst 1977) when I surveyed the area above the beach with binoculars. However, I did make a sight record (using 10 × 40 binoculars) of a colony about 5 m^2 in area at the base (10 m elevation) of the north face of the spur on the island's east side (Figure 2). The colony was west of the point where Tunnel Cave goes through the spur, and it was quite inaccessible, growing on a ledge in the sheer cliff.

Boraginaceae—heliotrope family

Heliotropium curassavicum L. (seaside heliotrope)

I found a small colony of this species on 25 May 1981 with several individuals growing at the bottom of the talus slope above the east edge of the beach (Figure 2). Although I did not collect specimens, I did photograph the species. This colony is probably at about the same location as the one Yen found in 1968 (reported by Herbst 1977). Earlier records are from collections on or adjacent to the beach.

Solanaceae—nightshade family

Solanum nelsoni Dunal

Like *Chenopodium*, this plant is abundant and widespread on Nihoa, averaging 22% cover (Table 4). It occurred in 95% of the sampling plots. There were a few flowers to be found at all times on my expeditions (Table 2), but in April–May 1983 most plants had large numbers of flowers. There were also large numbers of plants in flower in May 1981. The flowers of this plant on Nihoa have petals that are primarily creamy white in color but with dark purple centers. In contrast, on Pearl and Hermes Reef the petals are light purple or lavender in color and have dark purple centers as well.

Fruits were much less abundant than flowers, suggesting that pollinators may have been low in number or at least ineffective. For example, we observed very few individuals of the native bee, *Neoprosopis perkinsiana*. Fruits were green when immature, turning first to a reddish orange and then to dark brown or black when ripe.

Solanum nigrum L. (popolo)

This is another of the species reported from Tanager Expedition collections that has not been reported again, and I found no plants anywhere even after a thorough search of the collection locality.

Cucurbitaceae—gourd family

Sicyos nihoaensis St. John

This species, endemic to Nihoa, has been reported (Herbst 1977) only from three areas on Nihoa: below Tanager Peak (in 1924), upper West Palm Valley (in 1961), and on Albatross Plateau north of Miller Peak (in 1962). *Sicyos nihoaensis* is an annual with a growing season that probably begins following heavy rainfall. On Nihoa the late winter and spring months seem the most likely times one could expect to see this plant growing there (Table 2). The paucity of observations are probably due to the fact that it grows primarily during the season when safe landing on the island is most difficult. My observations (Figure 3) do not reveal a much more extensive distribution than that outlined by Herbst, but the species can be locally very abundant during its growing season, particularly during a wet year.

In February 1981, I found *Sicyos* in large numbers at the top of Devil's Slide, particularly just below Miller Peak, and I attempted to census the three different colonies in this area. From a vantage point on the northwest wall of Devil's Slide, I counted 27 individual vines, but on closer examination of the colonies many additional smaller vines and seedlings were found. Based on these observations I estimated the total number of plants in these three colonies to be about 60–80 individuals. Another colony of *Sicyos* on the north edge of Albatross Plateau was inaccessible, but with the aid of binoculars, I estimated the number

of plants at that locality to be about 15–20. I saw no other colonies in 1981.

In April 1983, W. C. Gagné (personal communication) saw a colony of *Sicyos* seedlings numbering in the high hundreds or low thousands on the west face of Tanager Peak about 20 m from the summit. The area was a series of rocky ledges where *Panicum torridum* had died back. Many of the seedlings still had their cotyledons attached.

Gagné and I located two *Sicyos* colonies in April 1983. The first of these was adjacent to or intermixed with plants in the *Amaranthus* colony on Miller Ridge (see section on *A. brownii*). There were about 30 *Sicyos* vines in this colony. Some were seedlings with cotyledons and some were mature vines with flowers and fruit, although none of these vines had ripe fruits. At the top of Devil's Slide, on the east southeast side, we found another colony covering an estimated area of 200 m^2 or more, with hundreds of plants of all ages from seedlings to vines with ripe fruits. This colony was so large, and our time so limited, that I was unable to attempt a census of the plants. Seeds and seedlings were collected and eventually deposited at the Waimea Arboretum. Phenological observations are summarized in Table 2.

Sicyos nihoaensis could be said to have a restricted distribution on Nihoa, and is a species whose limited growing season makes it (like *Amaranthus brownii*) a difficult species to monitor. Although it is rare, its status could be considered relatively stable as long as no disturbance to its habitat (e.g., introduction of exotic plants or insect pests) occurs.

CONCLUSION

The flora of Nihoa provide a unique example of a lowland, coastal type of ecosystem in Hawaii because it has remained unaffected for as long as 500 years by the impacts of an apparently brief human occupation. Today the flora consist of 20 species, which range from extremely rare to very common. Five of these species are endemic to this island. Nihoa's plant communities provide the most important constituents of essential habitat for at least 35 species of endemic, terrestrial arthropods; 6 species of endemic land snails; 2 species of endemic land birds; and 17 species of breeding seabirds numbering over half a million individuals (Conant et al. 1983).

The scientific value of the island is outstanding, as it provides a nearly undisturbed example of a lowland, dry Hawaiian community, almost untouched by the perturbations of continental cultures so familiar to the main Hawaiian Islands. In particular, the large number of endemic arthropods and mollusks, some of which may be peculiar to large seabird colonies with their immense inputs of nutrients via seabird guano, provide an opportunity for ecological studies of a sort as yet unexplored by naturalists in the Hawaiian Islands. Similarly, the island is noted for its unique cultural value in the form of extensive, remarkable, and virtually unstudied archaeological sites.

As part of the Hawaiian Islands National Wildlife Refuge, the island is protected by the limiting of all human access except specifically permitted and closely regulated scientific research. Proposals to allow very limited, and also closely regulated, access for Hawaiian religious ceremonies are being considered by the FWS. As long as such uses are controlled so as to prevent disturbance to the biota, and, particularly, to prevent the introduction of new species of organisms, it is unlikely that Nihoa's ecosystems will be significantly disturbed. However, in order to assure adequate protection of the island from disturbance, it is essential that monitoring of terrestrial ecosystems, including plants, invertebrates, landbirds, and seabirds, be conducted on a regular basis. In addition, agencies responsible for protection of the biota should be prepared to cope immediately with the elimination of any perturbations as soon as they are detected.

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