AN ASSESSMENT OF THE CURRENT STATUS OF NATIVE UPLAND HABITATS AND ASSOCIATED ENDANGERED SPECIES ON THE ISLAND OF HAWAI'I

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ABSTRACT

Considerable portions of the native Hawaiian biota have been destroyed or degraded since man's colonization of these islands beginning approximately 1,500 years ago. The loss of native species has resulted from 2 types of actions: 1) direct habitat destruction (e.g. for agriculture, habitation, etc.), and 2) displacement or replacement of native components by introduced species of plants and animals. The results of these changes include total or partial destruction of the native communities and changes in abundance and/or distribution of individual taxa.

Recent field surveys and summaries of existing data have been used to evaluate the current distribution and status of numerous endangered species of plants and animals and their habitats. Of the 17 major vegetation types mapped for the island of Hawai'i, 11 were classified as units with greatly reduced or no area totally dominated by native species, including 6 units with large numbers of endangered bird and plant species. In this evaluation the upper-elevation mesic koa-'ohi'a (Acacia koa-Metrosideros polymorpha) forest, which provides habitat for at least 6 endangered bird and 11 endangered plant species, is particularly threatened. Less than 15% of the original area occupied by this vegetation type now contains relatively intact mesic koa-'ohi'a forest.

More efforts need to be focused upon securing and managing the remaining relatively intact or partially disturbed portions of communities such as the mesic koa-'ohi'a forest which provide essential habitat for significant populations of endangered species. We feel that, ultimately, endangered species recovery efforts will be enhanced by dealing with research and management at the community level, rather than pursuing intensive programs focused on individual species.

INTRODUCTION

The native Hawaiian biota has been widely recognized as exhibiting dramatic examples of adaptive radiation and speciation in island ecosystems (Rock 1913; Zimmerman 1948; Carlquist 1970; Berger 1981; Carson 1982). The great degree of endemicity for higher life forms in Hawai'i is principally the result of the extreme isolation of this volcanic archipelago over the entire 25 million years of its aerial existence. Nearly all of the native forest bird species, including the Hawaiian honeycreepers (Drepanidinae), are known only from these Islands (Berger 1981). Similarly, approximately 96% of the 1,381 flowering plant species listed by St. John (1973), and 65% of the 168 native fern species (Wagner in Fosberg 1948) are endemic. The associations of the species which were able to become established in Hawai'i have led to the development of both fascinating and unique communities containing a combination of elements from the Indo-Pacific, American, Austral, Pantropic, and Boreal biotic regions (Fosberg 1948). The isolation of this island chain has also resulted in the absence of certain biological groups such as terrestrial mammals, reptiles, and amphibians, which are major components of continental ecosystems.

Unfortunately, since man colonized these islands, beginning with the Polynesians approximately 1,500 years ago, and Europeans since 1778, much of the native biota has been destroyed or diminished (Berger 1981; Carlquist 1970; Kirch 1982). The loss of native species has resulted from 2 types of actions: 1) direct habitat destruction by man (e.g. for habitation, agriculture, logging, etc.), and 2) displacement or replacement of native components by purposely or accidentally introduced species. The outcomes of these actions have included the total or partial destruction of the native communities and changes in abundance and/or distribution of individual taxa. Some of the native habitats, particularly below 600 m elevation, have been so degraded that now only remnant examples of these communities can be found. It has been reported that 28 taxa of birds (Berger 1981) and 273 of plants (Fosberg and Herbst 1975) became extinct in the last 200 years. Olson and James (1982) have also recently shown that at least 39 species of birds became extinct prior to 1778. Additionally, an extremely large number of other taxa of both plants and animals has become unnaturally rare due to human-related disturbances.

Since the adoption of the Endangered Species Act as law in 1973, the U.S. Fish and Wildlife Service (FWS) has officially designated 53 taxa of Hawaiian plants and animals as "endangered" or "threatened"

(U.S. Fish and Wildlife Service 1983). This list is dominated by terrestrial species including 30 birds, 9 plants, and an entire endemic genus of tree snails (Achatinella spp.). In addition, 784 taxa of plants are considered high priority (Category 1 and 2) candidates for being officially designated as endangered or threatened species (U.S. Fish and Wildlife Service 1980). A similar list of candidate taxa has also been prepared for insects and other invertebrate groups (W.C. Gagne, pers. comm.).

Programs developed to maintain the natural diversity of the native Hawaiian biota have the potential to be overwhelmed by the enormous number of species of both plants and animals which are currently listed, or proposed for official recognition as endangered or threatened species. Traditionally, most of the research or management programs in the United States focusing on endangered species have dealt with the problems on a single species basis. For example, in recent years endangered species research projects conducted through the FWS's Patuxent Wildlife Research Center have included intensive studies on the whooping crane (Grus americana), the California condor (Gymnogyps californianus), the Puerto Rican parrot (Amazona vittata), the gray wolf (Canis lupus), the black-footed ferret (Mustella nigripes), and the masked bobwhite quail (Colinus virginianus).

The extremely large number of listed or candidate endangered species from Hawai'i suggests the need for more of a community approach to these problems rather than establishing a series of intensive research and recovery programs for each species. Too often endangered species programs are left in the situation of initiating intensive research or management aimed at maintaining remnant populations of extremely rare species which are found only in highly disturbed habitats. Although single species programs are well intended, the management of rare species in the context of the preservation of functioning natural communities offers the greatest potential for the long-term survival of their elements. This approach is fully in accord with the intention of the Endangered Species Act, which states: "The purposes of this Act are to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, [and] to provide a program for the conservation of such endangered species and threatened species...." (U.S. Congress 1973).

The trend toward dealing with endangered species at the community level has been reflected in the FWS's research program in Hawai'i which, in the last 10 years, has largely focused on surveying the current

distribution and status of the native forest birds, rare plants, and upland habitats during the Hawai'i Forest Bird Survey (HFBS). Additionally, the FWS and cooperating agencies have established endangered species Recovery Teams which have developed Recovery Plans for groups of similar species such as the Hawai'i, Maui, and Kaua'i forest birds. The results of the HFBS and other recent research projects in Hawai'i, including those conducted by the International Biological Program (Mueller-Dombois, Bridges, and Carson 1981), the 'Ohi'a Rain Forest Study (Mueller-Dombois 1980), the State of Hawaii Division of Forestry and Wildlife (DOFAW) Endangered Species Program, the National Park Service, and the U.S. Forest Service, have provided a detailed data base that can be used as a starting point to identify critical ecological units and to guide management efforts aimed at maintaining their native elements.

The focus of the present paper is a discussion of the current status of the native upland vegetation on the island of Hawai'i, based on the information gathered during the HFBS. We then use this assessment of the plant communities as a framework for addressing the management of the endangered plants and animals. More detailed accounts are presented elsewhere on the results of this survey for birds (Scott, Kepler, and Sincock, this volume; Scott et al., in press); native plants (J. Jacobi and F.R. Warshauer, unpubl. data); and the vegetation maps (Jacobi 1983a).

METHODS

Background on Hawai'i Forest Bird Survey

The primary objective of the HFBS was to determine the distribution, abundance, and status of the native Hawaiian forest birds and their habitats. To accomplish this objective, all potential forest bird habitats on the islands of Hawai'i, Maui, Moloka'i, and Lana'i, plus the Alaka'i region on the island of Kaua'i, were surveyed along a series of systematically established transects from 1976-1981 (Scott, Jacobi, and Ramsey 1981). Information on the presence and abundance of all bird species was recorded at sampling points (stations) regularly spaced along each transect. Data were also collected on the structure and composition of the vegetation, and on the presence of listed or candidate endangered plant species encountered.

Nearly one-half of the total area of the island of Hawai'i was surveyed. Sampling was conducted at 7,438 stations located along 114 transects established within most of the upland forest bird habitats on the Island (fig. 1). For the most part, we did not sample areas

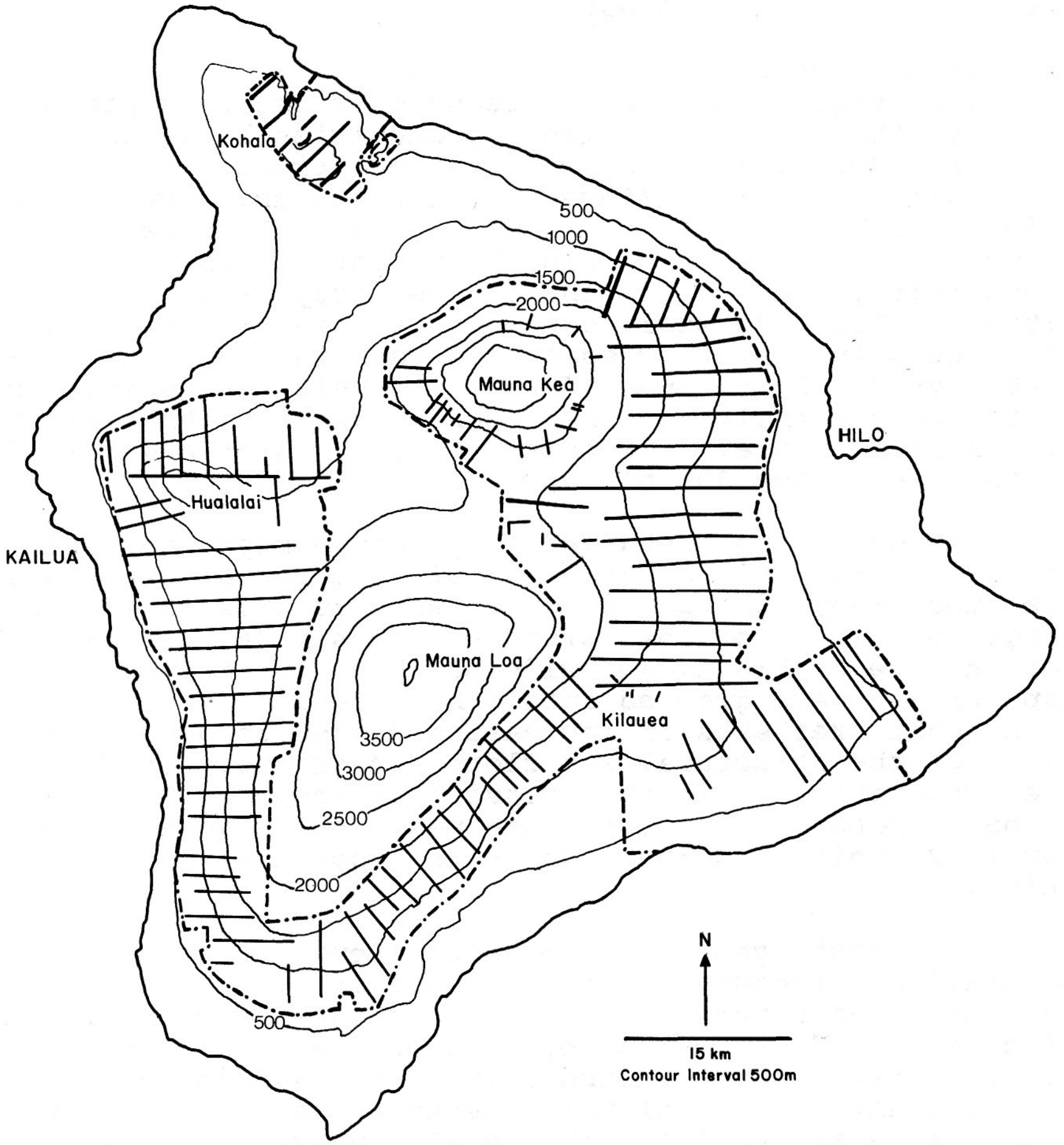

Figure 1. Location of the Hawai'i Forest Bird study areas and transects sampled on the island of Hawai'i.

below approximately 500 m elevation, or large upland areas which were generally devoid of native vegetation. The unsampled areas included much of the Waimea plain between Laupahoehoe and Waimea. We also did not survey large portions of the Pohakuloa Training Area in the saddle between Hualalai, Mauna Loa, and Mauna Kea volcanoes, although these areas do contain some large areas of native dry forest and scrub.

Vegetation Mapping

The vegetation maps produced during this project display the existing plant communities based on both species composition and vegetation structure. At the most detailed level (Level 3), the map units reflect 4 major components of the vegetation: 1) tree canopy crown cover, 2) tree canopy height, 3) tree species composition, and 4) dominant understory species composition. The understory category is chiefly represented by regularly repeating species groups in different habitat types. At the most detailed level, 369 vegetation units were identified for the area mapped on the island of Hawai'i alone. Of this total, 137 of the detailed units constituted 90% of the area mapped.

Although the detailed vegetation maps are useful for intensive field studies of specific areas, there are too many units to deal with at this level when large portions of the Island are considered. To allow for a more usable island-wide perspective, the detailed map units were grouped into a hierarchical classification that reflects an increasing degree of generalization of the structural and floristic characteristics of the vegetation. In this classification, the 369 Level 3 map units were first grouped into 81 more general Level 2 units, which, in turn comprise 17 Level 1 units.

The most general map units (Level 1) represent a generalized reconstruction of the original vegetation in the areas surveyed, as they might now be without the effects of disturbance by man or his introduced species. These reconstructed units were used in assessing the present status of the vegetation as mapped for the study area at Level 2. The Level 2 units, which represent actual vegetation components identified in the field, are grouped under the Level 1 units according to the degree of disturbance (as indicated by dominance of native or introduced species) of the overstory or understory components of the vegetation. For this classification, the tree component was considered the dominant layer if it had more than 25% crown cover (i.e., open or closed forest).

Four disturbance categories were distinguished in this system: 1) NN = communities totally dominated by

native species of plant (e.g. certain wet forest, many alpine areas); 2) NX = communities which have the subdominant vegetation layer predominately occupied by exotic species (e.g. closed canopy koa-'ohi'a (Acacia koa-Metrosideros polymorpha) forest with a grazed, mixed-grass understory); 3) XN = communities dominated by introduced species, but containing remnant populations of native species; no native community structure remaining (e.g. many lowland dry forest communities); 4) XX = communities totally dominated by introduced plants; almost no native species remaining (e.g. agricultural lands, urban areas).

Assessment of Status of Native Vegetation

An initial assessment was made of the status of the different vegetation units within the HFBS study area, by breaking down the area of each Level 1 unit into 4 component disturbance categories. By this means, a Level 1 unit which had the majority of its area mapped as still dominated by native species of plants (NN) would be considered to be in relatively good condition. There is an obvious problem in this approach, in that certain native-dominated vegetation types, such as early seral communities, have a relatively limited species composition and structure. However, other units, such as low elevation dry or mesic communities, may be severely disturbed overall, but have a large number of rare plant species in remnant populations. These examples emphasize the need to consider both the degree of disturbance of the structure of the community and the species complement which is still or previously found in that unit. One additional limitation is that only the areas sampled during the HFBS were considered in the analysis reported in this paper. The rest of the Island not covered during this survey originally did, and in some areas still does, contain native-dominated communities. This problem does not seriously affect the assessment of the distribution and current status of forest bird habitat on the island of Hawai'i, since nearly all habitats containing, or potentially containing, native forest birds were included in the survey. However, it does limit a realistic assessment of low elevation vegetation.

Analysis of Endangered Species Data

To streamline the discussion throughout the rest of this paper, we have used the term "endangered species" to include not only the presently listed endangered or threatened species of Hawaiian plants and animals, but also the Category 1 candidate endangered species of plants. This rationale is based on the expectation that eventually most candidate species will be officially designated as either endangered or threatened.

The information on endangered species of native forest birds and plants used in this analysis was also collected during the HFBS. For the purpose of the present paper, we have only dealt with individual endangered species on a presence-absence basis within particular vegetation units, although more detailed information was collected for both groups, particularly the birds. Here we address "rare species richness" within individual vegetation types (i.e. comparisons of vegetation units based on aggregations of endangered or threatened species). This approach allows the identification of vegetation units with several species of interest in common.

RESULTS

Current Status of Major Native Vegetation Units

On the island of Hawai'i the HFBS covered nearly 500,000 ha of the total area of the Island. Within that sampling universe, 17 Level 1 vegetation types were identified (table 1). The 3 "Unassigned Units" included in this table represent former native plant communities which have been so degraded that they could not easily be assigned to one of the other reconstructed vegetation categories. The largest unit sampled was the wet 'ohi'a forest which covered approximately 100,000 ha, or 20.5% of the total area. The smallest unit mapped was the wet, open bog community (28 ha). Over 11% (55,176 ha) of the study area was classified as "Not Vegetated."

The wet 'ohi'a forest (unit 32) occurs in the study area between approximately 500 m and 1,700 m elevation on the windward side of the Island and to 1,500 m in wet leeward areas. Just above this vegetation type, either the mesic 'ohi'a (unit 22) or mesic koa-'ohi'a forest (unit 21) is found, depending on the age and type of substrate. In some areas above the mesic communities a mountain parkland community occurs, comprised of a mixture of koa with mamane (Sophora chrysophylla) stands, native scrub, and grassland (unit 13). The highest elevation tree community on Mauna Loa is primarily dry subalpine scrub 'ohi'a (unit 19), but on Mauna Kea dry mamane (unit 16) or mamane-naio (Myoporum sandwicense) woodland (unit 15) predominates. Above treeline on all 3 tall volcanoes (including Hualalai), a dry alpine scrub community (unit 18) is found, composed chiefly of the shrubs Vaccinium spp., Styphelia tameiameiae, and Dodonaea viscosa with mixed grasses.

The mesic pioneer scrub (unit 24) and the tall wet 'ohi'a forest with a native shrub-matted fern understory (unit 33) represent early and slightly older seral stages of vegetation development on recent volcanic substrates in wet habitat. The 'ohi'a dieback

Table 1. List of the 17 reconstructed vegetation units in the HFBS study area on the island of Hawai`i.

#	Map Symbol	Description of Unit	Area (Ha)
18	D:(ns)	Dry native shrub community	6,715
19	D:(ns)Me	Dry native shrub community with scattered `ohi`a trees	35,231
11	D:Ac-Me-nt(ns-ng)	Dry koa-`ohi`a forest with a native shrub-grass understory	4,061
13	D:Ac-So(ns-ng)	Dry koa-mamane forest with a native shrub-grass understory	30,107
14	D:Me,nt(ns)	Dry `ohi`a forest with a native shrub understory	63,383
15	D:My-So(ns-ng)	Dry naio-mamane woodland with a native shrub-grass understory	12,012
16	D:So(ns-ng)	Dry mamane woodland with an native shrub-grassland understory	28,424
17	D:nt(ns)	Dry mixed native trees forest with a native shrub understory	5,933
10	D:UNASSIGNED	Dry habitat - unassigned units	10,265
24	M:(ns) pio	Mesic pioneer native shrub community	2,775
21	M:Ac-Me,nt(ns)	Mesic koa-`ohi`a forest with a native shrub understory	39,303

Table 1. Continued.

#	Map Symbol	Description of Unit	Area (Ha)
22	M:Me,nt(ns)	Mesic `ohi`a forest with a native shrub understory	35,361
23	M:nt(ns)	Mesic mixed native trees forest with a native shrub understory	75
20	M:UNASSIGNED	Mesic habitat - unassigned units	10,946
36	W:(bg)	Wet open bog community	28
35	W:(ns/mf)Me,nt [dieback]	Wet native shrub-matted fern community with scattered `ohi`a trees (dieback)	6,204
31	W:Ac-Me,nt(tf-ns)	Wet koa-`ohi`a forest with a treefern-native shrub understory	34,730
33	W:Me,nt(ns/mf)	Wet `ohi`a forest with a native shrub-matted fern understory	11,123
32	W:Me,nt(tf-ns)	Wet `ohi`a forest with a treefern-native understory	101,824
30	W:UNASSIGNED	Wet habitat - unassigned units	1,777
	NOT VEGETATED		55,176

		TOTAL AREA =	495,454

unit (35) is another successional unit which developed in response to natural and widespread periodic canopy tree defoliation or death in the mature wet 'ohi'a forest (Mueller-Dombois 1980; Jacobi 1983b). One other wet habitat vegetation type is the open bog community (unit 36). There are relatively few open bogs on the island of Hawaii, and they are generally scattered throughout the montane wet forest on relatively old ash substrates.

The restriction of the HFBS study area to current or potential native forest bird habitats resulted in an undersampling of certain vegetation types, some of which are known to have been quite extensive at lower elevations. These units included lowland wet forest (below 500 m elevation) and particularly dry mixed forest (unit 17) and mesic mixed forest (unit 23), recognized as originally being among the richest of the native plant communities (Rock 1919). Our study area included only 5,933 ha and 75 ha of dry mixed and mesic mixed, respectively. Two other units we did not sample were the mesic coastal lowland forest and the coastal strand.

The present condition of the native vegetation within the study area is summarized in table 2. It must be emphasized that the percentage values given in this table for the 4 disturbance categories in the different vegetation units reflect a summary for only the area sampled during the HFBS. Additionally, the percentages in each class for some of the units could actually be lower than reported if the "Unassigned Units" are eventually assigned to them.

The 6 vegetation types in group A of table 2 still appear to be in relatively good condition, based on the percentage of area dominated by native species (Category NN). All but one of the wet habitat communities mapped are included in this group of relatively undisturbed units. The other 2 members of Group A are the subalpine scrub community (Unit 19) and the mesic pioneer scrub community (unit 24).

The second group identified in table 2 includes most of the mapped mesic and dry units, plus the open bog community. Two units, the dry 'ohi'a forest (unit 14) and the mesic 'ohi'a forest (unit 22), still had nearly half of their total area mapped as native-dominated at the time of the survey. Of the remaining members of this group, 6 units had no mapped area still totally dominated by native species, although several of them had significant portions in the partly disturbed category (NX).

Table 2. List of the 17 reconstructed vegetation units in the HFBS study area, with a summary of percentage of total area in each of the 4 disturbance categories and the number of endangered or candidate endangered birds and plants for each unit.*

	Unit #	Map Symbol	Area (Ha)	Disturbance Category (%)**				Endangered	
				NN	NX	XN	XX	Birds	Plants
A.	Units with large portions still dominated by native species								
	19	D:(ns)Me	35,231	100.0	-----	-----	?	3	1
	24	M:(ns) pio	2,775	100.0	-----	-----	-----	2	--
	35	W:(ns/mf)Me,nt [dieback]	6,205	98.5	1.4	-----	?	1	--
*	31	W:Ac-Me,nt(tf-ns)	34,730	94.3	5.6	-----	?	5	9
	33	W:Me,nt(ns/mf)	11,123	100.0	-----	-----	?	-	1
*	32	W:Me,nt(tf-ns)	101,824	91.5	4.4	4.0	?	6	11
B.	Units with greatly reduced or no area totally dominated by native species								
	18	D:(ns)	6,715	-----	100.0	-----	?	1	--
	11	D:Ac-Me-nt(ns-ng)	4,061	-----	34.1	65.8	?	1	1
*	13	D:Ac-So(ns-ng)	30,107	-----	33.8	66.1	?	4	2
*	14	D:Me,nt(ns)	63,383	56.4	14.2	29.3	?	4	9
*	15	D:My-So(ns-ng)	12,012	7.9	64.1	27.8	?	2	3
*	16	D:So(ns-ng)	28,424	-----	47.8	52.1	?	4	2

Unit #		Map Symbol	Area (Ha)	Disturbance Category (%)**				Endangered	
				NN	NX	XN	XX	Birds	Plants
*	17	D:nt(ns)	5,933	-----	21.4	78.5	?	1	6
*	21	M:Ac-Me,nt(ns)	39,303	13.4	69.3	17.2	?	6	11
*	22	M:Me,nt(ns)	35,361	45.1	42.6	12.2	?	6	2
	23	M:nt(ns)	75	-----	100.0	-----	?	--	--
	36	W:(bg)	28	12.0	52.6	35.3	?	--	1
C.	Highly disturbed areas, few native species remaining								
	10	D:UNASSIGNED	10,265	-----	-----	0.8	99.1	--	--
	20	M:UNASSIGNED	10,946	-----	-----	1.2	98.7	1	--
	30	W:UNASSIGNED	1,777	-----	-----	-----	100.0	1	--
		NOT VEGETATED	55,176	-----	-----	-----	-----	--	--

* Units marked with an asterisk (*) had a relatively large number of endangered species recorded during the HFBS.

** NN = communities totally dominated by native plants.
NX = communities with subdominant vegetation layer primarily introduced plants.
XN = communities dominated by introduced species but containing remnant populations of native plants.
XX = communities totally dominated by introduced plants.

The third category in table 2 contains the 3 highly disturbed "Unassigned Units" in each habitat and the large "Not Vegetated" map unit. The unassigned units combined represent less than 5% of the total area surveyed.

Summary of Endangered Species Found Within Study Area

All 7 of the endangered terrestrial forest birds and 33% of the endangered or candidate endangered plants (42 of 129) from the island of Hawai'i were recorded at least once during the HFBS. The relatively low percentage of endangered plants encountered reflects: 1) the fact that the survey was focused on endangered forest birds and therefore did not include large portions of potential endangered plant habitat, particularly below 500 m elevation, and 2) the sampling framework used (transects established at 3.2 km intervals) was too coarse to adequately sample rare plant populations. Despite these limitations, the systematic information gathered on endangered plants during the survey allows a general overview of the distribution of some rare plants found within the study area.

The numbers of species of endangered birds and plants encountered in each of the Level 1 map vegetation units are listed in the last 2 columns in table 2. At least one endangered bird or plant species was recorded in every vegetation unit sampled except the mesic mixed native tree community (unit 23). As mentioned earlier, this large and extremely species-rich unit was barely sampled during our survey. In fact, a large number of endangered plants are known from this vegetation type (Wagner, Herbst, and Yee, this volume). The endangered bird listed for the unassigned wet and mesic units is the Hawaiian hawk or 'io (Buteo solitarius), which has an extremely broad distribution, including some highly modified habitats.

The 9 vegetation types marked with an asterisk (*) in table 2 had a relatively large number of endangered species recorded in them during the survey. Two of the species-rich units, the wet koa-'ohi'a forest (unit 31) and the wet 'ohi'a forest (unit 32) are included in group A of table 2. However, a more detailed analysis of the HFBS bird data set revealed that most of the endangered forest bird populations were found at greater than 1,500 m elevation (Scott et al., in press; Scott, Kepler, and Sincock, this volume). Only approximately 25% of the wet 'ohi'a forest and less than 20% of the wet koa-'ohi'a forest was found above 1,500 m. The rest of the species-rich vegetation types are in the more heavily disturbed group B. One of the most important units of group B is the mesic koa-'ohi'a forest (unit 21) which had 6 endangered birds and 11

endangered plants recorded in it. However, only 13.4% of this unit was mapped as native-dominated.

DISCUSSION

Factors Responsible for Degradation of Native Habitats

The most rapid changes to native communities have resulted from direct human activities such as agriculture, urbanization, logging, etc. The majority of habitat loss from land conversion for strict agricultural practices and urbanization has occurred below 1,000 m elevation. Recent evidence has also indicated that many of the lower elevation communities were severely modified by the Hawaiians prior to western contact (Kirch 1982). Most of the recent expansion of "urbanization" in still native habitats has been in the form of new housing developments, e.g. in the Volcano and Kona regions on the island of Hawai'i.

Logging activities have primarily been concentrated in the upper elevation mesic koa-'ohi'a forest. Koa is recognized as an exceptionally fine cabinet wood and is always in high demand. Following logging, a usual practice has been to convert the newly opened forest to ranchland by introducing both cattle (Bos taurus) and pasture grasses to the area. A detailed analysis of the HFBS data has shown that this combination of opening the tree canopy by logging and elimination of the understory by cattle results in significantly reduced quality habitat for forest birds (Scott et al., in press). Similar effects have been documented for some of the rare native plant species such as Vicia menziesii (Warshauer and Jacobi 1982).

Fire is another disturbance factor which can rapidly change the structure and composition of the native vegetation, particularly in the dry and mesic habitats. The history of fire in the natural Hawaiian ecosystem has received only limited attention (Vogl 1969). On the 2 youngest islands, Maui and Hawai'i, natural fires can still occur as the result of volcanic eruptions or rarely from lightning strikes. However, most of the recent fires in the Islands have been caused by man. In 1977, an accidentally started fire burned a significant portion of the mamane-naio woodland on Mauna Kea on the island of Hawai'i (Scott et al. 1984). This habitat is the only remaining area where the endangered palila (Loxioides bailleui) is found.

The most widespread disturbances to the native communities have resulted from the effects of the numerous species of both plants and animals introduced into Hawai'i by man. Particularly damaging have been

the large feral mammals including cattle, goats (Capra hircus), sheep (Ovis aries), pigs (Sus scrofa), and deer (Odocoileus hemionus and Axis axis). A small, but significant, proportion of the nearly 4,500 taxa of introduced plant species is recognized as being particularly damaging to the native habitats (Smith, this volume). Once established, species like fountain grass (Pennisetum setaceum) and Koster's curse (Clidemia hirta) cover large areas, replacing nearly all of the native ground layer species. Introduced vines such as Passiflora mollissima have the potential to drape tall koa trees and eventually break down the tree canopy with their weight (Warshauer et al. 1983).

Recovery Potential for Damaged Native Ecosystems

Despite what may appear as almost insurmountable pressures from the numerous habitat degradation factors, several of the native plant communities have the capacity for significant recovery if some of the detrimental factors are controlled. The review of exclosure studies in Hawai'i presented by Loope and Scowcroft (this volume) shows that in many habitats, elimination of feral animals alone will produce positive results to native vegetation. The greatest potential for habitat restoration appears to be in those communities above about 1,000 m elevation that still retain some degree of their original vegetation structure and composition (category NX in the earlier discussion in this paper). The only hope for the rehabilitation of units in the XN or XX disturbance categories would involve an intensive management program including large-scale replanting of key native components of the community. Even with this degree of manipulation, it is doubtful that widespread self-maintaining native communities could be reestablished.

Conservation Strategies

The maintenance of the greatest number of viable populations of the numerous endangered Hawaiian plants and animals appears to be best accomplished through the protection of relatively intact native communities. This approach seems to be valid for 2 reasons: 1) unnaturally rare species which evolved in a particular community would be expected to be most easily maintained there, and 2) many of the endangered species in Hawai'i are found to co-occur in certain community types. The management of a specific habitat for one endangered species should, in most cases, benefit other endangered species as well.

The development of a preserve system for the protection of endangered Hawaiian species should focus on securing and managing significant portions of those species-rich and threatened vegetation units identified in table 2 which are still dominated by native

species. Management programs should also be developed to reduce or eliminate alien pressures in adjacent parcels to eventually supplement existing intact portions of these units. Specifically, it is essential that no more of the remaining 13.4% of the native-dominated mesic koa-'ohi'a forest be destroyed. Any further loss will likely result in the loss of some of the dependent endangered species. The upland portions of the wet koa-'ohi'a and wet 'ohi'a forests which are also important endangered bird and plant habitats should be protected from further degradation. Other vegetation units with extremely urgent protection and management needs are the lowland mesic and dry mixed forest, of which little remains.

We must be careful not to direct all of our attention toward trying to maintain extremely rare species in highly disturbed habitats, while other endangered species with reduced, but more substantial, populations continue to decline in abundance and distribution. This is not to say that we should totally ignore so-called "basket-case" species; instead, we need to focus more of our efforts on protecting rare species still within natural or nearly natural environments. This approach should not only be more cost-effective than attempting recovery of single species, but should reduce the number of endangered species of concern in the future. In the final analysis, the success of research and management efforts will be measured in the year 2050, not so much by the number of species saved from extinction, but by how many species were prevented from becoming endangered.

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