Technical Report No. 8

BIRDS OF HAWAII VOLCANOES NATIONAL PARK

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TABLE OF CONTENTS

ABSTRACT

The dominant and subdominant plants are listed for 10 major vegetational and climatic areas within Volcanoes National Park. These areas are located at elevations between 1,400 and 10,000 feet. Information on the birds found in eight of the 10 areas during the late 1940s is available in the paper by Baldwin (1953); two of Baldwin's study plots are not included in the IBP transects, but data on the birds in these plots from 1970-1972 are included in this report.

Notable differences between bird populations in the 1940s and the early 1970s are:

1. The apparent disappearance from the Park of two species of rare and endangered honeycreepers: Akiapolaau and Ou.

2. An apparent disappearance of the Apapane from certain low-elevation habitats.

3. A decrease in the range, and probably in population density, of the Elepaio.

4. The disappearance of the Hawaiian Thrush from at least two plots at low elevations.

5. A reversal in density of the Red-billed Leiothrix and the Japanese White-eye. The White-eye was first recorded in certain regions of the Park between 1940 and 1944. It now is found at nearly all levels and in all habitats within the Park from sea level to above tree line, and it is now the most common exotic species in the Park. The Red-billed Leiothrix is now common in suitable habitat, but population density

probably is lower than during the 1940s.

6. The Hawaiian Goose now occurs regularly within Park boundaries, especially during the breeding season; the species was close to extinction during the 1940s and was not seen by Baldwin.

The discovery that the Apapane sometimes build nests in collapsed lava tubes is discussed. That this type of nesting behavior is not rare is suggested because it was found on Mt. Hualalai and at three widely separated sites on Mauna Loa.

At least three species of *Plasmodium*, the protozoan parasite that causes bird malaria, have been identified in the blood of one endemic (Apapane) and two introduced (Leiothrix and White-eye) species of birds in Volcanoes National Park. Studies on the mosquito vector for *Plasmodium* are needed.

Baldwin's (1953) thorough study of the insect food of the Amakihi, Apapane, and Iiwi is summarized, as is his discussion of the phenology of the tree species whose flowers provide nectar for the honeycreepers. The need for contemporary observations on the relationship of the Iiwi to lobeliad flowers is noted.

Birds of Hawaii Volcanoes National Park
A Preliminary Report

Andrew J. Berger

The five transects of the Hawaii IBP Island Ecosystems subprogram within the boundaries of Volcanoes National Park are in one of the few regions in Hawaii for which comparative data are available for earlier years. Baldwin (1953) made observations in Volcanoes National Park over the period of time extending from December 1937 to September 1949; he was an employee of the National Park Service from April 5, 1940, to April 6, 1946, and he devoted full time to intensive research for his Ph.D. thesis from September 18, 1948, to September 22, 1949. A number of his study plots correspond with those now being used by Hawaii IBP personnel.

Baldwin's thesis involved a study of the distribution, abundance, and annual cycle of three species of the bird family Drepanididae or Hawaiian honeycreepers (Amakihi, Loxops v. virens, Apapane, Himatione sanguinea, and Iiwi, Vestiaria coccinea), but he also included data on distribution and relative abundance of all other bird species that he found in the Park.

Dunmire (1962), a Park naturalist, conducted censuses of birds within the Park during the period from May 1959 through December 1961. I first visited Volcanoes National Park on March 30, 1964, have made observations on the birds within the park annually since that time, and have concentrated my studies on the transect plots and in the Kilauea Forest Reserve since July 1970.

Difficulties of Censusing in Hawaii

Direct comparisons of the results obtained by Dunmire and myself with those obtained by Baldwin are not possible because Baldwin made his counts in relatively small (1.7 to 5 acres) census plots, whereas Dunmire counted all birds actually seen while hiking either straight or loop transects, one of which covered a change in elevation of 1,500 feet. I relied on both sight and sound (songs and callnotes of the birds) for recording the number of birds found in a given habitat.

Significant differences in the bird species seen and in the relative abundance of certain species are apparent when comparing data obtained in the 1940s with those obtained during the past 15 years, as will be detailed later. It very soon becomes evident to anyone who begins to study Hawaiian forest birds, however, that it undoubtedly is impossible to obtain an exact count of the number of individuals of a given species in a rain forest ecosystem comprised of ohia trees and tree ferns. These forests are so thick and the dominant trees so tall that one must rely on sound more than on sight for tabulating the birds present. Moreover, many of the species (particularly the honeycreepers) range widely through the forest even during the breeding season, and a dozen individuals may be seen feeding in a single blooming ohia tree at the same time. Unlike most continental passerine birds, the Hawaiian honeycreepers do not defend a large breeding territory; they defend only a small area around the nest, and they often tolerate other species to feed within the nest tree itself.

The song pattern of most Hawaiian forest birds also differs importantly from that found among continental passerine species. In general, continental species sing only during their nesting period; this is not true of many of the Hawaiian forest birds, and some songs may be heard during nearly every month of the year, although the rate and persistency of singing does vary throughout the year. A "singing-male" census, therefore, is apt to give a highly misleading figure as to the number of birds actually present in an area.

The song pattern of the Elepaio (Chasiempis s. sandwichensis) demonstrates another complicating factor. Both sexes sing but the birds do not sing persistently throughout the nesting period; during most of this period, there is both a daily and a seasonal song rhythm. The Elepaio has a dawn singing period that begins about 6:00 a.m. and lasts for a half hour or more; this species also has a twilight song period that begins at approximately 6:30 p.m. and lasts for about 20 minutes. The birds sing most persistently throughout the day during the first week of nest building. By contrast, the birds sing infrequently during the incubation period. There is an increase in singing after the eggs hatch and a further increase after the young leave the nest. Only infrequently do the birds sing during the non-breeding season. Consequently, the amount of singing by Elepaio varies considerably with the time of the day, the stage of the nesting cycle, and the time of year. Hence, these factors must be known if one wishes to attempt to obtain a reasonably accurate census of the numbers of birds present in a given study area; such a census is impossible during much of the year.

A "singing-male" census, if conducted properly, of the Hawaiian Thrush (Phaeornis o. obscurus) during the nesting season can give reliable information on the population of birds present in the rain forests. The birds sing and call from early morning to late in the evening, and the males often perch on exposed limbs high in the forest. The birds defend a breeding territory, and, therefore, do not move throughout the forest as the honeycreepers do. However, I have heard thrushes sing during nearly every month of the year, although singing is infrequent during late August and September. There seems to be a resurgence of song (often whisper songs) during October, and singing frequency increases throughout the winter months. We do not yet know precisely how singing frequency corresponds with the nesting cycle of the thrush, however, because the total length of the breeding period has not yet been determined with certainty. The earliest nest (with two eggs) I found was on March 15, 1972; the latest nest (with two small young) I found on June 23, 1971. (To the best of my knowledge, no one else has found a nest of the Hawaiian Thrush). It also is quite possible that the length of the nesting season varies in different areas on Hawaii (that is, eastern slope of Mauna Loa, Kona coast of Mauna Loa, Saddle Road ohia forests, and Hamakua coast of Mauna Kea).

There are complicating factors in censusing birds even in the relatively open areas and those with small and/or relatively open kipukas. Examples of these areas are the Hilina Pali, Naulu Forest, the area around the end of the Mauna Loa strip road at an elevation of 6,662 feet, and the scattered *Metrosideros* trees in a matrix of shrubs that extend upward to approximately 8,200 feet elevation. It is clear that precise counts of the birds seen and/or heard in these areas on one or more days during a particular month have little meaning as to population size when compared with counts made during other months of the year.

That is, in addition to the quiet or nonsinging periods of the several bird species that inhabit these areas, there is an obvious (though poorly understood) seasonal shift in many of the species. For example, Apapane are common and conspicuous near the end of the Mauna Loa strip road during the winter and spring months; they are uncommon and inconspicuous during the late summer months.

From an elevation of approximately 4,300 feet on the Keauhou Ranch, Richard E. MacMillen, Ernest Christopher, and I observed a striking movement of Apapane and Iiwi on July 20, 1972. Beginning at 4:00 p.m., loose flocks of birds (primarily Apapane but with occasional Iiwi) were noted flying upslope from the vicinity of Volcanoes National Park toward the general direction of the Kilauea Forest area. Many of the flocks contained 20 or more birds, but there also were small groups. More than 300 birds were counted during the first 20 minutes of observation, and we estimated that more than 600 birds flew up the slope of the mountain during one hour of observation. By 5:00 p.m., only single birds or groups of two or three birds were seen following the same route past our observation post. Some birds flew at tree-top level, but the majority flew 100 or more feet above the crown of the forest. How widespread this evening flight to higher elevations is I do not know, but it may be a general phenomenon within the lower elevations of the Park. Not all of the birds leave their daytime feeding areas, however, because a small number of Apapane were seen and heard each evening in the residential area of the Park. I heard the last Apapane callnote of the evening at 6:45 p.m. on July 17, 1972, and at 7:08 p.m. the following night; these birds certainly roosted in the immediate vicinity.

All of these complicating factors make an exact census of the numbers of individuals of a given species virtually impossible in any large area within the Park. An accurate counting of all individuals of most of the species could be made only by finding every nest and nesting pair within a given area, and, because of the wide-ranging flights of the Apapane even during the nesting season, there undoubtedly would be two populations involved: the breeding population and the foraging population that nests outside of the census area. Such a nest census can be conducted effectively only by a person who has full time for such work during the entire breeding season.

Consequently, the numerical data presented by Baldwin, Dunmire, and myself must be interpreted primarily as being indicative of the relative abundance of the different species found in the several study plots, rather than as indices of population density.

Baldwin computed relative abundance in percent by "dividing [the] total number of days on which [a] species was recorded by [the] total number of days on which counts were taken at [the] plot and multiplying by 100" (Table 1). Dunmire listed the number of birds seen during each field trip and computed the percentage for each species seen by dividing the number of each by the total number of all birds observed. This method gave information on the relative abundance of the species seen during a short period of time but may not (for the reasons already given) have given a true measure of the birds actually present in the census strips. Dunmire's average trip lasted about 2.5 hours, "and no attempt

Table 1*

Relative Occurrence of Birds on Census Plots, 1940-1949[&]

Species	Census plot 1	2	3	13	17	18	7	4	8	6	12	10
Himatione sanguinea	26	66	85	89	72	97	99	100	100	97	68	90
Vestiaria coccinea	..	..	..	..	..	..	75	83	43	92	66	..
Loxops virens	50	86	88	94	71	70	65	83	72	100	70	95
Loxops maculata mana	..	..	..	..	..	..	2	..	2	9	..	..
Hemignathus wilsoni	..	..	..	..	..	..	1	..	..	44	2	..
Psittirostra psittacea	..	..	..	..	..	..	..	22	..	..	..	..
Chasiempis sandwichensis	..	12	30	33	2	6	84	87	67	91	55	..
Phaeornis obscurus	..	..	1	..	..	2	..	96	74	..	..	..
Carpodacus mexicanus	70	48	42	6	21	3	72	..	..	59	17	..
Leiothrix lutea	..	1	14	69	20	42	95	35	70	85	26	51
Zosterops japonica												
1940-1944	25	36	36	16	8	10	61	..	7	46	23	5
1948-1949	38	87	54	52	30	21	96	30	30	69	48	39
Alauda arvensis	3	1	..	..	7	..	..	..	..	..	8	..
Acridotheres tristis	45	23	32	13	2	3	4	..	..	..	..	..
Streptopelia chinensis	..	1	1	..	7	..	9	..	..	..	..	..
Asio flammeus sandwichensis	..	..	..	..	..	..	1	..	..	1	4	2
B[illegible]o solitarius	..	..	..	..	..	..	8	..	1	..	..	..
Pluvialis dominica	..	..	3	..	2	..	..	..	..	1	4	2
Lophortyx californicus	1	3	1	..	..	..	..	..	..	15	..	..
Phasianus spp	5	1	1	2	7	5	17	..	..	30	25	..
Lonchura punctulata	13	4	4	2	..	..	20	..	..	..	..	..
Garrulax canorus	..	..	..	6	..	2	..	..	..	..	..	..
Richmondena cardinalis	..	..	..	..	..	..	2	..	..	..	..	..
Number of days on which counts were taken	64	73	73	54	61	66	92	23	100	110	53	41
Number of species	9	12	13	10	11	10	16	8	9	13	12	6

* Modified from Baldwin, 1953, page 353; I have changed several scientific names in accordance with contemporary taxonomy.

& Relative occurrence is given in per cent computed by dividing total number of days on which species was recorded by total number of days on which counts were taken at plot and mutiplying by 100.

was made to establish a uniform pattern for time of day for the trips, so this factor varied considerably." Dunmire also pointed out, appropriately, that "it is not meaningful to compare the total number of each species observed per hour in one area with that of another, since the terrain, which plainly limits the distance that can be covered in an hour, and the vegetative cover differ so widely in the park." In short, census methods that are widely used in North American and European bird habitats (whether of grassland, coniferous forest, or deciduous forest) are not suitable for censusing most species of Hawaiian forest birds.

Bird Distribution Along the Transects

Ten significant vegetational areas for birds are discussed in the following pages.

1. Kipuka Keana Bihopa, plot no. 1 of Baldwin.
   Portions of segments nos. 4 and 5, figure 3, IBP Technical Report No. 2.

   Elevation: 2,300 to about 2,600 feet.
   Annual rainfall (est.): 30 inches.

   Dominant vegetation: Baldwin's study plot (of 2 acres extent) was within the kipuka, which consisted of a grove of mature trees (*Metrosideros* and *Sophora*) and a ground cover of perennials (*Bidens* sp., *Commelina diffusa*, *Hypochaeris radicata*, *Cynodon dactylon*) and the fern *Pteridium aquilinum*.

The IBP plot begins at the Hilina Pali (2,282 feet by bench mark at the resthouse), and is characterized as an *Andropogon* grassland. The two dominant grasses are *Andropogon glomeratus* and *A. virginicus*, but the creeping molasses grass (*Melinis minutiflora*) and the fern *Pteridium aquilinum* occur; there are scattered individuals of two native shrubs (*Dodonaea* and *Styphelia*). The plot also includes open

Metrosideros kipukas.

It seems likely that the bird species found in the Andropogon grassland at the top of the Hilina Pali are predominantly birds of passage. I have seen only Linnets (Carpodacus mexicanus) and Common Mynahs (Acridotheres t. tristis) in this region. I have never visited this area during the winter months, and it is possible that the Golden Plover (Pluvialis dominica) occurs in this grassland area. Baldwin found European Skylarks (Alauda arvensis) in the vicinity of Kipuka Keana Bihopa on three occasions, but I have not observed this species there. The grass cover may have increased so much since the 1940s that the habitat is no longer suitable for the plover or the skylark.

Baldwin found nine species of birds in his plot number 1 during 1948 and 1949 (Table 1). The chief difference now is the apparent absence of the Apapane from this lowland kipuka. The Amakihi still inhabits the kipuka, but both Japanese White-eyes (Zosterops japonica) and Linnets appear to outnumber the Amakihi by several fold.

2. Kipuka Nene, plots nos. 2 and 3 of Baldwin; not included in IBP transects.

   Elevation: 3,000 feet.
   Annual rainfall (est.): 40 inches.

Dominant vegetation: Both plots within Kipuka Nene consist of transition forest in which the dominant trees are Metrosideros and Sophora; the dominant shrubs are Dodonaea viscosa and Styphelia tameiameiae; and the ground cover consists of dryland plants (e.g., Pteridium, Carex, Tricholaena, and several species of grasses). Baldwin's two plots (each of 2 acres extent) within the same kipuka differed primarily in that one consisted of a "uniform, closed, four-storied forest," with an understory predominantly of ferns, whereas the second plot was a "mixed grove with open spaces."

A large segment of Kipuka Nene was altered drastically by a fire that swept through it in July 1970, killing many of the ohia trees and other plants. Baldwin found 15 species of birds (4 native and 11 introduced) in 1948 and 1949 (see Table 1). The most striking change since that time is the certain disappearance of two of the native species (Elepaio and Hawaiian Thrush) and the drastic reduction of a third, the Apapane, which now occurs in small numbers and, apparently, only seasonally. By contrast, Baldwin recorded the Apapane on 85 percent of the days on which he visited the kipuka. The Amakihi still inhabits the area in considerable numbers, and, on June 25, 1971, I watched an Amakihi singing while perched in one of the dead ohia trees.

The chief difference in the status of introduced birds is the apparent absence now of the Red-billed Leiothrix (*Leiothrix lutea*), which, however, is common in higher and wetter areas of the Park. The White-eye is one of the most common birds in the kipuka. Ricebirds (*Lonchura punctulata*; *Munia punctulata* in Baldwin 1953) apparently occur as birds of passage, feeding on the seeds of grasses and other plants. Linnets frequent the area, and flocks of 15 or more birds are common during the summer months. Golden Plover spend the winter months in the open areas.

3. Ainahou Gate, plot 13 of Baldwin; not included in IBP transects.

   Elevation: 3,050 feet.
   Annual rainfall (est.): 75 inches.

Dominant vegetation: This is a transition forest in which Baldwin found the dominant trees to be Metrosideros collina, Santalum paniculatum, and Myrsine sandwicensis. Styphelia and Vaccinium reticulatum were conspicuous shrubs. This is an early stage of forest on lava flows, and the shrub layer was prominent in 1949.

By "Ainahou Gate," Baldwin specified his study plot of 1.7 acres around the gate and fence that separates Park land from the Ainahou Ranch. The entire ranch is very heavily overgrazed, from the entrance at 3,050 feet as far down the slope as the Poliokeawe Pali at an elevation of approximately 2,000 feet.

Significant changes in the bird populations between 1948-1949 and the present are the apparent desertion of the area by the Elepaio and the great increase in the population of Lace-necked Doves (Streptopelia chinensis) at the 3,000 feet elevation on this slope of Kilauea volcano. Baldwin sighted Lace-necked Doves on only one occasion each in plots 1 and 2 of Kipuka Nene and he did not see the species at all at his census plot at the Ainahou ranch gate. This dove now occurs by the hundreds in the upper reaches (approximately 2,700 to 3,000 feet) of the ranch. It is not uncommon to see flocks of 35 or more birds feeding on the ground among the cattle and the watering troughs. The Apapane occurs in Baldwin's plot 13, but in reduced numbers.

The Amakihi is still a common species in the greatly disturbed forest at the Ainahou Gate, around the ranch house, and in other areas where a sufficient amount of forest remains. I also saw several Amakihi at an elevation of about 2,100 feet near the top of the

Poliokeawe Pali on July 19, 1972. Other birds seen in the area were Linnet, White-eye, and Lace-necked Dove. Frederick R. Warshauer told me that he had seen a Pueo or Hawaiian Owl (*Asio flammeus sandwichensis*) and a Cardinal (*Richmondena cardinalis*) there during the preceding month.

4. Naulu Forest above pali; segment no. 4, figure 5, IBP Technical report No. 2.

   Elevation: 1,400 to 1,700 feet.
   Annual rainfall: 91 inches (average 1966-1970)

   Dominant vegetation: This forest, located between approximately 1,400 and 1,700 feet elevation, consists of a mixed dry evergreen forest, in general, with sparse undergrowth. The dominant trees are *Metrosideros*, *Diospyros*, and *Aleurites moluccana*. Doty and Mueller-Dombois (1966:429) reported that the vegetation in this segment is "quite variable, forming open to scattered *Metrosideros-Diospyros ferrea* stands with either grassy undergrowth dominated by *Andropogon virginicus* ... and mixtures of native (i.e., *Styphelia*, *Dodonaea*) and introduced shrubs (i.e., *Lantana camara*, *Stachytarpheta jamaicensis*, and small *Psidium guajava*), or occurring on almost barren colluvial a'a lava surfaces with patch colonies of the fern, *Nephrolepis exalta* ..., or thirdly, forming closed patch-forests dominated by *Aleurites moluccana*."

This area was virtually inaccessible at the time that Baldwin conducted his study, and, therefore, was not included among his census plots. With the completion of the Chain of Craters road in 1965, the entire expanse of forest between Kilauea crater and the Holei Pali (as well as the lowland area to Kalapana) became readily accessible. A series of **eruptions** along the Puna rift zone, beginning in May 1969, however, have sent streams of lava across the Chain of Craters road in several areas, cutting off a segment of the road and the adjacent forest for a distance of about 14 miles; all but approximately two miles of the road are covered by lava, as is much of the former forest. Much of the area is still hazardous, and I have made no observations in this area since November 1970. 1972 lava flows destroyed more of this forest.

I have seen the Amakihi at elevations as low as 1,600 feet on several occasions in the Naulu forest, and, on August 4, 1969, I watched a pair of birds with at least two fledglings in the Naulu picnic area, only a short distance from the point where the road begins its steep descent of the pali. The young birds had been out of the nest only a few days and undoubtedly were hatched in the immediate vicinity.

I have thus far recorded only two other species of birds in the Naulu forest area: the Japanese White-eye and the Common Mynah. On November 21, 1970, however, I saw one Cattle Egret (Bubulcus ibis) in the Heteropogon grassland and Styphelia and Dodonaea shrub area (segment 3, figure 5) at an elevation of about 900 feet. The Cattle Egret was introduced to the island of Hawaii in 1959; this apparently is the first sighting of the Cattle Egret in the Kalapana region.

5. Lava Trees: 0.25 mile northwest of Napau Crater, plot no. 4 of Baldwin.
   Segment no. 7, figure 5, IBP Technical Report No. 2.

   Elevation: 2,850 feet.
   Annual rainfall: 100 inches.

Dominant vegetation: Metrosideros and Cibotium and their associated flora. However, several new lava flows have covered large areas in recent years, and these have made access to the crater and surrounding forest very difficult and hazardous; special permission must be obtained from the National Park Service to enter the area. No recent, detailed botanical study has been made.

Baldwin (1953:301) described this area as it appeared in the 1940s. "At plot 4, a stratification occurs in the vegetation. On the ground, Astelia veratroides, ferns, mosses, shrubs such as Wikstroemia and Cyrtandra, Freycinetia, ferns, and young trees form a fairly dense understory. Above these the tall tree-fern fronds and Gouldia trees make a continuous subceiling at 15 to 20 feet above the ground. Through the subceiling, the Metrosideros trunks, Cheirodendron, and those of other trees, as well as the Freycinetia vines, penetrate; and their branches spread to create an almost continuous ceiling at 40 to 60 feet, with the branches of Metrosideros predominating."

Baldwin found six species of endemic birds in this ohia-tree fern habitat in the 1940s: Apapane, Iiwi, Amakihi, Ou (Psittirostra psittacea), Elepaio, and Omao or Hawaiian Thrush. All of these except the Ou were recorded by Baldwin on from 82 to 100 percent of his visits to the forest, which suggests that all were permanent residents there. The Ou he found on 22 percent of his visits, although Baldwin does not say how many individuals he saw on any census day. Nothing is known about the annual cycle of the Ou, and there is no way of knowing how large the population was during the 1940s. The significant point about Baldwin's plot 4 and the surrounding forest in the vicinity of Napau Crater was, as Baldwin wrote, that it represented "one of the last remaining haunts of the drepaniid Psittirostra psittacea (ou), a bird once fully as widespread over the Hawaiian archipelago as Vestiaria" (page 301)..

Dunmire's censuses between Napau Crater (2,600 feet) and Makaopuhi

Crater (3,200 feet; segment 7, figure 5, IBP Technical Report No. 2) were made in July 1959, April (twice), and October 1960; he devoted almost 15 hours to his four trips to the forest. Dunmire did not see the Ou; moreover this species apparently was not observed within the Volcanoes National Park until June 1972, when Francis Jacot, a visiting biologist from the Western Regional Office of the N.P.S., told Donald W. Reeser that he had seen one Ou at Volcano House. On December 15, 1967, however, Ranger George Morrison saw four Ou along hiway 11 about .25 mile from the Hilo entrance to the Park.

Winston E. Banko, Clint Lostetter, and Ray Erickson saw one Ou in an ohia-tree fern forest on Puna trail number 2 north of the Park on July 19, 1970. This was only the second authentic record of the sighting of an Ou on Hawaii since Dunmire's report of three birds seen during 16.75 hours of observation in the Olaa tract (elevation 3,700 to 3,900 feet) in the Wright Road area a few miles north of the Park. Although I have done a considerable amount of field work on the island of Hawaii since 1965, I have never seen the Ou on that island.

Other significant changes have occurred in the bird populations in the Napau Crater region since the 1940s. Baldwin reported the Apapane on 100 percent and both the Iiwi and the Amakihi on 83 percent of his census trips in 1948 and 1949. By contrast, between July 1959 and October 1960, Dunmire gave the percentage of occurence of Apapane as 16, and he reported the Iiwi and Amakihi to constitute less than one percent of all birds seen on his four trips through the forest.

Baldwin saw the Hawaiian Thrush on 96 percent and the Elepaio on 87 percent of his visits to the Napau Crater census plot. Dunmire saw only nine thrushes and seven Elepaio during his counts.

Of the introduced species, the White-eye has shown the most spectacular increase in the Napau Crater area. Baldwin did not see the species there from 1940 to 1944; from September 1948 to September 1949, he recorded the White-eye on 30 percent of his visits. Dunmire wrote in 1962 that "the White-eye is by far the commonest bird now"; White-eyes comprised 58 percent of all birds he saw during nearly 15 hours of observation in the forest between Napau and Makaopuhi craters.

During my first trip to Napau Crater (12:00 noon to 3:00 p.m., January 22, 1966), I recorded only two species of endemic birds (Apapane and Iiwi) and one introduced species (White-eye). By November 1968, a new lava flow had made Napau Crater itself virtually unapproachable, but, in a census trip to the edge of the still-smoking flow, I recorded only the Apapane and the White-eye. The Amakihi probably still occupies the surrounding forest, but the Ou and Elepaio apparently no longer inhabit this lower region of the Park. The Omao appears to be rare there; James Jacobi heard one bird along the east wall of Makaopuhi Crater on March 16 and May 13, 1972. He saw one Chinese Thrush at Napau Crater during March 1972.

6. Twin Craters, plot 8 of Baldwin.
   Thurston lava tube, segment 12, figure 2, IBP Technical Report No. 2. Thurston lava tube is adjacent to, and on the southeast side of, the Twin Craters.

   Elevation: 3,650 feet.
   Annual rainfall: 110 inches.

Dominant vegetation: This is a classic, closed *Metrosideros-Cibotium* Hawaiian montane rain forest, and it is the dominant rain forest ecosystem in the Park. Doty and Mueller-Dombois (1966:409-410) wrote that the crown-canopy height of the ohia trees varies from 14 to 20 meters. The second level of the forest is formed by the tree ferns (*Cibotium*), whose crown height varies from 2 to 5 meters. Other tree species include Myrsine lessertiana, Ilex anomala, Coprosma ochracea and Gouldia terminalis. The lava substrate of the forest floor supports shrubs (Wikstroemia, Vaccinium calycinum, Pipturus albidus, and Cyrtandra platyphylla) and herbs (e.g., Gahnia gahniaeformis, Briza minor, Isachne distichophylla, Lycopodium cernuum, Hedyotis centranthoides, and Pepperomia spp.). Epiphytic mosses and ferns (e.g., Acroporium fusco-flavum, Elaphoglossum reticulatum) grow on the trunks of ohia trees.

The ohia-tree fern ecosystem is the characteristic habitat for a large number of endemic Hawaiian forest birds, and it is the habitat in which one finds only a relatively small number of introduced species. Most of the exotics that do invade this ecosystem demonstrate a high tolerance for the climatic and vegetational conditions found there, however, and, consequently, typically occur in high numbers. This is especially true of the Japanese White-eye and the Red-billed Leiothrix.

Only one of the endemic species found by Baldwin in the 1940s has not been seen in the Thurston lava tube area since that time: the Hawaii Creeper, Loxops maculata mana. This rare and endangered species has only infrequently been reliably reported on Hawaii in recent years. Dunmire saw one Creeper in the Olaa tract (north of the Park) during his study. I have seen only five birds that I felt sure were Creepers during my field work on Hawaii from 1965 through July 1972. Winston E. Banko saw one Creeper in 1970.

The Apapane and the Amakihi are abundant in the Thurston lava tube region throughout most of the year, and the Iiwi is fairly common there during the breeding season. At this elevation in the Park, the Apapane are relatively inconspicuous during the late summer and fall, but they are the most abundant species during the rest of the year, and they are in full song by November. Apparently no nests of the Apapane have been found in November or December in Volcanoes National Park (although I have found December nests in Saddle Road forests). That the Apapane does nest as early as January, however, was discovered by Baldwin, who wrote that "the earliest record for a fledgling off the nest was February 3, 1942." In the Thurston lave tube area, I found two active, but inaccesible, Apapane nests on February 5, 1972. One of these was built about 20 feet above the path to the lava tube on the upper surface of a tree-fern frond; the other was built approximately 50 feet above the ground in a slender ohia tree. On February 19, 1966, I watched a pair of Apapane building their nest about 10 feet from the ground in an ohia tree; at that time the birds were collecting pulu from a fern and adding it to the nest.

In the absence of figures on population sizes for the Elepaio and the Omao in Baldwin's five-acre census plot at the twin craters or in a comparable area at the Thurston lava tube (Dunmire did not census either area), it is impossible to comment precisely on possible changes in the population levels of these two species since the 1940s. Dunmire (1961) stated that the Omao was "moderately common in the wet ohia forest, especially along the Crater Rim Trail between Park Headquarters and Thurston Lava Tube." It has been my experience that the thrush is now uncommon or absent around the Volcano House, Park headquarters, and the western part of the Crater Rim Trail, so that it is possible that there has been a decline in numbers of the thrush in this portion of the Park. I have never heard more than three thrushes singing or calling at one time in the Thurston lava tube region. (I also heard three thrushes near Park cabin number 8 at 6:45 p.m. on July 17, 1972, but the birds are not common there.)

It seems certain that there has been a decrease in the Elepaio population in nearly every part of the Park since the 1940s. Dunmire (1961) characterized the Elepaio as being "common in the more heavily vegetated areas around Kilauea Crater and to the east." The Elepaio now appears to be rare or absent in most of the forests around the crater, and it is far from common in the Thurston lava tube region. Although I have made no special effort to study the Elepaio in this area, I have never seen or heard more than two birds on any visit to this habitat. The Elepaio also is now absent at lower elevations where Baldwin found it commonly in the 1940s.

There has been a reversal in the populations of the Leiothrix and the White-eye in the twin craters-Thurston lava tube area since the 1940s. The Leiothrix certainly is less common now than when Baldwin studied in the twin craters region; I failed to find the Leiothrix at all on a number of trips at different times of the year. By contrast, the White-eye is now a characteristic bird of this forest and can be found during every month of the year, whereas Baldwin found it on only 7 percent of his visits between 1940 and 1944, and on only 30 percent during 1948 and 1949.

7. Kipuka Puaulu (Bird Park), plot 7 of Baldwin.
Kipuka Puaulu, segment 9, figure 2, and segment 8, figure 3, IBP Technical Report No. 2.

Elevation: 4,050 feet.
Annual rainfall: 65 inches.

Dominant vegetation: Doty and Mueller-Dombois (1966:407-408) described the Bird Park area as follows: "This is the closed forest type of Kipuka Puaulu (Bird Park), which is however also represented by Kipuka Ki and others in the summer-dry climate on deeply weathered soil. The soil here is composed of deep (up to 6 m) **volcanic ash,** probably of dune origin ..., and it is much enriched with organic colloids. These closed forest types occur usually as islands (kipukas) throughout the same elevational range as the preceding savannah type, i.e., between 5000 and 4000 feet. However, this particular kipuka (Puaulu) ranges from about 4200 to 3900 feet exhibiting a broadly undulating secondary topography. ... The taller trees (20-30 m) are dominantly of Acacia koa, Sapindus and Metrosideros. A well-developed lower tree layer (of 2-10 m height) comprises a number of tree species among which Myrsine lessertiana, Coprosma rhynchocarpa, Myoporum sandwicense, Psychotria hawaiiensis, Osmanthus sandwicensis and Sophora chrysophylla are the most common. Several species of Pelea are also present. An abundant arborescent shrub, which dominates this stratum locally, is Pipturus albidus. The understory in the less dense parts of the forest is comprised largely of a native fern, Microlepia setosa. There are several noteworthy patch communities beneath the tree canopy. Of particular interest are the Peperomia cookiana patches on pig-scarified ground, and the introduced plants now forming communities such as the two shrubs, Rubus penetrans and Solanum pseudocapsicum, and the herb Commelina diffusa. The oldest trees are partly covered with epiphytic mosses."

Kipuka Puaulu has one of the older forests within the Park boundaries, and, despite a number of open grass areas and introduced plants, it still provides suitable habitat for the following endemic species: Apapane, Iiwi, Amakihi, and Elepaio. None occur in concentrations comparable to those in the wetter ohia-tree fern forests, however. Dunmire (1962) remarked that "a most striking feature of the population in these two kipukas /kipuka Puaulu and kipuka Ki/ is the absence of Amakihis." I have found this species in both kipukas, however, although in relatively small numbers.

Two endemic honeycreepers (Creeper and Akiapolaau, Hemignathus wilsoni) were seen by Baldwin on one or two occasions between 1940 and 1949. Dunmire (1962) wrote that these species had not been seen in the kipuka "in recent years," and I know of no observations of these two species in Bird Park in subsequent years.

It is interesting to note that although Baldwin found White-eyes to be uncommon at his census plots at lower elevations, he found them on 96 percent of his visits to kipuka Puaulu during 1948 and 1949. How common the species was at that time, however, was not stated. By 1962, Dunmire considered the White-eye to be the most numerous bird in the Kipukas." It probably is the most common species in Bird Park now.

Other introduced species that occur regularly or occasionally in Bird Park are: pheasants (Phasianus sp.), Lace-necked Dove, Red-billed Leiothrix, Common Mynah, Linnet, Cardinal, and Ricebird.

8. Kipuka Kulalio, plots 6 and 12 of Baldwin.
Kipuka Kulalio, segment 7, figure 2, IBP Technical report No. 2.

Elevation: 5,500 feet, and 5,900 feet.
Annual rainfall: 55 inches (plot 6), 52 inches (plot 12).

Dominant vegetation: This mountain parkland ecosystem is formed by _Acacia koa_ tree colonies (30-100 m in diameter), by tall scrub communities formed of _Styphelia_ and _Dodonaea_, and by patches of mixed high-altitude grasses (e.g., _Deschampsia nubigena_, _Trisetum glomeratum_, _Holcus lanatus_, _Festuca ernoides_, _Eragrostis atropoides_, and _Paspalum urvillei_). These three different types of plant communities exist in a diffuse pattern throughout the region from an elevation of approximately 4,200 feet upward to 6,800 feet (Doty and Mueller-Dombois, 1966). There also are breaks in this parkland community where more recent lava flows have entered the area.

Baldwin used two study plots in the parkland habitat along the Mauna Loa strip road: one of 5 acres (plot 6) at 5,500 feet and one of 3.7 acres (plot 12) at 5,900 feet elevation. The vegetation and annual rainfall are nearly identical in the two plots, but, although there was only a 400 foot change in elevation between the plots, there appeared to be significant differences in the occurrence of several bird species at the time of Baldwin's study. The apparent absence now of several species of endemic birds found by Baldwin casts doubt on any important differences among the birds in the two isolated plots within the same ecosystem. At any rate, only a detailed study throughout the year of the two plots would reveal whether or not there are significant differences in population size among the several species of endemic birds now found in this habitat.

Dunmire (1962) wrote that he had never seen either the Akiapolaau or the Creeper in the Park; I have never seen the Akiapolaau there. Park Naturalist Pat Crosland, however, saw one bird at 5,352 feet elevation along the Mauna Loa Strip road on April 28, 1970.

Baldwin observed the Akiapolaau on 44 percent of his trips to plot 6 and on 2 percent of his trips to plot 12 in the 1940s. He saw the Creeper on 8 percent of his census trips to plot 6, but he did not see it at plot 12. I know of no recent sightings of the Creeper in the vicinity of the Mauna Loa strip road.

There certainly has been a decrease in the population of Elepaio above 4,500 feet elevation since the 1940s. Although his figures do not give a true indication of population size, Baldwin recorded the Elepaio on 91 percent of his trips to plot 6 and on 55 percent of his trips to plot 12. Dunmire saw only 12 Elepaio during 10 census trips (totalling 30.5 hours) made between April 1960 and March 1961.

I have seen single pairs of Elepaio in several kipukas along the strip road at elevations of 5,300 (IBP climatic station), 5,653 (by bench mark), and 5,800 feet, and, on August 17, 1972, my daughter and I saw one Elepaio in a clump of small koa trees at an elevation of approximately 6,600 feet (a short distance below the shelter at the end of the strip road). The latter bird undoubtedly was a bird of passage. By contrast, the Elepaio is a common species in more suitable habitat at higher elevations north of the Park (e.g., Kilauea Forest

Reserve), as well as in the dry mamani-naio forest above 6,000 feet on Mauna Loa.

The chief difference in status of introduced species between the 1940s and the present is in the relative abundance of the white-eye and the Red-billed Leiothrix. In plot 12, Baldwin found the white-eye only 23 percent of the time between 1940 and 1944, and 48 percent of the time during 1948 and 1949. The White-eye is now ubiquitous at all elevations along the Mauna Loa strip road. Although now generally distributed, especially in the larger kipukas, on the eastern slope of Mauna Loa up to an elevation of about 7,400 feet, the Red-billed Leiothrix is far less common than is the White-eye, and this statement probably is true for all segments of the Park.

Neither Baldwin nor Dunmire distinguished the species of pheasants that they observed. Both the Ring-necked Pheasant (Phasianus colchicus) and the Japanese Blue Pheasant (Phasianus versicolor) occur in the Mauna Loa strip road region, although neither is abundant now. The two species have been known to interbreed in Hawaii.

I doubt that there is any significant difference in the populations of any introduced species at the two elevations (5,500 and 5,900 feet) in kipuka Kulalio, or in the populations of the endemic Pueo or Hawaiian Owl (Asio flammeus) or the Io (Hawaiian Hawk, Buteo solitarius), both of which appear now to occur only in small numbers within the Park. Both the hawk and the owl have very large home ranges or feeding areas, and I have, on several occasions, observed a hawk soar for distances far in excess of 400 feet of elevation.

9. Mauna Loa, plot 10 of Baldwin.
Segment 6, figure 2, IBP Technical Report No. 2.

Elevation: 7,500 feet.
Annual rainfall: 40 inches.

Dominant vegetation: Baldwin's plot 10 falls at the boundary between segments 5 and 6 of the ecosystems analysis program. Segment 6, an open Metrosideros-Sophora forest, extends from 6,662 feet (the elevation at the end of the Mauna Loa strip road) to 7,500 feet. Segment 5 begins at 7,500 feet and extends upward to approximately 8,100 feet; this is the tree line region on this slope of the mountain. Cushion shrubs (*Dubautia scabra* and *Coprosma montana*) are conspicuous elements of the vegetation in segment 5, and widely scattered ohia (*Metrosideros*) trees occur throughout the zone, making their appearance abruptly as full-grown trees (3 to 5 meters tall) at 8,100 feet elevation. Ferns (*Pteridium aquilinum* and *Asplenium adiantum-nigrum*) also occur. A small colony of silversword (*Argyroxyphium sandwicense*) occurred at an elevation of 8,100 feet in 1970, but these plants later disappeared, apparently destroyed by goats.

On 41 trips to his 5-acre census plot at 7,500 feet, Baldwin found six species of birds: Hawaiian Owl, Golden Plover, Amakihi, Apapane, Red-billed Leiothrix, and Japanese White-eye. It is of interest to note that Baldwin apparently never saw the Nene or Hawaiian Goose (*Branta sandvicensis*) in Volcanoes National Park despite his long experience there. The Nene was then (1937-1949) on the verge of extinction, and the nesting ground of the remnant population was unknown.

Dunmire (1962) listed four species of endemic birds (Omao, Amakihi, Apapane, Iiwi) and eight introduced species (California Quail, *Lophortyx californicus*; Chukar Partridge, *Alectoris graeca chukar*; Pheasant, *Phasianus* sp.; European Skylark; Common Mynah; Red-billed Leiothrix; Japanese White-eye; and Linnet) during one (apparently) census trip between elevations of 6,700 to 8,200 feet along the summit trail of

Mauna Loa.

It should now be obvious that the small census plots used by Baldwin were suitable as designed for his research, but that such limited plots are not adequate for delineating overall distributional patterns. The fact is that all six of the bird species found by Baldwin at 7,500 feet occur throughout the open ohia-mamani forest that extends from 6,662 to 7,500 feet. Two pertinent points are: 1. the populations of all of the resident species except the owl (which neither Dunmire nor I recorded in this region) tend to decrease in size with increasing elevation, and 2. the Amakihi population appears to be almost double the population of Apapane at these elevations. The upper limit of distribution for some species (e.g., Ring-necked Pheasant, Common Mynah, Iiwi) apparently occurs between 6,700 and 7,500 feet. I have seen two species in this zone that were not recorded by Baldwin or Dunmire: Nene and Hawaiian Hawk.

10. Vaccinium-Styphelia scrub desert (segment 3) and alpine aggregate-scrub desert (segment 4), figure 2, IBP Technical Report No. 2.

Segment 4 extends from 8,100 to 8,500 feet; segment 3, from 8,500 to 10,000 feet. The annual rainfall decreases from approximately 40 inches at 8,100 feet to 30 inches at 10,000 feet.

Doty and Mueller-Dombois (1966:401-402) state that the vegetation of segment 3 is limited almost exclusively to the two shrubs Vaccinium reticulatum and Styphelia douglassii. "These shrubs occur first as small (up to 30 cm tall), gnarled individuals with loose, cushion-like crowns. The term cushion applies here and in the following unit descriptions only to the semi-globose crown shape of the shrubs and does not imply a tightness or density feature of the crown habit. The distribution of the shrubs, from 10,000 to 9400 feet, is extremely scattered.

"They occur at distances of about 50 to 100 m apart only in the cracks of the buff-colored and steel-gray pahoehoe lava and on red pumice. The latter substrate is only of very restricted distribution. The older a'a flows at this elevation are still barren, except for the presence of Rhacomitrium lanuginosum var. pruinosum that continues also through this shrub type in the north-facing pahoehoe cracks. Trisetum glomeratum dominates as a scattered thin bunch grass on the few small areas strewn with fine cinder and red pumice. However, these areas are too small for recognition as a separate type on this scale.

"Other components in the scattered scrub type include the grass, Deschampsia nubigena (only where there is an accumulation of fine materials), the ferns, Pellaea ternifolia and Asplenium trichomanes, the composites, Tetramolopium humile, Gnaphalium sandwicensium var kilaueanum, Hypochaeris radicata, and Carex wahuensis var rubiginosa (in a sheltered blister-hole). All of these are extremely sparsely distributed in the cracks of the old, buff-colored pahoehoe."

Segment 4, which spans a change in elevation of only 400 feet, differs from segment 3 primarily in two ways:

1. "At 8500 feet shrubs began rather suddenly to grow taller (up to 75 cm) and to be more densely distributed, i.e., at every

5-10 m. They also tended to occur in clumps of several (about 3 or more) individuals with combined crown coverages of 1-3 m^2. This change occurred on the same substrate, i.e., the prehistoric, buff-colored pahoehoe, while on the older a'a lava, at parallel elevations, shrub growth appeared to be as sparse as in the previous type [segment 3] on pahoehoe."

2. "In addition new shrub species appeared, Dodonaea viscosa, at 8400 feet, Coprosma ernodeoides at 8250 feet, Dubautia ciliolata var laxiflora at 8150 feet" (Doty and Mueller-Dombois, 1966:403). The lichen Usnea also was first observed at 8,400 feet.

These two areas are discussed as a unit because the differences in the vegetational components appear not to be significant for the few species of birds encountered at these elevations.

Both the Amakihi and the Apapane occur in small numbers in the lower portion of the alpine aggregate-scrub zone (and James Jacobi saw a single Apapane at 8,600 feet on May 16, 1972), but whether these birds actually nest there, or are merely birds of passage, remains unknown. The possibility exists, however, that one or both species sometimes nest in collapsed lava tubes or other suitable crevices at these higher elevations.

Frank Howarth (1972) found several old bird nests in a collapsed lava tube a short distance downslope from the 8,000 foot marker on the Mauna Loa summit trail during 1971. I first visited this lava tube on March 16, 1972, and examined the six nests still in position on volcanic ledges in the roof and on the walls of the tube, but I was unable to make a positive identification of the nests. One Amakihi perched at the entrance as I was standing about 40 feet inside the tube, and seven Apapane flew over the entrance about 25 feet above the ground as I was leaving it. I also visited this nest site on May 22, 1972, but found no active nests, nor any birds in the tube.

James Jacobi and Frederick R. Warshauer discovered another collapsed lava tube containing bird nests during May 1972; this tube was located at an elevation of approximately 5,800 feet in the Kilauea Forest Reserve downslope from Puu Kipu. Jacobi gave me one of the nests containing egg fragments. I could not identify them with certainty except to say that they were not the eggs of the Hawaiian Thrush. I visited this lava tube with Jacobi and Warshauer on July 19, 1972, and, although one nest I found appeared to be relatively new, none of the nests contained any eggs, nor did we see any birds in the tube.

van Riper (in press) describes a nest that George Schattauer showed him (on June 22, 1971) in a lava tube at an elevation of approximately 5,300 feet on the southwest slope of Mauna Loa; no adults were observed at the nest, but, inasmuch as the nest had been built only seven feet from the ground, Schattauer "presumed it belonged to the Hawaiian Thrush." After examining this nest and one deserted egg, however, van Riper concluded that the nest was not that of a thrush.

On August 9, 1971, van Riper found six abandoned nests in five different lava tubes on the northwest flank of Mt. Hualalai. On February 12, 1972, he saw an Apapane fly from the entrance to a collapsed lava tube, and, upon entering the tube, van Riper found a nest containing two eggs. He watched an Apapane return to the nest 45 minutes later, and he saw a bird incubating the eggs on February 19. Both eggs were broken at a later date, and the nest was deserted. Whether or not the Amakihi and the thrush also nest in lava tubes remains to be determined.

The most puzzling feature of the birdlife above 8,100 feet elevation on the eastern flank of Mauna Loa concerns several sightings of the Hawaiian Thrush there. The typical habitat for the thrush is a very wet ohia-tree fern forest. Baldwin did not report the thrush at any elevation above 3,650 feet. Dunmire (1962), however, recorded two thrushes at some elevation between 6,700 and 8,200 feet, but he did not specify precisely where he found the birds. In his 1961 book, however, Dunmire wrote: "This strange thrush lives in two contrasting habitats within Hawaii Volcanoes National Park. In the dense forest you will usually find it singing from its perch part way up an ohia or other tree. But there may be no trees in sight at its other locality which is among the **barren** lava flows on Mauna Loa. ... The lava flow birds establish day-time roosts on the higher rocks and remain at these sites for long periods, judging from the accumulation of droppings. Old perch sites stand out clearly on a flow, for a yellow-green lichen colors the top of whatever rocks have been plastered with omao droppings."

On July 22, 1970, during the first orientation tour for IBP personnel in the Park, Park Biologist Donald Reeser told me, as we were hiking to the 8,200 feet level on the summit trail, that he, Patrick Crosland and Winston E. Banko had seen thrushes at elevations between 7,000 and 9,000 feet on several occasions during the months of October, November, and December.

James Jacobi told me that he saw one thrush at an elevation of 8,600 feet on the summit trail on May 16, 1972. I hiked to this area on May 22, had no difficulty in finding the accumulation of droppings on a particular large rock there, but neither saw nor heard any thrushes that day, nor did I see any other bird species at that elevation.

Only an intensive study at the higher elevations on Mauna Loa will reveal the nature of the thrushes' annual cycle there, that is, whether they are permanent residents or birds of passage during certain periods of the year.

Berger

A Perspective on Bird Distribution in Volcanoes National Park

As previously suggested, the use of small census plots was suitable for Baldwin's purposes, but such plots are not adequate when one attempts to understand: 1. the relationships of the birds to the other components in the ecosystem; 2. the distributional pattern and relative abundance of each bird species in relation to climatic and vegetational features; and 3. each species' annual cycle.

It seems reasonable to suggest, therefore, that the initial approach to the question of bird distribution within Volcanoes National Park should be made in terms of the vegetational zones already defined and described by Doty and Mueller-Dombois (1966). That one or more species (e.g., Amakihi, White-eye) may be found in almost **every vegetational** and climatic zone within the Park from approximately 1,500 feet to tree line (and above) simply demonstrates that we are dealing with some species that have a wide physiological and psychological tolerance for different plant associations and climatic conditions. By contrast, other species may have relatively narrow habitat requirements; these species are, in general, easier to analyze and explain, albeit after concerted effort. Of greater difficulty are the explanations to account for: 1. the disappearance of certain species (e.g., Akiapolaau) from areas where they were not uncommon 25 years ago; and 2. the considerable reduction in range and/or population size within this same period of time (e.g., Elepaio). These latter problems are especially difficult of solution, particularly in the absence of critical historical data, not only for Volcanoes National Park but also for all parts of the State of Hawaii.

Bird malaria apparently was first diagnosed in a wild bird in Hawaii in 1947, when Fisher and Baldwin reported the occurrence of _Plasmodium vaughani_ in one of 11 Red-billed Leiothrix from kipuka Puaulu (Bird Park). To the best of my knowledge, there have been no published reports on bird malaria within Volcanoes National Park since 1947. In his unpublished Ph.D. thesis, however, Navvab Gojrati (1970) reported that three out of nine Japanese White-eyes from an elevation of 4,000 feet within the Park were infected with _Plasmodium circumflexum_; this was the first recorded occurrence of _P. circumflexum_ in the Pacific region. Navvab Gojrati also found _Plasmodium_ (either

P. relictum or P. cathemerium) in one specimen of the Apapane, also from 4,000 feet elevation in the Park; this was the first report of bird malaria in any endemic bird species in its native habitat. Dr. Allen Y. Miyahara later found malarial organisms in blood from two Kona Coast Hawaiian Crows (Corvus tropicus) from material submitted to him by Winston E. Banko in 1970.

It is obvious that a thorough study of the prevalence of bird malaria in the birds of Volcanoes National Park is needed, together with a companion study on the distribution and abundance of the mosquito vector (Culex pipiens quinquefasciatus) that transmits malaria to the birds. Moreover, I have, thus far, been unable to learn from any source what affect bird malaria has on the infected birds, that is, it is always, or sometimes, fatal, or is it self-limiting and generally not fatal?

A number of other bird diseases (e.g., Coccidiosis, Haemoproteus, Leucocytozoon, bird pox) have been diagnosed at various locations in Hawaii, but virtually nothing is known about them in the Park. Nor is information available on other internal or external parasites of the endemic and introduced birds that inhabit the Park.

Further speculation on the role of disease as a factor in causing changes in the populations of endemic birds should be withheld until accurate information on both internal and external parasites and diseases of both endemic and introduced birds is available.

Finally, the first thorough study of the interrelationships of introduced bird species to the endemic species remains to be initiated. No data are available on possible competition for food or nest sites between any introduced species (e.g., Leiothrix and White-eye) and any endemic species!

Insects as **Food** for Honeycreepers

Baldwin (1953: 312-314) studied the occurrence of insects on the three dominant tree species in Volcanoes National Park: ohia (*Metrosideros collina*), koa (*Acacia koa*), and mamani (*Sophora chrysophylla*). He reported that "insects are abundant and ever-present in the area studied, certain types of foliage- and twig-dwelling types produce broods the year around, and the insect faunas of the same host trees are alike in host-specific types found but differ in types whose distribution is related to other factors. The insect faunas of the three host trees differ from each other as to the nature of host-specific forms, abundant in individuals on each." There is, indeed, no evidence available at this time to suggest that insect food is in any way limiting for populations of either endemic or introduced bird species in Hawaii.

Baldwin also investigated the food habits of the three species of common honeycreepers by examining stomach contents of birds collected throughout the year. He collected these birds in habitats comparable to his census plots but located outside the boundaries of Volcanoes National Park. Baldwin's **analyses** of food habits were [redacted] based on the examinations of the stomachs of 63 specimens of the Amakihi, 63 of the Apapane, and 32 of the Iiwi.

Baldwin wrote (pages 320-321) that "we can say that not all kinds of insects available to the birds are taken by them, that some are taken in small degree compared to their availability, and that others are utilized extensively. In *Loxops virens* the several types of insects were represented in the food samples in the following order of decreasing occurrences:

Homoptera (75 per cent)	Corrodentia (10 per cent)
Lepidoptera (71 per cent)	Heteroptera (8 per cent)
Araneida (33 per cent)	Diptera (6 per cent)
Neuroptera (24 per cent)	Hymenoptera (3 per cent)
Coleoptera (11 per cent)	Thysanoptera (2 per cent)
Acarina (10 per cent)	Mollusca (not represented)

"In *Himatione sanguinea* the representation of these types was similar for the two leading groups but divergent in those of more moderate occurrence, as follows:

Lepidoptera (87 per cent)	Diptera (21 per cent)
Homoptera (75 per cent)	Coleoptera (17 per cent)
Neuroptera (60 per cent)	Thysanoptera (14 per cent)
Araneida (43 per cent)	Heteroptera (10 per cent)
Hymenoptera (43 per cent)	Acarina (3 per cent)
Corrodentia (41 per cent)	Mollusca (2 per cent)

"In *Vestiaria coccinea* the two leading groups were again the same, and the order and the magnitude of occurrence of the less important groups resembled the situation in *Himatione* more than in *Loxops virens*:

Lepidoptera (100 per cent)	Heteroptera (30 per cent)
Homoptera (73 per cent)	Araneida (30 per cent)
Neuroptera (60 per cent)	Coleoptera (27 per cent)
Corrodentia (43 per cent)	Thysanoptera (7 per cent)
Hymenoptera (33 per cent)	Mollusca (3 per cent)
Diptera (30 per cent)	Acarina (not represented)

"Lepidopterous larvae and both larvae and adults of homopterous insects were collected the year around on all the trees and in relatively large numbers. They are among the most available insects, and they are also highly acceptable to the birds. In groups less frequently represented in the food samples, availability is usually less. This may be due to seasonal occurrence of the insects, to smaller populations, or to the incidental occurrence of the insects in the habitats in which the birds forage.

"Because of the general similarity in foraging habits of the three species, the major categories of insects are equally available to the three avian species. Yet we see differences in proportions of insects eaten. Vestiaria takes more Diptera, Heteroptera, and Coleoptera than the other two. Two of these insect groups consist of rather **hard-bodied** insects, Coleoptera and Heteroptera. Loxops virens is low in consumption of these types, but Himatione is somewhat higher. Himatione takes more Hymenoptera and Araneida as well as many Corrodentia and Diptera. The trend in this species is toward use of the flying forms. Loxops virens takes a large proportion of nonflying forms obtained from leaves and twigs.

"All these differences are overshadowed by the similarity of foods for these three birds, however. It appears that the unspecialized insect eaters take soft-bodied types in proportion to their availability on the small branches and foliage where the three birds typically forage. The types thus eaten are primarily moth larvae, homopterous insects; neuropteran larvae, and psocids. Types which are seemingly by-passed in large degree despite their availability are heteropterans, ants, roaches, beetles, larger wasps and flies, moths, adult lacewings, and land snails.

In the last groups, use is not proportional to the availability of the insects."

We have virtually no information on the relationship between birds (either endemic or introduced) and the many species of Drosophila found in the Park and in the Kilauea Forest. Such information would, of course, be of considerable interest both to ornithologists and entomologists. Preliminary efforts by Herman T. Spieth and myself to determine whether or not Drosophila were eaten by two bird species (Amakihi, White-eye) in the Waikamoi stream area of Maui produced only negative results.

Baldwin (page 315) also pointed out that "scale insects are not native to Hawaii; hence those used are necessarily new to the diets of the birds. Perkins recorded the use of Coccus acuminatus (Signoret) by L. virens (Zimmerman, 1948b, p. 294), a fact which I confirm. Much more prominent use was made of Saissetia hemisphaerica (Targioni-Tozzetti), however. This scale was readily identified by its characteristically pitted derm. All three birds utilized it, the per cent of occurrence being 18 in L. virens, 11 in Himatione, and 10 in Vestiaria. I have no data on the distribution or host plants of this insect in the area studied, but birds feeding in the forests of middle and high elevations, from about 4,000 to 7,000 feet, commonly had it in their stomachs. Species of Coccus identified in this study were from birds feeding between 3,000 and 4,000 feet. Howardia biclavis (Comstock) was from birds feeding in forests around 1,000 feet in the Kau and North Kona districts. Munro (1944, pp. 109 ff.) found that Loxops coccinea frequently ate scale insects."

Hence it is clear that insects play an important part in the diet of these three common species of honeycreepers even though all three also are nectar feeders. No comparable food-habits study has been conducted for any other endemic forest bird.

Nectar as Food for Honeycreepers

The flowers of Metrosideros and Sophora undoubtedly are the most important sources of nectar for all extant nectar-eating honeycreepers. The birds do, however, obtain nectar from the flowers of a wide variety of other plants, both native (e.g., Santalum, Pelea, Alyxia, Pritchardia, Freycinetia, Styphelia, and arborescent Lobeliaceae) and introduced (e.g., Passiflora, Fuchsia, Lonicera, Bryophyllum).

Although Baldwin presented a thorough analysis of the insect food eaten by the Amakihi, Apapane, and Iiwi, no one has found it possible, thus far, to determine the relative percentage of nectar to insect food in the diet of any nectar-eating honeycreeper. That is to say that it is a relatively easy matter to identify many insects parts found in the stomachs of birds examined, but it is impossible to determine the volume of nectar that a bird eats over a period of time. Moreover, one usually cannot be certain when watching a honeycreeper foraging at an ohia blossom, for example, whether the bird is sipping nectar or catching an insect. Baldwin did conclude, however, that the Amakihi seems to eat a smaller proportion of nectar than the Apapane or the Iiwi, "since it was observed to spend less time at flowers."

Baldwin also noted (page 312) that the Amakihi is "unique among the birds studied in that it frequently seeks the juices of fruits.

Perkins said that the berries of Wikstroemia are eaten by L. virens stejnegeri of Kauai, and Physalis by L. v. virens. I saw the latter pierce the fruits of Solanum pseudo-capsicum (Jerusalem cherry) and take juices. I never saw L. v. virens eat entire fruits."

Much additional information is needed on the flowering and fruiting seasons of the dominant plants in the different climatic and vegetational zones on Mauna Loa. Baldwin (1953:308-310) discussed his findings and postulated several possible explanations for the variations he found:

"The differences in conditions of climate and substrate at the plots suggest that a group of environmental factors influences local variation in period of flowering. It is also possible that in adjacent populations which differ in timing of flowering, as at 4,050 and 4,025 feet, genetic differences may exist in the plants. In this case, the young, small trees at the latter station may have been seeded from a population of different flowering period from that of the large, old trees in the adjacent kipuka. The extreme variability characteristic of the anatomy of Metrosideros collina may well extend to the physiology of the plant.

"For my purpose it is sufficient to show the occurrence of such variation and its approximate timing, since thereby it is demonstrated that the most copious nectareous food of the birds is itself of varying availability in place and time in the local environment. A continuous supply of Metrosideros nectar is likely to be available in a locality which includes some diversity of geographic and climatic conditions, as in the upper part of the transect. This is far less likely to be true in localities with great uniformity of conditions, as in much of the lower part of the transect or in the near-by wet, uniform forests of Olaa.

"Records from parts of 1941 and 1942 at some of these same stations agree as to the timing of the flowering periods. This indicates that the flowering period for a local area is repeated annually at about the same time of year. For the station at 7,500 feet, counts were made in nine months between March, 1941, and April, 1942. In March, April, June, August, and February, the proportion of trees in flower was between 1 and 25 per cent, whereas in September, October, November, and January, the proportion of trees in flower was more than 25 per cent, thereby agreeing with the data for 1948-1949 in that the greatest flowering occurred in the fall and winter months. At the 3,650-foot station, counts were taken in eight months between April, 1941 and April, 1942. These indicated that flowering was less than 25 per cent between September and April but higher than this for at least the early part of the summer period of May through August. At 3,000 feet, counts and field notes showed that in 1941 the peak of flowering was reached between May and July and that it was less than 25 per cent in the early spring and late summer. At 2,300 feet, counts in February and April, 1942, showed that flowering was less than 25 per cent during this period but that a large number of maturing cymes would be in flower at the end of April.

"Records for certain conspicuous individual trees between 5,500 and 6,300 feet, however, showed that the same trees may not have heavy blooms in two successive years, or, in fact, that heavy blooms may not be repeated for several years.

"Records for the duration of bloom of individual flowers were made at 4,025 feet between November, 1948, and March, 1949. Three developing cymes were watched at daily or slightly greater intervals. Cyme 1 had 10 flower buds, the first of which opened on November 2, and the tenth on November 9 (7 days); stamens were shed between November 9 and 14 (5 days). Cyme 2, with 18 flower buds, commenced opening on November 7, and all buds were opened by November 19 (12 days); stamens were shed between November 12 and 30 (18 days). Cyme 3 had 22 flowers, the first of which opened on November 24, and the last on December 12 (19 days); stamens were shed between December 6 and 26 (12 days for first flowers to shed stamens). From these data it can be said that cymes were variable in size, typical examples having from 10 to 22 flowers; buds in cymes opened at a rate between 1.25 and 1.5 per day until all flowers in the cyme were open; and the flowers when opened retained their stamens from five to fourteen days. Rainfall affected the retention or shedding of stamens.

"Other observations suggest that the secretion of nectar is heaviest during, and actually probably limited to, the period when the flower is fully open and before the stamens fall; thus the production of nectar would not last more than about twenty days for a 10-flowered cyme and about forty days for a 22-flowered cyme.

"Finally, many observations indicate either that cymes may come into bloom in large numbers simultaneously in a tree or that flowering may progress slowly and extend over several months.

"Perkins (1913, p. 403) mentioned the periodic flowering of Sophora chrysophylla, but no information is readily available about the nature of the periodicity or season of flowering in this species. Data were obtained on the flowering of Sophora in the same manner as for Metrosideros. Three stations at which counts were made to determine the proportion of trees in flower twice each month were located at 5,500, 4,050, and 3,000 feet. The number of trees examined was about 80 at 5,500, 100 at 4,050, and 45 at 3,000 feet.

"At 7,000 feet in the transect, occasional observations indicated that flowering commenced during the second half of November, 1948, and was at a peak in January, 1949, with 81 per cent in flower in the second half of the latter month. At 5,500 feet, flowering commenced in October and reached the peak in December and January (fig. 4). No flowering occurred here between late May and early October. At 4,050 feet, the peak was slightly earlier, November and December; but at 3,000 feet, it was in December and January. At these last two stations a new wave of flowering on a small scale occurred in March. It appears from these data that the flowering of Sophora in the transect was fairly synchronous throughout, in that it occurred during the fall and winter at all three stations. Minor variations in the time of onset, development of maximal flowering, and cessation of flowering occurred among the three stations. My field notes before 1948 indicate that the fall and winter bloom was typical for the transect and that heavy flowering in these months was to be expected.

"In other parts of the island the period of flowering did or did not coincide with that in the Kau forests. In late November, 1942, Sophora trees at 5,000 to 6,000 feet in central Kona, the western slope of Mauna Loa, were coming into flower, agreeing with the average trend in Kau. In mid-April, 1943, Sophora at Puu Laau, above 7,000 feet on Mauna Kea, was without flowers but had well-developed green pods which were large enough to attract and be opened by the finch-billed drepaniid Psittirostra [=Loxioides] bailleui. In early November, 1948, Sophora forests from 6,000 to 9,300 feet on Mauna Kea between Hale Pohaku and Puu Laau were from 40 to 60 per cent in flower, and small pods were forming; this was slightly in advance of the Sophora forests of the upper southeast slopes of Mauna Loa in the transect. In late August, 1949, the Sophora forest at Puu Kihe on the north slope of Mauna Kea between 7,000 and 9,000 feet was in a late stage of flowering with many young green pods already formed; at this time there was no flowering in the stations in my transect. In all, it appears that the periodic flowering of Sophora is more uniform seasonally than Metrosideros but still is subject to local variation.

"Finally, it should be pointed out that although arborescent members of the Campanulaceae on Hawaii flower chiefly during the summer months, some species flower in fall, winter, or spring, according to Rock (1913).

"It is thus apparent that the flowering of Metrosideros is periodic, but that the periodicity is subject to variations. There is a general correlation between rise in altitude and delay in onset of flowering. *Metrosideros* at 2,300 feet comes into full bloom in April, at 3,650 feet in May, and at 5,500 feet in June; however, certain localities show an offset periodicity with maximal flowering reached in October or November, as at 3,850 and 7,500 feet. The facts that in localities of diversified conditions different trees came into bloom at different times and that individual trees produced flowers for several successive months mean that in many areas nectareous food is obtainable from *Metrosideros* trees at nearly all times of the year. *Sophora* is more restricted to an autumn and winter flowering period in the transect, although wide departures from this were seen in other areas on Hawaii. Other trees bloom variously at all seasons of the year, so that nectar from one source or another is obtainable throughout the year in most Hawaiian forests."

Lanner (1965) studied the phenology of koa on Mauna Loa and reported that the heaviest flowering occurred between February and May in 1964. In a study in the same area, C. H. Lamoureux and J. R. Porter, however, found that the heaviest flowering occurred between October and December in 1971 (see page 61, IBP Technical Report No. 2, January 1972). They wrote that this difference in time of flowering of *Acacia koa* "suggests that we need to obtain much more data on flowering times in koa." Lamoureux and Porter have been studying the flowering, fruiting, leaf production, and leaf fall of 83 plant species within the Park and in the Kilauea Forest during the past 18 months. Their findings should have special significance for increasing our understanding of the seasonal movements exhibited by some species of birds, as well as for understanding variations in specific items in diet with change of season and fruiting periods.

Contemporary information is needed on the use of lobeliad flowers as a source of nectar by the Hawaiian honeycreepers. Baldwin's comments (page 310) are of interest:

"Perkins (1913, p. 384) wrote that nectar was probably eaten by some species in all genera of drepaniids, except the finch-billed types and possibly the aberrant Ciridops. The main source of this food was Metrosideros, the masses of flowers of which attracted assemblages of Vestiaria, Hemignathus, Himatione, and Loxops virens. Sophora, on Hawaii, was second only to Metrosideros as a source of nectar, and to it went large numbers of the red birds when the tree was in bloom. Drepanis and Vestiaria were said by the earliest observers distinctly to prefer honey from the lobelialike plants to that from Metrosideros. Perkins thought that these plants must have offered the major source of nectar in an earlier period of the Hawaiian flora, and that when Metrosideros at a relatively late time made its advent in these islands this new source of food must have permitted a great increase in the populations of honeycreepers. So close was the mutualism between the birds and the lobelias that Perkins (1913, p. 385) believed that the long, tubular flowers were capable of pollination only through the agency of the birds, a conclusion with which Rock (1919, p. 31) and other botanists disagreed, although Rock agreed to the role of birds as pollinating agents."

Baldwin added (page 311) that "despite the reputed preference of _Vestiaria_ [Iiwi] for feeding at flowers of the lobelias, of all the many shrubs of _Clermontia_, _Cyanea_, and _Lobelia_ I observed in bloom on Hawaii and Maui, not one was visited by _Vestiaria_ or any other drepaniid, although the birds were present and feeding on _Metrosideros_ or other plants."

Spieth (1966), however, presented contrary observations, made on Maui, and discussed the earlier theory of Perkins regarding the coadaptation between lobeliad flowers and the bill and feeding habits of the Iiwi:

"The Iiwi flies to the flower and quickly perches on the flower-bearing twig just basad of the flower pedicel. The bird then quickly swings into an _up-side-down_ position under its perch and simultaneously twists its body so that its head is under the open corolla, with the bill pointing upwards. It then easily and with precision slips its slender decurved beak into the corolla. The nicety of fit between the bird's head and bill and the fleshy corolla of the flower is indeed striking (Fig. 1). The entire bill and fore part of the head are thrust deeply into the corolla, reminding one of a finger slipping into a well-fitting glove. After probing into the corolla for a few seconds, the bird flies to another flower, performs its acrobatics and probing, and then on to another flower. Within a few minutes a bird will have visited and fed upon dozens of flowers. As Perkins (1903) and others have noticed, these visitations to the flowers seem to exhilarate the birds and they become visibly excited as they fly about in the tree.

"Despite the observations and reports of Perkins (1903 and 1913), Bryan (1908), and Munro (1960) that the honeycreepers fed frequently on lobeliads and were presumably the major pollinators of these plants, doubts have been raised subsequently by both botanists and ornithologists, for the following reasons:

"1. Numerous observers have seen the honeycreepers feeding and presumably collecting nectar from flowers of diverse plant species, especially those of the Ohia _Metrosideros collina_ (Gaud.), and the Mamani, _Sophora chrysophylla_, but have not seen them feeding upon lobeliads (see Baldwin, 1953).

"2. Since the lobeliads continue to exist and set seeds upon the various islands despite the extinction of many species of honeycreepers or despite the absence of species such as _Hemignathus_ sp. from Maui where lobeliads are common, botanists have concluded that the honeycreepers are not necessary as pollinating agents for the lobeliads (Rock, 1919, p. 31; Amadon, 1950, p. 200).

"It should be recalled that the _Clermontia_ flowers are protandrous. When the pollen reaches maturity, the antheral sections of the staminate column are easily ruptured by any slight abrasion and the sticky pollen immediately oozes out. The staminal column of _C. arborescens_ is equipped with an 'upper' and a 'lower' row of stiff, inwardly directed antheral hairs at the distal end of the column. Presumably these scrape pollen from the bird's head as it is retracted from the flower. The enclosed style eventually elongates and pushes out of the end of the staminal column, but this does not occur until the flower has shed its pollen. As the **style** elongates, the stigma brushes against the antheral hairs which have previously accumulated pollen due to the actions of the birds.

"The Iiwi originally were extremely numerous and ranged throughout the forest areas of the major islands without racial variation. The unique posture that they display in feeding upon the lobeliads, which results in the decurved bill of the birds fitting with such precision into the decurved flower of the plant, would seem to indicate a long-time association between the two organisms. I observed no other birds visiting the flowers that were physically able to feed upon these particular lobeliad flowers in the manner displayed by the Iiwi. In a broader context, however, it should be noted that many of the Hawaiian honeycreepers, both small and large species, have decurved bills and, with few exceptions, the Hawaiian lobeliad species also are unique in posessing decurved flowers. Thus we can reasonably suggest that there exists a significant coadaptation between a number of species of the lobeliads and various species of the honeycreepers."

Thus, it is evident that further observations are needed on the relationships of the Iiwi and other drepanids to the lobeliads of Volcanoes National Park.

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