Technical Report No. 11

BIRDS OF THE KILAUEA FOREST RESERVE, A PROGRESS REPORT

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ABSTRACT

The Kilauea Forest Reserve is notable for the island of Hawaii because it provides habitat for at least nine species of endemic birds, of which six species are members of the Hawaiian Honeycreeper family (Drepanididae): Amakihi, Akepa, Creeper, Akiapolaau, Apapane, and Iiwi. The other endemic species are the Hawaiian Hawk, the Elepaio, and the Hawaiian Thrush. The thrush is abundant throughout the forest, and is common even in areas that have been disturbed by cattle and by logging operations.

Two species of introduced birds occur in relatively large numbers: Japanese White-eye and Red-billed Leiothrix. Other species of introduced birds are found in the pasture land adjacent to the forest but have not been seen within the forest itself.

The foraging behavior of endemic and introduced species is discussed. No data are available to suggest that introduced species compete with endemic birds for food or for nesting sites.

Nesting data are presented. An apparently unusual feature about the Apapane is that this species not uncommonly builds its nest on the tops of tree fern fronds, rather than in ohia trees, which is the typical site for nests of this species in ohia-tree fern forests.

The adaptability of three endemic species (Elepaio, Amakihi, Akiapolaau) and two introduced species (Japanese White-eye, Red-billed Leiothrix) to wide vegetational and climatic conditions is discussed. Physiological data obtained by Dr. Richard E. MacMillen on captive Amakihi from Hawaii and Kauai are presented.

Birds of the Kilauea Forest Reserve, A Progress Report

Andrew J. Berger

The Kilauea Forest Reserve is owned by the Bernice P. Bishop Estate; IBP personnel were invited to conduct studies in the Reserve by Mr. Norman K. Carlson, the manager of agricultural and forestry lands of the Estate.

Dr. Dieter Mueller-Dombois selected a 200-acre portion of the forest for study, and R. G. Cooray and Jean Craine laid out four 1,000-meter transects (figs. 1, 2) within the study plot and analyzed the vegetation found there. A climatic station at the northwestern corner of the study plot has been in operation since August 1, 1970. The rainfall for 1971 totalled 112 inches (2810 mm) under the trees, and 94 inches (2342 mm) under open skies.

The study plot falls within segment 11 of figure 31 in the work of Doty and Mueller-Dombois (1966: 418-419), which corresponds to segment 11 of figure 3 in IBP Technical Report No. 2 (January 1972).

The Kilauea Forest Reserve is an excellent example of a near-virgin, Hawaiian, montane rain forest, and very few such forests remain on the island of Hawaii. It consists of a mixed ohia (Metrosideros collina var polymorpha), koa (Acacia koa), and tree fern (Cibotium spp.) forest at an elevation (about 5,400 feet at the climatic station) that is intermediate between that of a typical Acacia forest (found, in general, between 5,000 and 6,000 feet) and a typical Metrosideros rain forest that is characteristic of elevations below approximately 4,500 feet (Doty and Mueller-Dombois, 1966: 418-419).

In addition to the dominant tree species (Metrosideros and Acacia), several others were found "scattered throughout the forest": olapa,

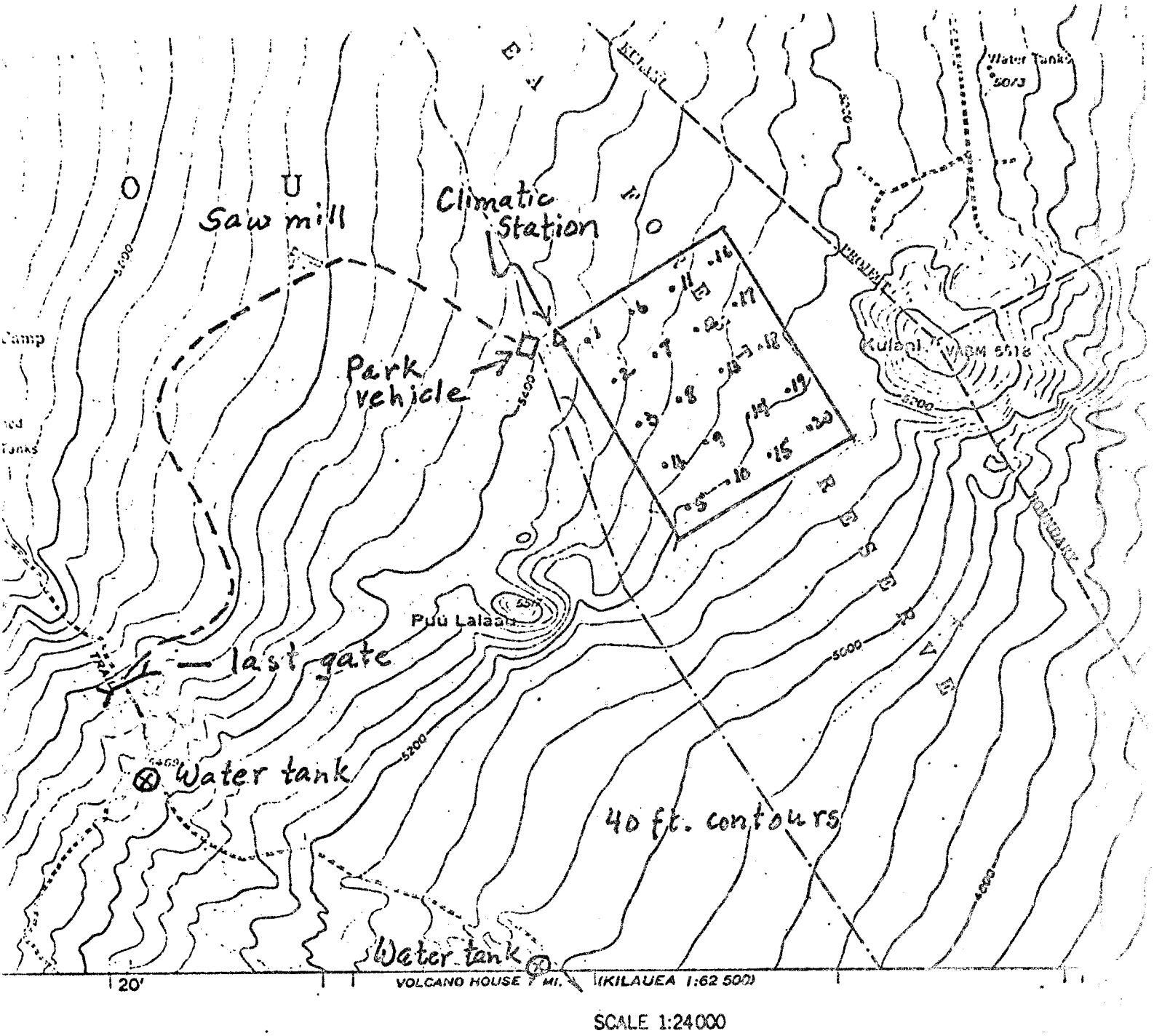

Fig. 1. Map of 200 acre study site (Section of Kulani, Hawaii Topogr. sheet).

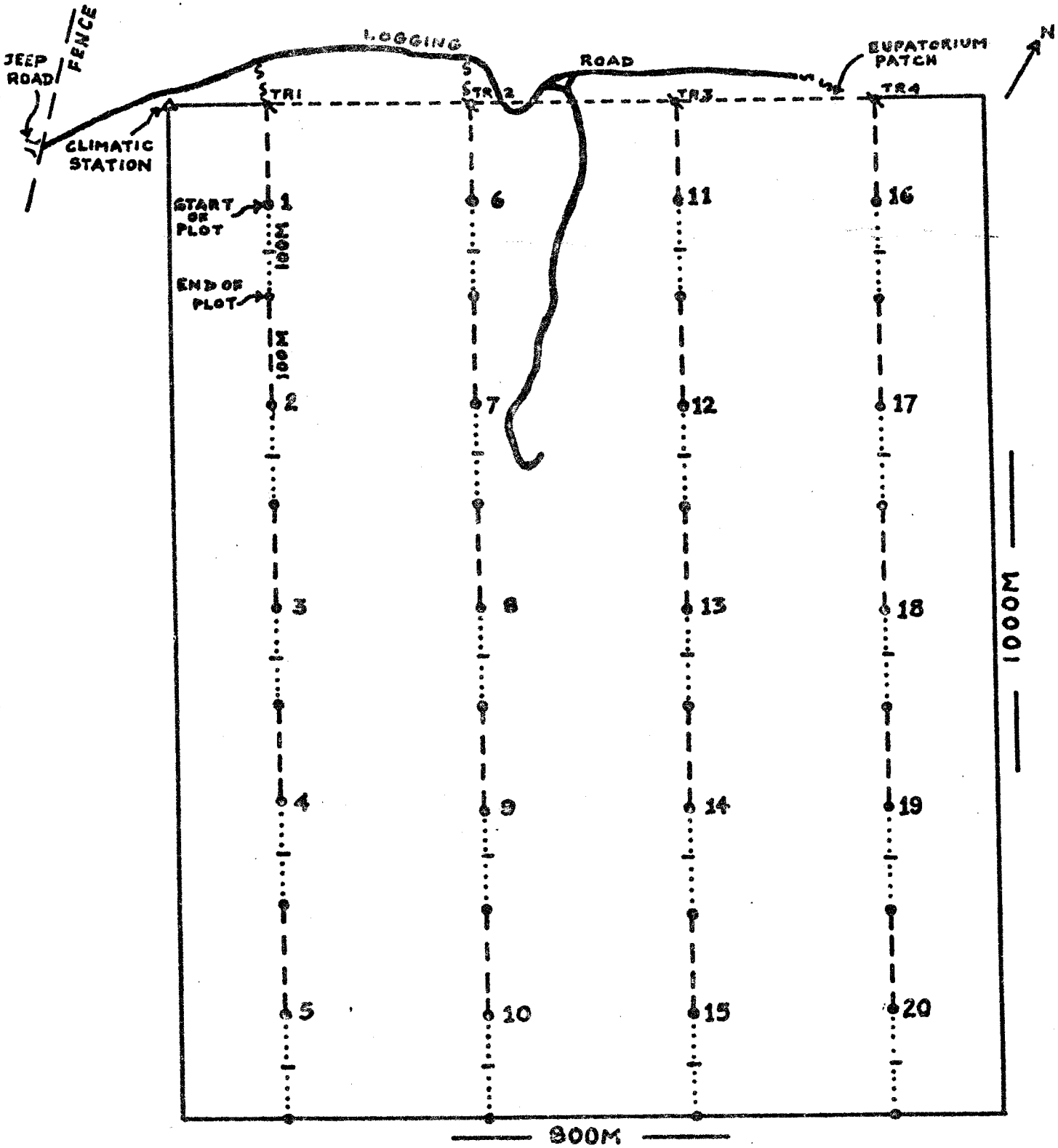

Fig. 2. Kilauea Forest Reserve IBP study site orientation map for participants.

_____ outline of study site.
--------- base line (55°NE) white flags every 5 meters.
•- - - -• blue flags every 5 m from base line to start of plots 1,6,11 & 16 and between plots on transects. (145°SE)
•.....• orange flags every 5 m in plots on transects.(145°SE)
~ ~ ~ blue flags from logging road to base line.
starting points of transects marked with tag & blue & white flags.
starting & end points of plots marked with tag, blue & orange flags.
50 m point in plots marked with tag, blue & orange flag.

(Cheirodendron trigynum), kawau (Ilex anomala), and alani (Pelea spp.). The olapa is of special importance for the Omao or Hawaiian Thrush (Phaeornis o. obscurus), because the birds eat large quantities of the fruit of this tree.

A third group of plants was described as being rare--"less than 5 individuals per species were enumerated in the entire sample" (IBP Technical Report No. 2, page 51). Examples are: oha-kepau (Clermontia hawaiiensis), kue-nui (Cyanea spp.) kolea-laulii (Myrsine sandwicensis), and mamaki (Pipturus hawaiiensis).

A simple listing of the plants within the 200-acre (800 x 1,000 m) study plot, however, in no sense gives a true picture of the nature of the Kilauea Forest, nor does the statement that the plot contains four 1,000-meter transects extending from the baseline road to the lower end of the plot. The baseline road runs at an elevation of approximately 5,400 feet; the transects descend to an elevation of approximately 5,200 feet.

Although Doty and Mueller-Dombois (1966: 419) refer to certain areas in the ohia-koa-tree fern ecosystem that contain "relatively deep, well-weathered soil," the substrate is aa lava in the study plot, and there are many areas where the angular lava blocks occur at surface level. In general, the lava, crevices, and holes are more or less covered and concealed by mosses, ferns, and other ground-cover plants. This makes hiking both difficult and hazardous, so that one has to look at the ground before taking almost every step. Moreover, there obviously was a series of prehistoric lava flows in this region, because there are several places on the transects where there is a steep drop of 20 or more

feet, suggesting the line at which a particular flow stopped. In addition to this great irregularity in the ground, there are many fallen trees in the forest, some of which exceed five feet in diameter. Hence, one either has to crawl under or climb over these fallen giants, which typically are moss-covered and slippery. Seedlings of many species of plants (including tree ferns) find conditions suitable for germinating and growing on the upper surfaces of these dead tree trunks.

The ground usually is wet, and, where there are accumulations of soil in low areas, it is not uncommon to sink a foot or more into the mud while following a transect. Areas, and there are many, where pigs wallow are especially difficult to cross. (I have seen one or more pigs every time I have walked a transect.) At several sites, there are larger bog areas that support associations of Carex and scattered trees; these sometimes hold as much as a foot of mud and water.

All of these features of the Kilauea Forest make ordinary hiking hard work and bird study very difficult. Gaps in the crown canopy occur primarily only in two situations: where there are bogs, and where large koa trees have fallen to the ground. Throughout the rest of the forest, there is a complete crown cover at heights of 70 to 80 feet.

Transects 1 and 2 were "flagged out" during January 1971; transects 3 and 4 were completed during late June. I made my first trip to the Kilauea Forest Reserve in company with Norman Carlson, Dieter Mueller-Dombois, and other IBP personnel on July 23, 1970. I visited the area again on November 20 that year, and on January 11, and June 24, 1971. Detailed census counts along the transects were first made on January 11

and 12, 1972. Tables 1 through 4 show the results of census trips through July 1972.

Only two transects were covered on any one day. Cross trails (flagged by P. Quentin Tomich), near the lower ends of the transects, interconnect transects 1 and 2 and transects 3 and 4. The cross trails make it possible to cover the pairs of transects in from 2.4 (July only) to 4.75 hours, depending upon weather conditions and the amount of bird activity at the time of the census. The average time for five census trips on transects 1 and 2 was 3.6 hours; the average time for six census trips on transects 3 and 4 was 3.9 hours.

1. Honeycreepers

The Kilauea Forest is notable because it provides habitat for at least six species of Hawaiian honeycreepers (family Drepanididae), three of which are rare and endangered: Creeper (Loxops maculata mana), Akepa (Loxops c. coccinea), and Akiapolaau (Hemignathus wilsoni). All three species are so rare that very few sightings of any of them have been made during the past 15 or more years; virtually nothing is known about the annual cycle of any of these rare species. Although I have done a considerable amount of field work on the island of Hawaii since 1965, I had seen only four Creepers and two Akepas prior to visiting the Kilauea Forest. I had seen the Akiapolaau only in the mamani (Sophora chrysophylla) and naio (Myoporum sandwicense) ecosystem on Mauna Kea; during 71 days of field work in the Kaohe and Mauna Kea Game Management areas, I saw one or more Akiapolaau on 21 days (Berger, 1972b).

The data obtained thus far suggest a minimum of three pairs of

Table 1

Transect Number 1
Kilauea Forest Reserve

Number of Individuals Recorded During Each Census Count

Date: (1972)	Jan. 11	Feb. 6	Mar. 14	May 20	July 20
Time:	9:45-noon	11:30-2:00	9:55-12:25	12:20-2:10	1:15-2:30
Species					
Apapane	61	100	87	78	29
Iiwi	--	6	6	5	2
Amakihi	4	5	5	8	2
Akepa	--	--	--	--	--
Akiapolaau	2	--	--	1	--
Creeper	2	--	--	--	--
Thrush	22	53	36	35	27
Elepaio	1	4	4	10	6
White-eye	4	5	14	11	11
Leiothrix	--	1	6	9	19
Hawaiian Hawk*	--	--	--	2	--

*One hawk was perched on a dead branch in one of the tallest trees; the other was soaring nearby just above the crown of the forest.

Table 2

Transect Number 2
Kilauea Forest Reserve

Number of Individuals Recorded During Each Census Count

Date: (1972)	Jan. 11	Feb. 6	Mar. 14	May 20	July 20
Time:	12:15-1:25	2:27-4:18	12:46-2:00	2:25-3:35	2:45-3:38
Species					
Apapane	30	75	74	76	34
Iiwi	--	5	8	2	3
Amakihi	5	4	5	4	3
Akepa	1	1?*	--	--	--
Akiapolaau**	--	--	--	--	--
Creeper	--	--	--	--	--
Thrush	21	33	29	25	23
Elepaio	2	--	--	2	3
White-eye	4	--	15	4	5
Leiothrix	--	--	5	5	11

*The question mark means that I heard the song but did not see the Akepa.

**James Jacobi saw two Akiapolaau near the end of plot no. 10 on August 24, 1972.

Table 3

Transect Number 3
Kilauea Forest Reserve

Number of Individuals Recorded During Each Census Count

Date: (1972)	Jan. 12	Feb. 7	Mar. 15	April 23	May 21	July 18
Time:	12:15-1:20	12:40-2:30	9:30-11:25	9:10-11:25	12:25-1:37	12:03-12:55
Species						
Apapane	21	62	91	106	58	19
Iiwi	--	8	12	13	1	--
Amakihi	3	7	2	6	1	--
Akepa	--	--	--	--	--	--
Akiapolaau	--	--	1	--	--	--
Creeper	--	--	--	--	--	--
Thrush	16	34	35	37	19	14
Elepaio	2	2	6	3	1	4
White-eye	--	6	15	9	3	5
Leiothrix	3	--	6	7	7	5

Table 4

Transect Number 4
Kilauea Forest Reserve

Number of Individuals Recorded During Each Census Count

Date: (1972)	Jan. 12	Feb. 7	Mar. 15	April 23	May 21	July 18
Time:	9:23-11:35	10:00-12:15	11:51-1:50	11:48-1:25	9:50-11:40	10:15-11:40
Species						
Apapane	43	79	97	84	95	43
Iiwi	--	4	10	10	4	--
Amakihi	3	9	6	6	1	2
Akepa	--		1?*	1?	--	--
Akiapolaau	1	1	1	--	1	--
Creeper	--	--	--	--	--	--
Thrush	20	42	36	23	30	29
Elepaio	5	5	--	4	6	5
White-eye	5	3	11	8	11	9
Leiothrix	4	11	8	7	15	12

*The question mark means that the song of the Akepa was heard but that the bird was not seen.

Akiapolaau and two pairs of Akepa in the 200-acre study plot, but much additional work will be needed to determine the actual population of these, and other, species in the forest.

It is possible that the Akiapolaau population in the Kilauea Forest region is the largest surviving group of these unique birds. In addition to birds seen in the study plot, I have, on several occasions, also seen from one to three Akiapolaau near the climatic station along the logging road within the Forest Reserve. On May 21, 1972, I found one bird singing in the cutover area about .25 mile south of the study plot; on August 19, three birds were singing in this area. James Jacobi saw two birds and heard a total of four or five along the upper fence of the Forest Reserve about .25 mile north of the weather station on August 16, 1972. I have never seen as many birds on one day in the mamani-naio forest on Mauna Kea. I also have seen Akiapolaau at an elevation of approximately 5,700 feet on the jeep trail to the Keawewai camp.

One of the difficulties in studying the Akiapolaau is that its singing behavior has not been studied in detail. Although the birds sometimes sing from exposed perches, more often their perch is on a thick-leaved branch. Moreover, a song period may last only one or two minutes, after which the bird may be quiet for as much as a half hour. Consequently, it often is difficult to get a good view of a bird before it disappears. We do not yet know how the song periods correspond with the breeding season. On Mauna Kea, I have heard Akiapolaau sing during the winter months (November-January), as well as during the summer (April-July). In the Mauna Loa habitat, I have heard songs from February to August.

As the tables show, I identified only two Creepers in the study plot, both on January 11, 1972. In color, and often in habits, Creepers are very similar to the Amakihi, and positive identification of the Creeper can be made only if one can get a good look at the bird's bill.

A high percentage of the other bird species in the forest was identified by sound (songs and callnotes), rather than by sight. This is essential, both because of the density of the forest and because the Apapane (Himatione sanguinea) and the Iiwi (Vestiaria coccinea) are primarily birds of the crown of the forest. The Apapane is by all odds the most abundant bird in the forest, and I suspect that the margin of error in the census counts is greatest for this species. The reason is that the majority of Apapane are seen not only in the crown of the forest but also in the tallest trees when they are in flower. There is nearly a constant chorus of Apapane songs and callnotes throughout the day from November through May, and, as one moves along a transect, it probably is impossible either to identify every bird or to avoid some duplication in the counting. Moreover, all species of honeycreepers that have been studied in detail defend only a small territory around the nest, and the birds forage for food over a considerable area. When feeding, they are highly tolerant of other species as well as of other individuals of their own species. Consequently, it is not unusual to see a dozen or more Apapane, Iiwi, and Amakihi (Loxops v. virens) in the same flowering ohia tree.

2. Hawaiian Thrush

The Kilauea Forest Reserve obviously is ideal habitat for the

Omao or Hawaiian Thrush. I recorded 162 thrushes (including a number of pairs) along the four transects during the two-day period of February 6 and 7, 1972, or one pair for approximately every 1.4 acres. This appears to be a very high density, but, in the absence of a thorough study on the breeding biology of this endemic species, the margin of error in my censusing is unknown.

I have not yet found so many thrushes in any other habitat on Hawaii (e.g., Volcanoes National Park, Kona Coast of Mauna Loa, ohia-tree fern forests along the windward portion of the Saddle Road). Thrushes are, however, very common in two other areas; unfortunately, segments of these forests already have been destroyed, and the future of both is uncertain.

The ohia-tree fern and the ohia-koa-tree fern ecosystems once covered an extensive area on the windward slopes of both Mauna Loa and Mauna Kea. The lower portions of these forests were destroyed early in this century in order to plant sugarcane. The upper reaches of these forests were first devastated by feral cattle, horses, sheep, goats, and pigs, beginning in the early part of the 19th century. The destruction by the feral animals was supplemented later by man when cattle ranching was initiated. The destruction of fine forest still continues on the Keauhou Ranch in order to provide more cattle range, even though the lease on this land expires in 13 years.

Extensive destruction of near-virgin ohia-tree fern forest north of the Kilauea Forest Reserve also has occurred since the 1960s. The State Division of Forestry bulldozed large areas of magnificent forest along

the Stainback Highway as recently as 1965 (Berger 1966); I have been told recently that the exotic tree species planted in this portion of the Waiakea Forest Reserve have not grown well--because of inadequate soil and climatic conditions--but the virgin forest is gone. Further bulldozing of virgin forest has occurred in comparable forests under the jurisdiction of the Kulani Prison Project, and portions of this forest also were subjected to military nerve-gas experiments during the 1960s.

Moreover, work on a road through the so-called Laupahoehoe Forest Reserve was begun in 1969, and harvesting of koa and ohia has been underway since 1971 (Berger 1972a). I have seen Omao at elevations as low as 2,500 feet in the Laupahoehoe Forest Reserve.

Although the Omao on Hawaii is one of the few species of endemic forest birds that is not included in the "rare and endangered" category, serious inroads into its preferred habitat have been made during the recent past and are still being made at present. It should be emphasized, as well, that the subspecies of Hawaiian Thrush formerly found on Oahu and Lanai are extinct, that the race on Molokai is very rare (and possibly now extinct), and that the race in the Alakai Swamp region of Kauai is considered to be "endangered" by personnel of the U.S. Bureau of Sport Fisheries and Wildlife. Hence, only on the island of Hawaii does the Hawaiian Thrush survive in large numbers; its continued survival depends on the maintenance of suitable habitat.

Available evidence suggests that most species of honeycreepers are highly intolerant of changes in their forest environment. The thrush may

be somewhat more tolerant, although, in the absence of previous baseline studies, only time will tell how tolerant this species is to drastic changes in the environment. Thrushes still occur, for example, in fair numbers in the forest adjacent to slashings and other debris left after harvesting, and/or bulldozing to create more pasture, on both sides of the jeep trail (Puu Oo Volcano trail) that runs through the Keauhou Ranch; and there is a widespread population along the spur trail that goes from the Puu Oo trail to the Kilauea Forest, an area in which harvesting and bulldozing took place during the past several years. It remains to be determined if the thrushes will be able to continue to nest successfully in these greatly disturbed habitats.

3. Elepaio

The Elepaio (Chasiempis s. sandwichensis) is the only Hawaiian representative of the Old-world flycatcher family (Muscicapidae); subspecies are found on Hawaii, Oahu, and Kauai. My figures suggest a minimum of 25 pairs of Elepaio in the study plot, or one pair to each 8 acres. This may be an underestimate for the reasons given in my paper on the "Birds of the Hawaii Volcanoes National Park, a Preliminary Report. Frings (1968) studied a population of the Oahu Elepaio (C. s. gayi), and reported that the birds there defended a territory averaging 4.9 acres. Her study, however, was made in an area (upper Manoa Valley) where nearly all of the dominant plants were introduced species. One might expect a higher density of birds in an endemic forest where the species evolved, but, obviously, a careful study of the annual cycle in a rain forest is needed.

4. Introduced bird species

It is notable, and somewhat surprising, that only two species of exotic birds have been seen in the 200-acre study plot during the past two years: Red-billed Leiothrix (Leiothrix lutea) and Japanese White-eye (Zosterops j. japonica). The explanation probably is related to both the density and the near-virgin state of the forest, as well as to the kinds of exotic species that have reached this region of the island of Hawaii. Two species that have not yet been seen in the study plot are:

a. The Cardinal (Richmondena cardinalis) occurs in limited numbers in Volcanoes National Park, where there are open areas; for example, I have seen it in Bird Park and in kipuka Ki; I also have seen the cardinal in disturbed forest at an elevation of approximately 5,200 feet near the upper boundary of the Laupahoehoe Forest Reserve.

b. The Chinese Thrush (Garrulax canorus)-- which is not a thrush at all but a member of the babbler family (Timaliidae), as is the Red-billed Leiothrix--does invade endemic forests. Baldwin (1953: 353) saw Chinese Thrushes on several occasions between 1940 and 1948 near the entrance to the Ainahou Ranch and at Lua Manu in the Chain of Craters region in Volcanoes National Park. Dunmire (1961) said that this species could be seen occasionally "in the wet ohia forest such as around Park Headquarters," but I have not yet seen or heard this species within the Park. The Chinese Thrush is widely distributed in the Alakai Swamp region of Kauai.

Several other exotic species do occur in considerable numbers in the pasture land at all elevations along the jeep trail to the study plot.

The most common are the Ricebird (Lonchura punctulata) and the Linnet or House Finch (Carpodacus mexicanus frontalis). These species prefer grassland, brushland, and open forest, but they also invade dense forests along stream beds and jeep trails.

c. White-eyes begin to sing and nest earlier in the year than do the Leiothrix. This is indicated by the census data: the maximum number (55) of White-eyes was recorded in March; the maximum number (47) of Leiothrix, in July. These preliminary data suggest a population of one pair of White-eyes per 3.63 acres, and one pair of Leiothrix to each 4.25 acres. Such densities during the nesting season appear reasonable. Both species are highly gregarious, however, and large flocks form during the non-breeding season. Fisher and Baldwin (1947) wrote that the "density reaches 80 to 100 birds an acre at times at Kipuka Puaulu (4,000 feet)" in Volcanoes National Park (such densities have not been recorded in recent years, however). They added that "virgin tree fern forests favorable to the native Hawaiian birds are in some areas without Leiothrix. A forest of this type at the Twin Craters (3,800 feet) in Hawaii National Park usually had not more than one individual per acre. Similar forests of the Uppper Olaa Forest Reserve near a farming district exhibited a somewhat greater density."

Foraging Behavior of the Birds

No one has yet demonstrated that there is any adverse competition among the several species of endemic forest birds, nor between them and any introduced species. No information is available to suggest that

insects, nectar, or fruits are limiting factors for population sizes of any Hawaiian bird species.

Among the six species of honeycreepers known to inhabit the study plot, the Apapane and Iiwi characteristically are birds of the crown of the forest. Both forage for food (nectar and insects) there; similarities and dissimilarities in the kinds of insects eaten by these two honeycreepers were studied in detail by Baldwin (1953), and were summarized in my paper on the "Birds of the Hawaii Volcanoes National Park, a Preliminary Report." Baldwin also analyzed the stomach contents of 63 Amakihi. The Amakihi feeds on insects and nectar, but it spends more time on twigs and branches than do the Apapane and Iiwi. Baldwin wrote: "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 the use of the flying forms. Loxops virens takes a large proportion of nonflying forms obtained from leaves and twigs."

The food habits of the Creeper, Akepa, and Akiapolaau have not been studied since Perkins (1903) wrote of the stomach contents of the birds he collected. Based on Perkins' descriptions and on my own observations

of the Creeper (primarily on Maui and Kauai), however, it appears that this species forages throughout most of the vertical strata of the forest, from low shrubs, ferns, and trees to the tops of the ohia trees. The Creeper received its English name because, like the Brown Creeper (Certhia familiaris) of North America, it obtains its food from tree trunks and the larger branches of the trees, the birds being adept at working both upwards and downwards on the trunks and on both the upper and under surfaces of large branches. Perkins found the Hawaii Creeper to be "extremely partial" to large koa trees, but the birds also feed on mamani, ohia, and other trees in their habitat.

The Akepa searches for its food primarily among leaves and twigs, and Perkins wrote that it fed largely on caterpillars and spiders, although it also drank nectar. Perkins considered the Akepa to be "of high value in the forests" because they destroy insects which "are well concealed and obtained only to a comparatively small extent, or not at all, by the other native birds."

The Akiapolaau is unique among the family of honeycreepers because the upper mandible is much longer than the lower mandible, and the upper mandible is strongly decurved whereas the lower mandible is straight and heavy. The Akiapolaau has woodpeckerlike feeding habits in that it lifts the upper mandible out of the way and pounds into dead wood with the lower mandible. I have watched Akiapolaau feed only a few feet from the ground on dead tree trunks and 50 or more feet above the ground in koa trees. The birds also work upward on tree trunks and on both the upper and lower surfaces of large branches.

Although it not uncommonly flys to the ground and to fallen trees after moths or other insects, and also forages high in the trees at times, the Elepaio is, basically, a bird of the understory. It frequently darts from a perch to snap up a flying insect, but also searches the under surfaces of leaves, on twigs, and in crevices of bark for food. It seems likely that the feeding habits, as well as the niche in the forest occupied by the Elepaio, preclude any substantial competition for food with any endemic bird species.

Male Hawaiian Thrushes spend much of their time during the breeding season in the higher parts of the forest. Favorite singing perches typically are high branches (often dead) of the taller trees, and the birds have a flight song, during which a bird may fly at, or above, crown level where there are gaps in the crown cover. The birds also feed at mid-levels in the forest: for example, on the fruits of Cheirodendron trees. The birds nest among understory plants, however, and spend much of their time there in quest of food (primarily insects and fruit) and in preening and resting.

The Leiothrix is primarily a bird of the understory, whereas the White-eye, although perhaps more typical of low and mid-elevations, feeds at nearly all levels, including the crowns of the trees. Fisher and Baldwin (1947) analyzed the stomach contents of 13 Leiothrix collected in Volcanoes National Park, and found fruit (e.g., thimbleberry, Rubus rosaefolius) and animal material (Hymenoptera, Lepidoptera, Diptera, and Mollusca). They also reported observations of Leiothrix on Oahu eating the fruit of strawberry guava (Psidium cattleianum), overripe papaya,

flower petals, and small new buds of various plants. No detailed study of the food preferences of the White-eye has been made. This species is largely insectivorous, but it is presumed to eat some nectar as well.

Nesting Data

It is not possible while attempting to census the numbers of birds along given transects to stray far to either side of the transects in search of nests. All of the nests that I have found thus far were built either along the transects or not far from them.

The most surprising feature about the nesting behavior of the Apapane in the Kilauea Forest study plot was discovered on June 24, 1971, on which date I found four deserted nests (two on transect 1 and two on transect 4) that had been built on the upper surfaces of tree-fern fronds. One of the nests held three addled eggs; the orange yolk color characteristic of the Apapane, however, was still obvious. Two of the nests contained large numbers of wing and body feathers of adult Apapane; proof remains to be gathered, but it seems likely that incubating birds were killed at night by roof rats (Rattus rattus). The fourth nest held a few feathers and the bones of at least one wing, probably of a large nestling. Each of the four nests had been built approximately 12 feet from the ground. Later (February 5, 1972), I found an Apapane nest built on the upper surface of a tree-fern frond in Volcanoes National Park (at Thurston's lava tube), but I have not yet found this kind of nesting site used by Apapane in other ohia forests I have studied on Hawaii, nor has this site been reported in the literature. The Apapane typically builds

its nest in the crowns of ohia trees in mature forests.

I also found ten active Apapane nests in tree ferns during 1972; all of these nests were built on the upper surfaces of the fern fronds; the distance from the nest to the ground varied from about seven to 15 feet. The nests were found between January 11 and May 21:

1. January 11: a nest under construction; I watched an adult carry nesting material to the nest (transect 1).

2. January 12: a nest under construction (transect 4).

3. February 6: two new nests--one still incomplete, the other, complete but empty (transect 1). One of these nests held three or four nestlings about six days old on March 14; it is very difficult to check the contents of Apapane nests built on tree-fern fronds because the entire frond will break off if pulled down very far.

4. February 7: a new, complete but empty nest (transect 3).

5. March 14: a nest with three nestlings estimated to be four or five days old. This nest was about 15 feet from the ground, and the tree fern was growing on top of a dead tree trunk (transect 1).

6. March 15: a new but empty nest (transect 4).

7. April 23: a new nest with three nestlings, estimated to be between two and three days old (transect 3).

8. May 20: a nest with three eggs (transect 1).

9. May 21: a nest with two eggs (transect 3); I saw another Apapane carrying nesting material (transect 4).

I also found an inaccessible nest about 30 feet from the ground in a slender ohia tree on May 20 on transect 1, and three inaccessible nests

high in ohia trees along the cross trail between transects 3 and 4 on May 21. I was unable to visit the study plot during June 1972, and I found no active nests there on my July visit. Nevertheless, the information collected during one breeding season reveals a nesting season lasting at least from mid-January into June (i.e., two nests with eggs on May 20 and 21 and a bird carrying nesting material on the latter date). I have found Apapane nests as early as mid-December in ohia forests along the Saddle Road; in writing about his experiences in Volcanoes National Park, Baldwin said that the earliest date on which he found a fledgling Apapane was February 3 (1942). In the Kilauea Forest study plot, I have seen fledgling Apapane on all visits to the study plot during March, April, and May.

I found several deserted, but no active, nests of the Iiwi, and no nests of any other species of honeycreeper in the study plot. I saw one independent Iiwi in immature plumage on April 23, 1972, and I have heard the distinctive food-call of the fledgling Amakihi on several occasions between April 23 and July 20.

Thus far, I have found only one nest of the Hawaiian Thrush in the study plot. This nest, built about six feet from the ground on the side of a tree-fern trunk, held two eggs on March 15, 1972. This nest probably was unsuccessful, however, and I found it on the ground on my next visit to transect 3.

The earliest evidence for nesting of the Leiothrix in the study plot is a fledgling, just out of the nest and unable to fly, that I found on May 20 (1972). The birds undoubtedly begin to nest before May. Fisher

and Baldwin (1947) said that the earliest hatching date they observed on Hawaii was March 14; their latest date for hatching was June 16. I have found several nests later than that: one nest with three eggs on June 24, 1971, and another nest with three eggs on July 23, 1970. Both of these nests were suspended from the under surface of a tree-fern frond; one was placed about 12 inches, the other about 16 inches, from the tip of the frond. One nest hung about seven feet, the other about nine feet, above the ground. Fisher and Baldwin apparently are the only authors to mention the tree fern nesting site for Leiothrix nests. They wrote that they had found Leiothrix nests on Hawaii built in aalii (Dodonaea viscosa), pukiawe (Styphelia tameiameiae), mamani, and fronds of tree ferns.

Adaptability of Five Species

Although there is considerable evidence that the endemic forest birds are intolerant of extensive changes in their habitat, three species exhibit a wide tolerance--or a marked adaptability--for different vegetative and climatic conditions: Elepaio, Amakihi, and Akiapolaau. All three are found in the Kilauea Forest study plot, and the Elepaio and the Amakihi occur in comparable forest (e.g., Thurston lava tube area) in Volcanoes National Park. All three species also inhabit the mamani-naio forest on the south and southwestern slopes of Mauna Kea at elevations from approximately 6,500 to 9,000 feet. The annual rainfall in the Puu Laau cabin area (elevation 7,400 feet) varied from 13.87 inches (347 mm) to 40.9 inches (1022 mm) and averaged 25.6 inches (640 mm) during the

five-year period of 1965-1969. This is a sharp contrast to the rainfall of 112 inches at the Kilaeua Forest study plot during 1971.

All species that inhabit the mamani-naio ecosystem also must be physiologically adapted to wide temperature fluctuations at elevations between 6,000 and 9,000 feet. The monthly differences between maximum and minimum temperatures at Pohakuloa (elevation 6,500 feet) varied from 41° F (5° C) to 62° F (16° C) during the four-year period 1966-1969, and averaged 51° F (10.5° C). During very few months of the year does the nighttime temperature not fall to freezing or below, and during only one month in the four-year period did the temperature not drop below 37° F (2.7° C). Monthly extremes in temperature-range varied from 20° to 82° F (-6.6° to 27.7° C) in January and from 35° to 76° F (1.6° to 24.4° C) in June.

Unexpected was my discovery (Berger 1969) that the Amakihi in the mamani-naio ecosystem initiate their nesting cycle by mid- or late-October in most years. For example, I found five Amakihi nests on November 3 and 4, 1966. Two of the nests were being built; two held eggs; and one nest contained three nestlings that I estimated to be three or four days old. The Amakihi in this habitat, therefore, begins nesting activities at a season when daylengths are decreasing and when freezing, or below-freezing, temperatures are the rule. I have been unable to learn of any other passerine bird in any other part of the world that begins its breeding season under similar conditions.

During the summer of 1971, Richard E. MacMillen studied the physiological responses of honeycreepers in my aviaries in Honolulu:

Amakihi from the mamani-naio forest on Hawaii (Loxops v. virens) and from the ohia forests of Kauai (L. v. stejnegeri). (See IBP Technical Report No. 2, January 1972: 172-173.) MacMillen found that the Amakihi from both sources were effective thermoregulators and maintained a constant body temperature of about 40° C between an ambient range of 10 to 30° C. He noted, however, that the most "unexpected response" was the nearly complete intolerance of the Amakihi to elevated ambient temperatures. "Of a sample of six L. virens subjected to T_A 39-40° C (their usual body temperature) for two hours, four birds ultimately perished .... Under conditions of dry air, and apparently stressful temperatures," the Amakihi "were capable of only moderate evaporative cooling, in spite of rather high levels of pulmocutaneous water loss." MacMillen concluded by saying that "insular evolution of these drepanidids has resulted in certain bioenergetic adjustments, and that the (presumed) ancestral ability to cope physiologically with ambient heat stress has been lost by the amakihi." Continuing experiments on other species of honeycreepers will shed further light on the physiological adaptations in this family of birds.

Comparable information, however, is not available for any other Hawaiian bird, either endemic or introduced. The Elepaio, an insectivorous species, for example, also obviously is physiologically adapted for living in these two highly different ecosystems.

The puzzling feature about the present distribution of the Akiapolaau is that, even though adapted to life both in the dry mamani-naio ecosystem and in the very wet ohia-koa-tree fern ecosystem,

and even though it was a common species on Hawaii during the 1890s (Perkins, 1903), it is now rare in both habitats, and has not been seen in other regions of Hawaii for more than a decade.

Two introduced species--Leiothrix and White-eye--also inhabit both the wet ohia forests and the dry mamani-naio forest. In fact, it is difficult to find any region from sea-level to tree line on Hawaii that is not inhabited by the White-eye. Unfortunately, nothing is known about the physiological characteristics of either species.

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