

Lanai Bird Survey--1975-1976.

By L. T. Hirai

Lanai Bird Survey

Lanai is the sixth largest island in Hawaii, covering about 140 square miles. About 20% of the island is in pineapple cultivation and most of the rest is in forest or game-management use. From August 1975 through the first weeks of November 1976, a field survey of the island birds and small mammals was done to provide base-line information for the assessment of possible environmental affects caused by the United States Department of Agriculture Hawaiian Fruit Flies Laboratory Lanai eradication program.

The Island of Lanai

Lanai is a pear-shaped island, the sixth largest in Hawaii, covering 139.5 square miles, about 2% of the total state area (Figure 1). The extreme length of the island is 18 miles and its extreme width 13 miles, with the highest elevation at Lanaihale, 3,370 feet (Armstrong 1973). Because Lanai lies in the rain shadow of West Maui and East Molokai, the island is rather dry (MacDonald and Abbott 1970). Mean annual rainfall varies from 10 inches along the coast to 35 inches near the summit (Armstrong 1973), although a substantial quantity of water, estimated to be as much as the annual rainfall, is directly intercepted from the cloud cover by the vegetation in the upper mountain areas (Ekern 1964). Armstrong (1973) and MacDonald and Abbott (1970) have summarized other aspects of the geology and natural environment of Lanai.

The cultural history of Lanai is interesting, although not well known. Bissell (1971), Emory (1969), Tabrah (1976), and Tuttle (1959) have written about it.

Today over 98% of the island is owned by Castle and Cooke, Inc., through its subsidiaries Dole Company and Lanai Company, with most of the population of 2,200 living in Lanai City and economically dependent on the pineapple plantation (Armstrong 1973).

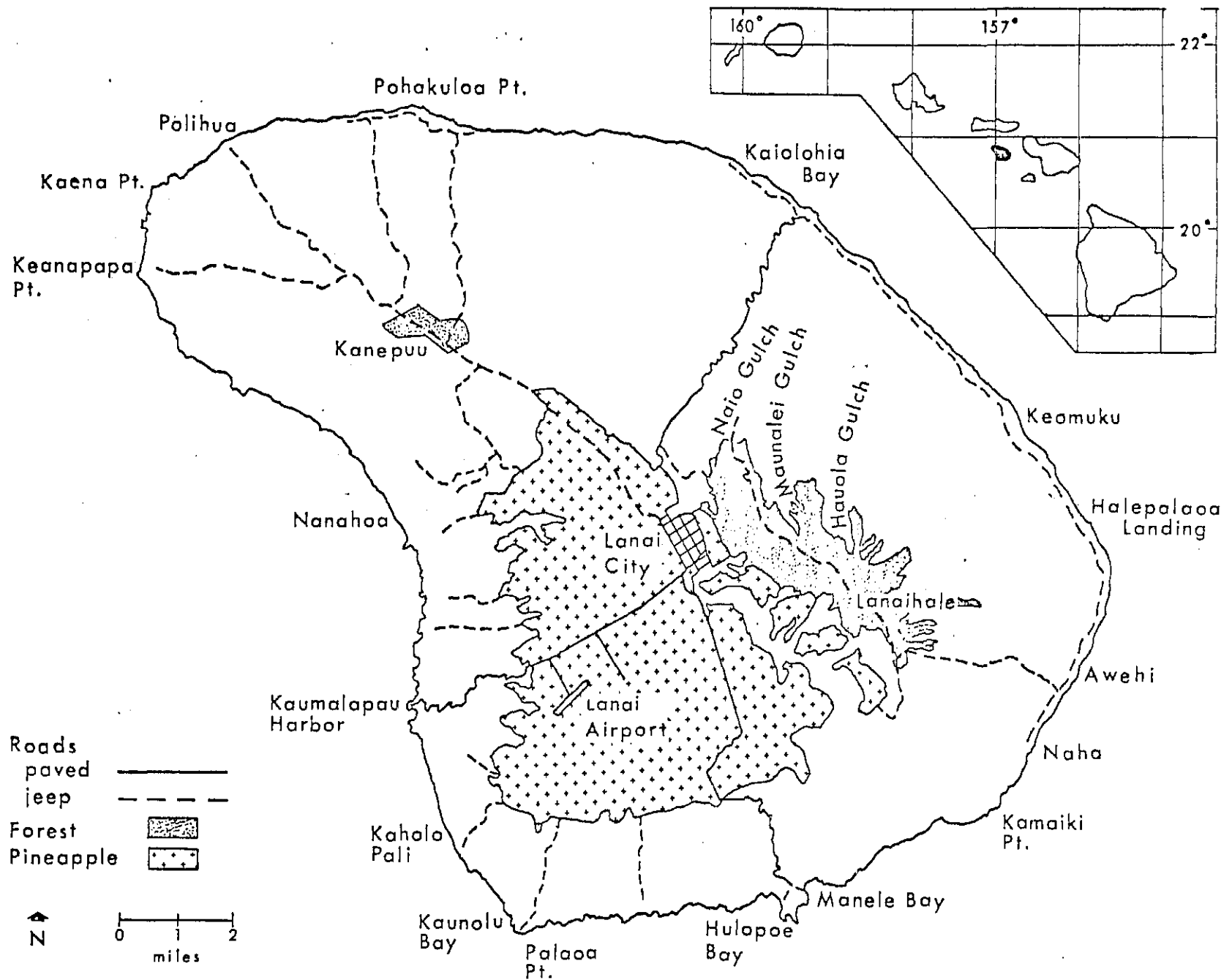


Figure 1. Island of Lanai, Hawaii.

In summary, Lanai could be considered a microcosm of elements of the other Hawaiian islands in terms of mountain, valleys, forest, scrub, cliffs, and beaches; dominated by one crop, pineapple; with one company in sole ownership of its lands; and one town, the most sophisticated plantation settlement in the islands (Armstrong 1973).

Vegetation Zones

A native forest may have once covered most of Lanai, but by the early 1900s the forest had been destroyed by cattle, sheep, and feral goats (Perkins 1903, Rothschild 1893-1900, Wilson and Evans 1890-1899), with goats probably the main cause of the destruction of the mountain forest. Today Lanai may be divided into four vegetation zones, with the distribution of plants closely related to climatic factors such as annual rainfall and temperature (Figure 1, Tables 1 and 2).

Vegetation Zone A. Zone A includes the arid and hot coastal lands. The coastline may be divided into a Pali Coast on the south and west half of Lanai from Kamaiki Point to Kaena Point and a Beach Coast along the north and east half. The Pali Coast is dominated by 14 miles of sea cliffs, reaching heights greater than 1000 feet at Kaholo Pali (Armstrong 1973). Sea caves, sea arches, and stacks are seen at a number of places along this coast. The cliffs are believed to have been formed entirely by wave erosion (MacDonald and Abbott 1970). The Beach Coast, on the other hand, is low and flat, with broad expanses of alluvium and beaches and no appreciable sea cliffs. This coast is generally sheltered from strong wave action.

Inland from the coast, koa haole (Leucaena leucocephala) and kiawe (Prosopis pallida) dominate the southern and western half of Lanai, ending at the pineapple fields (Ananas comosus). The northern and eastern half is

generally a windy section, with a kiawe belt along the sandy coastline, above which is found a grassy range with scattered kiawe and koa haole. The coastal kiawe belt is especially well formed and about one mile wide from Maunalei to Naha. In this belt, the first 0.25-mile strip from the shore is green and rather thick, with the remaining 0.75 mile drier and sparser. In many places, but especially in the north end of the island, the grassy range ends in rather extensive wind-eroded areas, often completely devoid of vegetation and much of the soil.

A number of roads, most of them unpaved, lead to the coastline; other roads end a few miles from the coast but often have footpaths leading to the shore. Because of the excellent fishing, there are a number of popular fishing sites along the coastline, with fishing shacks or beach homes located near Palaoa Point, Keanapapa Point, and between Kaiolohia Bay and Naha. Extensive white-sanded beaches are found at Polihua and Hulopoe. Manele-Hulopoe and Kaumalapau are the recreation and harbor centers of Lanai. Water troughs are located irregularly in this zone, as are brackish water holes, especially from Maunalei to Naha. Most of the zone is in game-management use.

Vegetation Zone B. Zone B includes most of the central plateau, since the 1920s in pineapple production. The plantation now covers about 20% of the island area and recently was enlarged on the Flats and toward Kanepuu. Lanai City, about one mile long and half a mile wide, and Lanai Airport are strategically located on the plateau. About the only area on the plateau not in pineapple use is Kanepuu, with its remnants of a dry native forest that possibly once covered much of that section of Lanai.

Vegetation Zones C₁ and D₁. The last two vegetation zones include the summit region, commonly referred to as "the Hale." The Hale is the principal forested area on Lanai, generally wet and cool, especially

at Lanaihale. Zone C₁ includes the pineapple fields on the Flats and the lower slopes of the mountain; zone D₁ includes the upper lands. A great deal of the vegetation at the lower elevations is introduced molassas grass (Melinis minutiflora), guava (Psidium species), eucalyptus (Eucalyptus species), Christmas berry tree (Schinus terebinthifolius), and ironwood (Casuarina species). Most of the lower-elevation forest stands were planted in the 1920s and early 1930s for windbreaks, fence posts, fuel, and watershed improvements (Wong 1966). The native vegetation of ohia-lehua (Metrosideros collina) and false staghorn fern, or uluhe, (Dicranopteris species) is only significantly evident above elevations of 2000 feet. Even in the native habitat there are many introduced grasses and trees.

The forested region on Lanai is quite small, less than 7% of the island area, with the northeast side of the Hale dissected by a number of gulches, the two most important being Maunalei and Hauola Gulches. The Munro Trail, a jeep road, winds for 10 miles through the forest, along the ridge crest, with a number of foot trails radiating from it.

Scope of the Study

Initially the study was to assess the possible environmental affects on nontarget animals (birds and small mammals) caused by the United States Department of Agriculture Hawaiian Fruit Flies Laboratory eradication program. However, delays in implementing the program resulted in the work providing mainly base-line data on the distribution and relative abundance of the avian species on Lanai.

Field work was done from August 5, 1975 until November 10, 1976, with periodic trips off the island. Surveys were made throughout the day and sometimes at night, usually in good weather. There were two types of surveys. In one detailed counts of birds seen and heard calling and singing were

Table 1. Vegetation Zones of Lanai.

1	2	2	3	4	4
Zone	Altitude (feet)	Rainfall (in./yr.)	% of island area	Use	Characteristic Plants
A kiawe and lowland shrubs	0 - 1000	<20	51.1	game management	bristly foxtail, false mallow, kiawe, pili, swollen fingergrass
B lantana-koa haole shrubs	1000 - 1800	20-30	40.4	pineapple, game management	lantana, ilima, Natal redtop, kiawe, indigo, prickly pear, Guinea grass, ekoa
C1 open guava forest with shrubs	1800 - 2500	30-35	7.1	pineapple, game management	panicum, guava, lantana, Kikuyu, ekoa, joea, Hilo grass
D1 closed guava forest with shrubs	2500 - 3500	>35	1.4	game management, forest	guava, ohia lehua, tree fern, Hilo grass, sedge

Adopted from Armstrong 1973, Ripperton and Hosaka 1942, and Sahara et al. 1967

1

From Armstrong 1973

2

Altitude and Rainfall reflect Lanai conditions and not the information, generalized for all the Hawaiian Islands, that is given in the sources. Rainfall does not include water intercepted by the vegetation from the cloud cover. If the water thus collected were included, the quantities for C1 and D1 would be appreciably greater.

3

From Schwartz and Schwartz 1951a

4

From Sahara et al. 1967

Table 2. Land Use on Lanai.

Land Use	Area	
	Acres	% of Total

Pineapple	16,236	18.2
Forest	5,926	6.6
Recreation	106	0.1
Game Management	66,577	74.6
Urban	435	0.5
Total	89,280	100

Adopted from Armstrong 1973

done in different sections of the island. Surveys were made by jeep, with regular stops for timed intervals, and walks, usually one mile long, in the areas. In the other type of survey, the areas were only reconnoitered, usually by jeep, and no detailed counts kept.

A limited rodent-trapping program was also conducted during 1976, to provide information on rodent distribution and diet. Snap-type traps were used in the mountain forest along the Munro Trail, on the northeast side of the island around Halulu, in the native dry forest at Kanepuu, on the southern side of the island at Manele-Hulopoe, in Lanai City, and in the pineapple fields.

In April, 1976 the Hawaiian Fruit Flies Laboratory was able to aeri-ally treat three areas on Lanai in a preliminary test to eliminate the Oriental fruit fly. On April 15, 1976 the mountain region, from Puu-alealea to Awehi Road, was treated with a thickened spray of 58% methyl eugenol, 25% technical naled, and 17% Thixcin E, at the rate of 10 pounds per square mile. On April 16, 1976 cigarette filter tips, containing 1.4 grams of a solution of 70% methyl eugenol and 30% naled, were dropped at the rate of 6000 tips per square mile in Kanepuu. Also on April 16, 1976, 4000 six-inch pieces of string (24 ply), holding 0.3 gram of 70% methyl eugenol and 30% technical naled solution, were dropped in the kiawe strip along the shore from Maunalei to Naha. Surveys were done in the three areas before and after the treatments to assess the possible affects on the bird populations.

Following are generalized species accounts of the birds noted on Lanai, a discussion section with a more detailed analysis of the distribution and relative abundance of the island avifauna and the affects on the bird populations of the aerial treatments in the three areas, and the results of the rodent-trapping program. The generalized species accounts are divided

into native and introduced categories. The native category also includes brief passages on species formerly found on Lanai. Species are listed phylogenetically and bird names follow Berger (1972, 1976) and Titcomb and Gayne (1976). No diacritical marks are used for Hawaiian words and only for the native birds are Hawaiian names mentioned.

Native Birds of Lanai

In historical times a number of native bird species were found on Lanai. Present were a petrel, an owl, a thrush, and six members of the endemic Hawaiian Honeycreeper family (Drepanididae). Although the Lanai native forest was much reduced by the late 1800s, the birdlife was considered to be rather abundant (Munro 1960, Perkins 1903). However, by the 1930s the native avifauna had been virtually eliminated, until today only three species are considered present. A fourth, the Dark-rumped Petrel, was rediscovered on Lanai during this study.

The causes of the extinction of so many of the Lanai avifauna is not definitely known, but have been popularly attributed to mosquito-borne avian diseases from birds, especially poultry, introduced with the establishment of the pineapple plantation in the 1920s (Munro 1960), the destruction of the native mountain forest (Greenway 1967), and, to some extent, predation by feral cats (Felis catus) and pigs (Sus scrofa) (Munro 1960, Perkins 1903, Rothschild 1893-1900). Other possible causes are discussed by Berger (1972) and Greenway (1967).

Because the Dark-rumped Petrel was rediscovered on Lanai during this study, it is conceivable, although very unlikely, that one or more of the forest birds now considered extinct could still be extant, most probably surviving in small numbers deep in one of the many valleys on the north

side of the mountain. However, in all the time spent in the field no sighting or call was believed that of one of the extinct species.

Wedge-tailed Shearwater, or Uau-kani (*Puffinus pacificus chlororhynchus*).

The bird is found throughout the tropical Pacific Ocean and the Indian Ocean, with this subspecies nesting on the Leeward Islands, the offshore islands, Kauai, and probably Niihau (Berger 1972). On Lanai a small colony probably nests on Puupehe Island, a sea tower standing off of the point between Manele and Hulopoe Bays (Figure 2). The islet is about 150 feet from land, 80 feet high, and 70 feet in diameter. On the grassy top is located a platform, believed to be a Hawaiian bird shrine (Emory 1969). Guano deposits were evident on the island top throughout the study period, and in June and July, 1976, at and after sunset, shearwaters were observed flying low over the water toward the island, circling the rock, and landing on the grassy top. On August 20, 1976, a chick was observed in a hole located near the top of Puupehe Island. Guano deposits were very evident around the entrance of the hole. By mid-September, 1976, shearwater activity around the rock had ended.

The colony is small, numbering at least five and probably less than 10 adults. Although no moans or cries were heard from the birds, they resembled light-phase colored Wedge-tailed Shearwaters. Because the nesting season for this species on other islands is from June through November (Berger 1972) and activity on Puupehe Island seemed to have ceased in September, it may be that the nesting attempts for 1976 failed. Other birds, notably the smaller petrel species, may also nest on the island, but their presence there could not be verified because of the difficulty in reaching the islet. Emory (1969) did succeed in reaching the top of the island and found there the bones and egg shells of birds, many of which he believed

to be terns. Other islets and stacks dot the Pali Coast and may also provide nesting grounds for the species.

Dark-rumped Petrel, or Uau (*Pterodroma phaeopygia sandwichensis*).

Two subspecies are known, one in the Galapagos Islands and the other in Hawaii. The Hawaiian race formerly nested on most of the main islands, but is now considered restricted to Maui and Hawaii (Berger 1972). The population on Lanai was believed extirpated by pigs and cats (Munro 1960), before then nesting on the ridges on the northside of the mountain and in the dry forest on the northwest end of the island, presumably Kanepuu (Munro 1941). Remains of petrel wings were found along a valley trail in 1926 (Munro, in Gregory 1927), and on October 26, 1973 a Dark-rumped Petrel, possibly a juvenile, was caught at night along the Munro Trail above Kaiholena Gulch, when it was attracted to the ground by the light of a coleman lantern (Shallenberger 1974).

Night field work, starting in June, 1976 and ending in October, 1976, established the presence of the Dark-rumped Petrel on Lanai. On June 23, 1976 a colony was located on the upper ridge slopes along a 0.25-mile stretch of the Munro Trail, about 0.25 mile eastward from the fog-drip station, at an elevation of about 2800 feet (possibly Kanalo or Kumoa Gulch) (Figure 2). The colony was estimated from the number of calls heard and birds seen flying overhead to be less than 100 individuals, probably closer to 50 birds. Although no burrows were found, it is strongly believed that the petrels nest there on the ridge slopes, which are covered by uluhe fern and ohia-lehua.

Petrels were noted in the area soon after sunset, with calls and flights back and forth over the ridge being most noticeable for the first one or

two night hours. Activity then seemed to decline, ending a few hours before sunrise. Petrel numbers seemed to decline as the nesting season progressed, probably due to the adults leaving the grounds when nesting attempts failed and the natural tendency for progressively less care of the chicks as they developed. By October 1, 1976 no adults were heard or seen in the area.

From the available information, the nesting season of the Dark-rumped Petrel on Lanai seems to be similar to that of the population in Haleakala Crater, Maui, from May to November (Berger 1972). Although other petrel colonies may exist on mountain ridges not as accessible, the one discovered seems to be the only one on the Munro Trail. Observations were made for at least a few hours before and after sunset in June, 1976, at five sites along the Munro Trail between Puu Kilea and Haalelepaakai Puhielelu Ridge (excluding the location of the colony). Only sporadic petrel calls were heard, possibly indicating a few scattered nesting attempts, although most of the calls were believed made by adults flying to the colony site. Two night trips, one in June, 1976 and the other in July, 1976, were also made to Kanepuu. No petrel activity was noticed.

It is unknown whether the bird was always on Lanai during the many years it was considered extinct or reestablished itself there only recently. However, the area close to the location of the colony, and possibly the colony site itself, was cleared a number of times in the 1950s in connection with a fog-drip station experiment. The removal of the vegetation could have opened the area for petrel colonization.

Populations of Dark-rumped Petrels on Maui and Hawaii are generally found at higher elevations, in habitats devoid of much vegetation cover (Berger 1972). It may be that the introduced small Indian mongoose (Herpestes auropunctatus) on those islands prevents the establishment of

petrel colonies at lower elevations. The present colonies at the upper elevations may still exist because they are above the normal range of the mongoose. So far, only on Lanai are Dark-rumped Petrels still found nesting at a lower elevation, in dense vegetation, and only on Lanai (and Kauai) are mongooses not present. The future status of the Dark-rumped Petrel on Lanai probably depends on preventing the introduction of the mongoose.

White-tailed Tropicbird, or Koae kea (*Phaethon lepturus dorotheae*).

This tropicbird is found throughout the tropical Pacific but is known to nest regularly in Hawaii only on Hawaii, Maui, Kauai, and a few of the offshore islands (Berger 1972). On Lanai this race is found along the Pali Coast and in Naio, Maunalei, and Hauola Gulches (Figure 2). Tropicbirds probably also frequent other gulches whose slopes are devoid of much vegetation cover. Because of the nesting locations and the behavior of the birds, the population size was not easily determined but probably number a few hundred. As many as 18 individuals were seen in the Kaapahu area along the western coastline at one time (Connally 1976a) and 16 and 13 birds in Naio-Maunalei and Hauola Gulches, respectively. The tropicbirds were observed flying back and forth against the cliffs or soaring high and low in the gulches, frequently paired and calling.

Actual nests were not found during this study; however, Munro (1947) did locate one, with a chick in it, in pasture land on the northside of Lanai. Adults were observed landing on ledges or entering holes in cliffs along the coast or in the gulches in October, 1975, from late February through early June, 1976, and in August, 1976. These may have been nesting sites. Two young, feathered and lacking streamers, were found dead on the grounds of the abandoned plant nursery in Maunalei Gulch in August, 1975. They probably were from nests located in the cliff face behind the nursery;

adult birds were often seen there. Adults were also seen, especially in the gulches, in all months of the year. From the observations, the breeding season of the White-tailed Tropicbird on Lanai is prolonged and possibly year-round.

Red-tailed Tropicbird, or Koae-ula (*Phaethon rubricauda rothschildi*).

This tropicbird breeds on the Bonin and Hawaiian Islands, most commonly in Hawaii on the Leeward Islands (Berger 1972). On Lanai it is found along the Pali Coast, nesting in holes in the high sea cliffs (Figure 2).

Because of the nesting habitat and the behavior of the birds, the population size was difficult to determine but probably numbers in the low hundreds. Usually only one or two individuals were seen, but on June 9, 1976, at Kaneapua, as many as 10 adults were observed low against the sea cliffs and over the ocean, calling frequently.

The first sighting of a Red-tailed Tropicbird was on February 22, 1976. The seabird was flying low, against the sea cliffs near Kolokolo Cave and Kaneapua. Tropicbirds were noted in succeeding months in the vicinity of Kaneapua-Kaholo Pali, Kaumalapau Harbor, and Nanahoa. The last sighting was of at least one bird near Nanahoa on August 25, 1976. Others (Connally 1976a, 1976b; Wilson 1974) have also seen Red-tailed Tropicbirds along the western coast, as far east as Manele Bay. No individuals were noted in the many gulches on the island.

On a number of occasions Red-tailed Tropicbirds were observed entering holes in the sea cliffs, probably their nesting sites. In one case, on July 9, 1976, near Kaumalapau Harbor, three tropicbirds were seen flying near the cliffs. In a few minutes one was lost from view and the other two landed and entered the same hole in the cliff face. On other islands

birds return to the nesting grounds in February or March, with eggs being found from April to August (Berger 1972). The breeding cycle of the Red-tailed Tropicbird on Lanai seems similar.

Brown Booby, or A (*Sula leucogaster plotus*). This species is found throughout the tropical Pacific (Berger 1972), with solitary individuals infrequently seen flying along the southern coastline of Lanai. Both adults and immatures were noted, but the species is not believed to nest on Lanai.

Great Frigatebird, or Iwa (*Fregata minor palmerstoni*). The Great Frigatebird is found throughout most of the tropical Pacific (Berger 1972), and individuals were seen along the Pali Coast of Lanai. The birds were soaring or flying high overhead, and seen especially when there were storms at sea. Usually only one or a few individuals were noted, but on August 17, 1976, during a period of "kona weather," about 20 frigatebirds were observed soaring high overhead in the Kaunapali Harbor area. On January 23, 1976, around midday, a female frigatebird was seen perched on a sea stack at Nanahoa. The seabird was observed sunning itself, with its wings held open.

Other seabird species were noted over the nearby waters. White Terns (*Gygis alba rothschildi*) were infrequently seen (Connally 1976a). Terns and Noddies were observed rather far out at sea flying low over the water in the direction of Oahu. Positive identification was not possible, but the birds probably were Sooty Terns (*Sterna fuscata oahuensis*) and Common Noddies (*Anous stolidus pileatus*).

Black-crowned Night Heron, or Aukuu (*Nycticorax nycticorax hoactli*). This heron is found from Washington and Oregon south to northern Chile and south-central Argentina, as well as in the Hawaiian Islands. In Hawaii it is found on the main islands, particularly abundant on Maui (Berger 1972). On August 20, 1975, an immature bird was seen flying along the shore, close

to the kiawe trees, in the vicinity of Halepalaoa Landing. Because Maui is situated only a few miles away and clearly visible from the Landing, the heron undoubtedly flew from across the channel. Others (Connally 1976a, Munro 1960) have mentioned occasional sightings of Black-crowned Night Herons on Lanai, and the species is probably a regular, though infrequently seen, visitor.

Pacific Golden Plover, or Kolea (*Pluvialis dominica fulva*). This plover is a regular migrant, nesting in Siberia and arctic America in the summer and spending the rest of the year in Hawaii and other Pacific islands (Berger 1972). Although a few birds were seen on Lanai the whole year, most of the plovers depart for the nesting grounds by early May. On May 3, 1976, a number of Golden Plovers were noted along Kaunalapau Highway, from Lanai City to the Airport Road. By May 10, 1976, no shorebirds were seen along this stretch. Plovers return from the nesting grounds quite early, at least by mid-July. Six individuals, in breeding and wintering plumages, were seen on the city golf course on July 17, 1976. In fact, as early as June 1, 1976, two birds, at least in partial breeding plumages, were observed on the golf course.

The Pacific Golden Plover is the most common of the migratory shorebirds on Lanai. It is found from sea level to Lanaihale (Figure 3). Plovers were especially common along the Beach Coast, in the horse pasture at Malau, the pineapple fields being tilled, and on the runway at Lanai Airport. Individuals were also noted in the mountain forest, on the Munro Trail.

Ruddy Turnstone, or Akekeke (*Arenaria interpres*). A regular winter resident in Hawaii, breeding in the summer in northwestern North America and northern Eurasia (Berger 1972). On Lanai its migratory cycle is probably similar to that of the Pacific Golden Plover, with a few individuals

remaining for the entire year. Turnstones were observed in small flocks along the coastline, especially from Kaiolohia Bay to Halepalaoa Landing, and in pineapple fields being tilled (Figure 3). Occasional flocks were seen on the city golf course, in the horse pasture at Malau, and on the runway at Lanai Airport.

On February 21, 1976, at Kaunolu Bay, a Ruddy Turnstone was observed for several minutes bathing in a tidal pool. The bird sat down in the pool and splashed water about, wetting its entire body. The turnstone eventually flew to a dry rock, where it dried itself out.

Bristle-thighed Curlew, or Kioea (*Numenius tahitiensis*). A regular migrant from western Alaska to the Leeward Hawaiian Islands and, in smaller numbers, to the main islands (Berger 1972). Munro (1960) mentions that in 20 years on Lanai only once, in 1931, did he encounter this curlew. On July 18, 1976, a Bristle-thighed Curlew was seen for a few minutes on the sandy shoreline at Polihua (Figure 3).

Wandering Tattler, or Ulili (*Heteroscelus incanus*). A regular winter resident in Hawaii, nesting in Alaska and northwestern British Columbia (Berger 1972). Its migrations probably follow the other shorebird species. Individuals were seen on Lanai throughout the year. Solitary birds were noted along rocky shores, regularly observed at Puupehe Island, the Kaunolu Bay area, from Kaiolohia to Halepalaoa Landing, and at Naha (Figure 3).

On August 20, 1976, at the base of Puupehe Island, a Wandering Tattler was noticed bathing in a small tidal pool. The shorebird sat down in the shallow pool, and was observed dipping its head down to allow water to cover the back, flapping its wings, and head scratching directly. Whenever the waves splashed into the pool, the tattler moved onto higher ground. After bathing for at least five minutes, the shorebird moved to a drier

location, where it preened itself and flapped its wings until it was dry. The bird then flew off.

On January 9, 1976, at Kaneapua, a tattler was seen feeding on a small crab. When the crustacean was examined, only its legs remained.

Sanderling, or Huna-kai (*Crocethia alba*). A common winter visitor to all the Hawaiian Islands, breeding in the arctic regions (Berger 1972). On Lanai it occurs almost year-round along the sandy shores, singularly or in small flocks, following close to receding waves. Sanderlings were commonly seen along the Beach Coast, especially from Kaiolohia Bay to Halepalaoa Landing (Figure 3).

White-capped Noddy, or Noio (*Anous tenuirostris*). This tern is found throughout most of the tropical Pacific, nesting on the Leeward Islands, the offshore islands, and at least on the coasts of Maui and Hawaii (Berger 1972). On Lanai a small colony, numbering up to 30 individuals, was located at Kaneapua (Figure 2). The terns were light-phase colored birds and were often seen standing or preening at the point or fishing in the nearby waters, especially where the waves broke on the rocky shore. The White-capped Noddies seemed to be more noticeable in the area on trips made there in January, February, and November, 1976, and less evident in September, 1975, April, and June, 1976. Because the terns are abundant only within 50 miles of their breeding or roosting islands (Berger 1972), it is probable that the species nest or roost in the nearby Kolokolo Cave or on the high cliffs. In January, 1976, at least five terns were observed flying into and out of the cave, with two more preening themselves on the rocks near the cave entrance. A few individuals were also seen in the Hulopoe-Manele area, flying along the coastline or even fishing in the breakers. Because of the high cliffs and sea caves located along this southern coastline, other colonies of White-capped Noddies may exist.

Short-eared Owl, or Pueo (*Asio flammeus sandwichensis*). The Pueo is a permanent resident on all the main Hawaiian islands, found in a wide range of habitats (Berger 1972). On Lanai owls were noted in the grasslands on the north and northeast sides of the island, in or near the pineapple fields, and over the mountain forest (Figure 4). The population size of the Pueo on Lanai could be termed "common," with the species apparently in no immediate danger of becoming extinct. Numbers probably are well below 100 individuals.

Pueo were active both in the day and at night, frequently seen soaring at considerable heights above the ground or hovering lower, especially over pineapple fields, before diving to the ground, probably after mice or rats. At least in August and September, 1976, and probably for the other months as well, Pueo were noted in the early morning hours, well before sunrise, on Manele Road, within three miles of Lanai City. As many as four birds were observed on the road in one night; the reason for the owls being there was not known but possibly they were digesting their catches. Owls were also seen perched on the telephone wire along Kaunapali Highway during the same hours, but were believed to be introduced Barn Owls.

Nesting information on the Pueo is scant and the species may breed throughout the year, depending on the food supply (Berger 1972, Munro 1960). A nest with four eggs was found in the middle of November, 1892 on Lanai (Rothschild 1893-1900). On June 22, 1976, two young were found by the side of a pineapple road, in a molasses grass habitat, at Kakaalani. The chicks were not in a nest. The owls were about eight inches long, rather fully feathered with the head feathers still unsheathing, bodies dark colored with tannish spots on the backs, and eyes green-yellow. They were capable of weak flights, barely flapping over the molasses grass for distances

up to 10 yards. The young made a hissing sound occasionally, probably when they felt threatened. No adult Pueo were seen with the chicks and their fates are unknown. The young were noted in the area until June 26, 1976. Another young was also reported by K.N. Hirai by the side of Keomuku Highway, near Puulala, on October 1, 1976.

Lanai Thrush, or Olomau (Phaeornis obscurus lanaiensis). Subspecies or races of the Hawaiian Thrush evolved on all of the main Hawaiian Islands except Maui (Berger 1972). Today only the subspecies found on Kauai, Hawaii, and possibly Molokai are extant; the Lanai race is undoubtedly extinct. At least until the 1920s the bird was considered common, inhabiting the mountain forest, especially the north and south ends (Munro 1960). However, from 1923 the thrush started to decline in numbers (Munro 1960), although it was still "not uncommon" as late as 1934 (Munro, in Gregory 1935). The demise of the Lanai Thrush was believed due to the establishment of the pineapple plantation and the resultant introduction of avian diseases, which proved fatal to the nearby native bird population (Munro 1960).

Amakihi (Loxops virens wilsoni). The species inhabits all of the main Hawaiian Islands, divided into four subspecies found on Kauai, Oahu, Maui-Molokai-Lanai, and Hawaii. It is considered to be the second most common of the surviving honeycreepers (Berger 1972). The Lanai population was considered common before the 1920s, but then declined in numbers, possibly due to the affects of introduced bird diseases (Munro 1960). Today it is said to be rare (Berger 1972).

During this study the bird was encountered in late February, 1976 on the Hauola Trail North, between Hauola and Maunalei Gulches, in a rather good native forest habitat (Figure 5). For a few minutes one Amakihi was seen and a second heard in a Norfolk Island pine tree (Araucaria heterophylla).

On no other occasion was Amakihi noted, raising the possibility that the population on Lanai may be close to extinction.

Lanai Creeper, or Alauwahio (*Ioxops maculata montana*). Subspecies of the Creeper evolved on Kauai, Oahu, Molokai, Lanai, Maui, and Hawaii (Berger 1972). It is still found on the other islands but is presumed extinct on Lanai. In the 1890s this honeycreeper was common throughout the Lanai forest from 1500 or 2000 feet elevation to Lanaihale (Perkins 1903, Rothschild 1893-1900, Wilson and Evans 1890-1899). A pair was last reported seen in 1937 and by then the subspecies was considered scarce (Munro 1960). Munro (1960) did not feel that avian diseases led to the extinction of this bird. Probably the lost of suitable habitat was the main factor (Greenway 1967).

Akialoa (*Hemignathus obscurus lanaiensis*). Subspecies of the Akialoa were found on Oahu, Lanai, and Hawaii, with only the Hawaii race possibly surviving in small numbers (Berger 1972). The Lanai Akialoa was found in the late 1800s in the upper mountain forest region (Perkins 1903, Rothschild 1893-1900). It seemed to be quite rare even then, with the last definite sighting of an individual by Perkins in 1894. Lost of habitat is believed to be the reason for the extirpation of this curvebilled honeycreeper, although the true causes will probably never be known (Greenway 1967).

Ou (*Psittirostra psittacea*). A single species once inhabited the main islands, but today it is found only on Kauai, Hawaii, and possibly Maui (Berger 1972). In the 1890s this parrot-billed honeycreeper was quite common in the forested regions of the island but probably disappeared around 1932 (Munro 1960). It is believed that introduced bird diseases decimated the island population (Munro 1960). Predation by feral cats could have contributed to its decline (Perkins 1903).

Apapane (*Himatione sanguinea sanguinea*). A single species inhabits six of the main Hawaiian Islands and is considered to be the most common of the surviving species of honeycreepers (Berger 1972). It was considered to be rather abundant in the Lanai forest in the 1890s (Perkins 1903), but by the mid-1930s only a few remained (Munro 1960). From the survey work, Apapane are presently confined mainly to the native mountain forest (Figure 5). Apapane were most commonly seen in the areas between Hauola and Maunalei Gulches, above Puu Kilea (Kauhilua?), and in the forest behind Lanai City, about Puu Nene. Birds were also regularly heard in the valleys, but few Apapane were noticed near the Munro Trail. A rough estimate of the population size would be in the very low hundreds.

The honeycreeper was occasionally noted in introduced vegetation. On February 17, 1976, an adult Apapane was "flushed" from Keomuku Highway, about a mile from Koele at Puuialealea, and observed for several minutes perched quietly on a shrub in a molassas grass-guava habitat. Only at one site were Apapane regularly noted in an introduced habitat. About 0.75 mile in Hulopoe Gulch from the Munro Trail (commonly called 0.8-mile Trail), in a eucalyptus-ironwood forest, at least one Apapane was seen or heard five of the eight times the trail was surveyed from November, 1975 until August, 1976.

The breeding biology of the Apapane is not well known on any of the islands (Berger 1972), and during this study no nests were found. However, on two occasions immature birds were seen. On January 17, 1976, in the Puu Nene area, an immature, brownish colored, was sighted perched on a dead koa branch about six feet from an adult Apapane. Both birds flew off in a few minutes without any observed behavioral interactions. On April 28, 1976, in the area between Maunalei and Hauola Gulches, an adult and a juvenile were noted gleaning in Norfolk Island pine trees, calling, and finally

flying off. It seemed at times that the immature was following the adult bird when they were in the trees and leaving. The juvenile had a dull red body and brownish colored head, with blotches of red. Also, singing seemed greater in the winter months and reduced in summer, possibly reflecting the breeding and nonbreeding seasons.

There have been speculations of interisland flights by Apapane (Berger 1972) and it may be that such movements have restocked the population on Lanai. Today, however, the Apapane population on the island seems to be stable and viable, although the species probably will never increase to great numbers, due to the quality and quantity of the forest.

Iiwi (*Vestiaria coccinea*). A single species once inhabit the main Hawaiian Islands (Berger 1972). The population on Lanai is probably extinct today. The bird was considered quite abundant throughout the forest on Lanai in the 1890s (Perkins 1903), still fairly common up to 1923, but extirpated by 1929 (Munro 1960). Munro believed avian diseases wiped out the Lanai population.

Introduced Birds of Lanai

Today most of the birds seen or heard on Lanai are introduced, with over 20 species present. Many were deliberately released on the island but a number probably became established unaided from populations on neighboring islands. A good proportion of the birds were released to provide hunting opportunities and Lanai is now considered one of the better bird hunting areas in the state. Possible affects by the introduced species on the native avifauna is unknown.

Cattle Egret (*Bubulcus ibis*). This heron was introduced in 1959 from Florida to Kauai, Oahu, Molokai, Maui, and Hawaii (Berger 1972). On Lanai two individuals were seen near the paddock at Koele in late November and

early December, 1975, being observed close to horses, probably feeding on insects disturbed by the movements of the grazing animals. Another Cattle Egret was noted in July 1976, along the rocky shoreline at Kaumalapau Harbor (Connally 1976b). From conversations with the residents on Lanai, the heron is an almost annual visitor, with small numbers noted in the winter months around Koele. Individuals probably fly over to Lanai from nearby Molokai, Maui, or even Oahu.

Gambel's Quail (*Lophortyx gambelii*). This game bird is found in the southwestern United States and was introduced into Hawaii, except for Molokai, from Nevada in 1958 (Kramer et al. 1973, Walker 1967). On Lanai Gambel's Quails were found in two dry, kiawe locations, the Manele-Hulopoe and the Beach Coast areas (Figure 6).

The population at Manele-Hulopoe is small, usually noted behind the restrooms or on the peninsula. Coveys numbered as many as 10 individuals, but usually contained less than five birds. Quails were also noted inland along the pineapple-field edge, from Manele Road to Kaunolu Road. Along the Beach Coast small coveys were seen in the belt of coastal kiawe, as far west as Pohakuloa Point and east almost to Naha. Good numbers were also encountered in Maunalei Gulch, at least until the abandoned plant nursery.

Egg laying is said to occur in March and April, with an incubation period of 21 to 24 days (Kramer et al. 1973). Adults with young were seen along the Beach Coast on May 18 and May 26, 1976. The chicks were small but capable of flight.

Chukar Partridge (*Alectoris chukar*). The Chukar Partridge was introduced from the Orient to Oahu in 1923, with subsequent releases on the other islands (Berger 1972). In 1946-1947 the population of partridges on Lanai was estimated to be only 50 birds, found in the Manele-Hulopoe and Maunalei

areas (Schwartz and Schwartz 1949).

This game bird is still not found in great numbers on Lanai, usually seen in the Manele and Maunalei areas (Figure 6). A small number of birds, possibly only five individuals, were noted behind the Manele Harbor restroom. Greater numbers were seen in the first few miles of Maunalei Gulch, often on the rocky sides of the gulch, and in the coastal kiawe belt as far eastward as Keomuku. Individuals were also observed along Keomuku Highway, from the end of the paved road upwards about three miles to the Fish and Game water trough. In August and September 1976, small groups of Chukars were noticed along Kaumalapau Highway, from the City Refuse Site to the harbor. The birds were probably there to feed on pineapples that had fallen from the trailer trucks going to the harbor. Partridges were also observed picking at fallen, dried kiawe seed pods.

North Indian Gray Francolin (*Francolinus pondicerianus interpositus*).

A game bird native to India and introduced on all islands except Oahu in 1958 (Berger 1972, Kramer et al. 1973). On Lanai only 467 birds were released (Walker 1967) but the species is now the most abundant of the larger-sized game birds on the island. Gray Francolins were found in the coastal kiawe-koa haole forest, the grasslands, and in the pineapple fields and especially those tracts with fruits (Figure 7). Rarely were individuals noted in the mountain forest, although one was seen on February 5, 1976 at Lanaihale, during a raging storm.

On August 9, 1976, adults with at least three chicks were discovered in the cleared pineapple fields near Lanai Airport. The young were small in size and not capable of flight. While the chicks ran across the fields or hid in the grass, one of the adults displayed broken-wing behavior, in a direction away from the young. Gray Francolins have also been observed

taking dust baths in the loose dirt of a tilled and cleared pineapple field at Manele. This game bird is omnivorous, seen feeding on discarded bread, ripe pineapple, and picking at fallen, dried kiawe seed pods.

Breeding takes place from March through June, with a reported incubation period of 18 to 19 days (Kramer et al. 1973). The earliest sighting of adults with chicks was on April 14, 1976 and the latest on October 3, 1976. During this time span numerous broods were noticed in many parts of the island.

Erckel's Francolin (*Francolinus erckelii erckelii*). This species is native to Africa and was introduced from a mainland game farm in 1957 to Hawaii, initially on all the major islands (Berger 1972, Kramer et al. 1973). It is now found in appreciable numbers only on Kauai, Oahu, Lanai, and Hawaii. On Lanai it is not open for hunting.

Erckel's Francolins were distributed on Lanai in the Maunalei area and well into the mountain forest, being most common in the first two miles of Maunalei Gulch (Figure 7). Individuals were noted in the coastal forest as far east as Halepalaoa Landing and in the mountain forest at the summit. Because in the upland section Francolins were usually seen in the Malau-Puualealea area, on Koloiki Ridge, and on the northern side of the mountain, especially the northwestern portion, this species is probably spreading up and out from Maunalei Gulch and its tributaries. Of all the game birds on Lanai, the Erckel's Francolin is probably the most successful in at least penetrating the mountain forest habitat.

Nesting occurs in the spring and early summer months (Kramer et al. 1973). On September 25, 1976 two adults and three medium-sized chicks were seen crossing Keomuku Highway, at Puulala. Birds have been observed picking at fallen, dried kiawe pods.

Ring-necked Pheasant (*Phasianus colchicus*). A pheasant found originally in eastern China and northern Indo-China and introduced into Hawaii as far back as 1865, with subsequent releases made until 1941 with stocks obtained from the mainland United States, the Territorial game farm on Oahu, and possibly from its native range (Schwartz and Schwartz 1951b). It is found and hunted on all the islands. In the mid-1940s, pheasants on Lanai were distributed over the entire island, except for the upper mountain area (vegetation zone D₁), with birds most abundant in the pineapple fields (Schwartz and Schwartz 1949, 1951b).

The present distribution of this game bird is similar (Figure 7). Only Ring-necked Pheasants or hybrids were noted on Lanai, commonly found in the horse pasture at Malau-Puu Mahana, in the grassy borders of the runway at Lanai Airport, and in or near the pineapple fields, especially those tracts left fallow for a few years. Sparser numbers were noted in the coastal grasslands and at Kanepuu. A few individuals were also seen in the lower mountain areas but never at the summit. Only occasionally were Ring-necked Pheasants found in the coastal kiawe-koa haole areas. Individuals were rarely seen in the Manele area and once a pheasant was flushed in the gulch at Kaunolu Bay.

The Schwartzes (1949, 1951b) found that the breeding season of the pheasant in Hawaii was from February through July. Most laying began early in March, incubation for about 23 days in April and May, and most hatching from early May through June. However, young were seen as early as March 7 and as late as October 31. During this study nesting on Lanai seemed to correspond to the findings of the Schwartzes. Numerous chicks and juveniles were noticed in various sections of the island. The earliest observation of young was on April 19, 1976, when a hen and eight small-sized chicks

crossed Kaunalapau Highway, near the Airport Road. The latest sighting was on August 20, 1975, when a hen and a small-sized chick crossed Kaunalapau Highway, about one-half mile from Lanai City.

Rio Grande Turkey (*Meleagris gallopavo intermedia*). This is the largest game bird in Hawaii, introduced from Texas in 1962 and now found on all the main islands (Berger 1972, Kramer et al. 1973). The species may be distributed, at least sparsely, on Lanai in the entire coastal kiae-koa haole and grassland habitats, although turkeys were common only in the dry, kiae forest along the Beach Coast, from Kaiolohia Bay as far east as Lopa, and in the first two miles of Maunalei Gulch (Figure 6). Individuals and small groups were also seen rather regularly in the Kanepuu and Puualealea areas and along the pineapple fields between Manele Road and Kaunolu Road. Small numbers were noted on one occasion at Pohakuloa Point and one or two miles upland from Polihua; a good-sized turkey was flushed from the gulch at Kaunolu Bay. A large Rio Grande Turkey was even seen by Kaunalapau Highway, about one mile from Lanai City.

Nesting is said to take place during the spring months, with an incubation period of about 28 days (Kramer et al. 1973). On June 22, 1976 two adults and five young were seen at Pohakuloa Point. The young were smaller-sized but capable of flight. On July 1, 1976 up to 13 immatures were noticed at Maunalei. Turkeys were observed picking at fallen, dried kiae pods.

Rock Dove (*Columba livia*). This species is the wild form of the common domesticated pigeon and was introduced into Hawaii as far back as 1796 (Berger 1972). It is listed as a game bird but not open for hunting. On Lanai Rock Doves were considered rare in the early 1930s (Caum 1933) and numbered about 100 in the 1940s, roosting along the Pali Coast (Schwartz and Schwartz 1949). A small population presently roost and nest in holes

in the sea cliffs at Kaumalapau Harbor (Figure 8). Numbers varied but did not exceed 25 birds. The doves seen were mostly bluish colored but a few were also pale white-brown. Although Rock Doves may be present at other locations along the southern coastline, they were noted only in the vicinity of Kaumalapau Harbor. On occasion a few individuals were observed in Lanai City, but they were believed there for feeding purposes only.

On January 18, 1976, a squab was seen in a hole located in a sea cliff at Kaumalapau Harbor. Two adults eventually entered the hole and at least one adult fed the chick.

Spotted Dove (*Streptopelia chinensis chinensis*). The Spotted Dove is widely distributed in eastern Asia and was introduced into Hawaii, probably initially on Oahu, by 1879 and by 1900 had become established, possibly by itself, on the other main islands (Schwartz and Schwartz 1951a). The bird is hunted at certain times of the year. In 1946-1947 this dove was found over 98% of Lanai, most abundantly in vegetation zone B, in fair numbers in zones A and C₁, and absent in zone D₁, the upper mountain forest (Schwartz and Schwartz 1951a).

Today the Spotted Dove is similarly distributed as in the 1940s (Figure 8). Doves were most common near or in the pineapple fields, especially those tracts left fallow for a few years, and in Maunalei Gulch, with its good water sources. Fair numbers were noted in Lanai City; individuals were also regularly seen along the shoreline from Maunalei to Kahea, probably there to drink from brackish streams. To only a limited extent the species penetrates the mountain forest.

Barred Doves (*Geopelia striata striata*). The Barred Dove was brought into Hawaii, beginning in 1922, from Australia or Malaysia (Berger 1972,

Schwartz and Schwartz 1951c). Today the species is common to abundant on all the main islands, being listed as a game bird. According to the Schwartzes, the bird was initially released on Oahu, Kauai, Maui, Lanai, and probably Molokai. The original introduction on Lanai did not succeed and it seems the dove established itself on the island unaided from Maui after 1929. Survey work in 1946-1947 found Barred Doves inhabiting 98% of Lanai, excluded only from the upper mountain forest (Schwartz and Schwartz 1949).

Presently the Barred Dove seems to be similarly distributed (Figure 8). It is found from sea level to the edges of the mountain forest and is probably the most abundant of the game birds on the island. The species is especially common in the drier sections of Lanai, concentrating in large numbers at water sources. Barred Doves and Spotted Doves are found over much of the same range, but Spotted Doves seem to penetrate farther up the mountain forest, tolerating greater rainfall and denser-forested habitats.

Other game birds present on Lanai but not seen during this study include the California Valley Quail (Lophortyx californicus californicus) and the Japanese Quail (Coturnix coturnix japonica).

Barn Owl (Tyto alba pratincola). This nocturnal owl was brought in from California, starting in 1958, to Hawaii, Kauai, Oahu, and Molokai, to aid in rodent control in the sugarcane fields (Berger 1972). The bird most likely reached Lanai on its own from nearby Molokai or Oahu (or possibly Maui if it is now present there) and it is probably established and breeding on the island. The population size was difficult to determine, but probably is well below 100. The species appears to be distributed over much of the non-forest areas of Lanai, especially in the central plateau (Figure 4).

At least in August and September 1976, in the early morning hours, as many as five Barn Owls were noted perched on the telephone wire along Kaunapali Highway, from Lanai City to the Airport Road. Owls were also seen on Manele Road but most were believed to be Pueo. Individual Barn Owls were also noticed during the day on August 25, 1975 at the abandoned plant nursery in Maunalei Gulch and on April 6, 1976 adjacent the pineapple fields at Koala Gulch. The bird at Koala Gulch had been flushed from the slopes by a raging brush fire. Dead individuals were recovered on October 1, 1975 at the plant nursery in Maunalei Gulch (and could have been the owl seen there in August) and on April 7, 1976 at Kanepuu. Whether competition between the Barn Owl and native Pueo exist is not known.

European Skylark (*Alauda arvensis arvensis*). The Skylark was first introduced into Hawaii in 1865 from England and again in 1870 from New Zealand (where it was released from England in 1864), with releases eventually made on all the main inhabited islands (Berger 1972, Caum 1933). Today on Lanai the species is rather common in the open grasslands above the coastal kiawe-koa haole forest, in the horse pasture at Malau-Puu Mahana, on the fairways of the city golf course, and in the grassy borders of the runway at Lanai Airport (Figure 10). Individuals were also regularly noted in pineapple fields being tilled or cleared for planting.

Mockingbird (*Mimus polyglottos*). The Mockingbird is found from southern Canada, throughout the United States, to southern Mexico, being introduced on Oahu and Maui in the early 1930s. Subsequently the species established itself on Kauai, Molokai, Lanai, and Hawaii (Berger 1972). Today on Lanai the bird is widely distributed, especially in the drier areas (Figure 9). Mockingbirds were rather common in the coastal kiawe-koa haole and the pineapple fields containing fruits. Birds were also noted in Lanai City

and to some extent in the mountain forest.

Two Mockingbirds were observed on October 5, 1976, taking water baths by hopping in and out of the wet leaves of a Malabar chestnut tree (Pachira aquatica) in Lanai City, during a light drizzle. On several occasions a bird was seen feeding on the fruits of the night cestrum (Cestrum nocturnum), located behind the Hawaiian Fruit Flies Laboratory field station.

Information on the breeding biology of the Mockingbird on Lanai is scarce. Singing seemed to be greater from January through July, decreasing and ceasing the remainder of the year. Many old nests were found in the coastal areas, but few actual nesting observations were made. In Maunalei Gulch two active nests were located in kiawe trees on July 17, 1976. One nest contained a complete clutch of three eggs and the other two eggs (possibly an incomplete clutch). As early as May 18, 1976, however, Dr. Andrew J. Berger heard a fledgling calling in a kiawe thicket near Naha.

Japanese White-eye (Zosterops japonica japonica). This White-eye was brought in from Japan, starting in 1929, to Oahu, and since has spread unaided to the other Hawaiian Islands. Today on Lanai the bird is probably the most abundant of the avian species, commonly found from sea level to Lanaihale (Figure 9). White-eyes were numerous in the coastal kiawe forest, the dry native forest at Kanepuu, the pineapple fields and especially those tracts that contained fruits, urban Lanai City, and the wet mountain forest. A few individuals were also noted in the more open grasslands.

White-eyes on Lanai were seen feeding on a wide variety of food, including fruits from fig trees (Ficus species), pineapple, papaya (Carica papaya), mountain apple (Eugenia malaccensis), night cestrum, pilo (Coprosma species); nectar or insects from blossoms of ohia-lehua and silky oak (Grevillea robusta); and inch worms (Lepidoptera, Geometridae).

Singing was heard throughout the year, although there was a noticeable increase in quantity and intensity of songs from late March through May, corresponding with the breeding season. A nest, with a clutch of three eggs, was located in a kiawe tree in Maunalei Gulch on March 24, 1976. On the same day three fledglings were seen at the abandoned plant nursery. The young had no eye rings, short tails, and were begging with calls and wing flappings to be fed. They were able, however, to fly upwards. The last sighting of a fledgling being fed by an adult was at Manele Harbor on May 12, 1976. However, an immature with no eye ring was noted with a flock of adult White-eyes on September 2, 1975 at the head of Kaiholena Gulch; the bird flew well and had a rather fully developed tail. The nesting season of the Japanese White-eye on Lanai, based on the limited data, seems roughly similar to the February-to-July period found for the population studied in urban Oahu (the University of Hawaii Manoa campus) by Guest (1973).

Common Myna (*Acridotheres tristis tristis*). This species is native to the Indian region, reportedly brought to Hawaii by William Hillebrand in 1865 to combat the army worm in the pasturelands (Berger 1972, Caum 1933). Today it is commonly found in the lowlands of the main islands. On Lanai the bird was common near centers of human activity, such as in Lanai City, at the City Refuse Site, at Manele-Hulopoe Bays, at beach homes and fishing sites along the coast, and in pineapple fields being tilled and cleared (Figure 10). In the fields large numbers were observed following the plowing machines, probably feeding on the exposed insects. Mynas were also noted in more rustic areas, in the eucalyptus groves at Kanepuu, at Keanapapa Point, and the Kaunolu-Kaholo Pali area. Birds were found only at the borders and rarely farther in the mountain forest.

Mynas were observed feeding on fruits of fig trees, octopus trees (Brassaia actinophylla), pineapple, and seeds from ripe bitter melon (Momordica charantia).

Nesting for the Common Myna on Oahu occurs from February through August (Berger 1972). On Lanai nesting was observed under a roof of a house in Lanai City. Nest building started by April 1, 1976, young had hatched and were being fed by the adults by mid-May, and activity ceased at the site by May 26. Fledglings and immatures were seen in Lanai City throughout June, 1976 and as late as July 7, 1976.

Spotted Munia (Lonchura punctulata). The native range of this bird includes Ceylon, India, Nepal, Burma, Malaysia, the Indochina region, and the Philippines. It was brought into Hawaii about 1865, and now is common on all the main islands (Berger 1972). On Lanai the species is distributed over the entire island (Figure 9). Spotted Munias were abundant on the fairways of the golf course and in the upper mountain forest from August through November, but decreasing or absent in the other months of the year, possibly indicating seasonal abundances and movements. Fair numbers were also noted at Kanepuu, in Maunalei Gulch, and along the coastline from Maunalei to Naha, and in pineapple fields left fallow for a few years. Individuals or small groups were occasionally seen or heard in the other sections of the island.

Spotted Munias were observed feeding on grass seeds of foxtail (Setaria species), feathery pennisetum (Pennisetum setosum), dallis (Paspalum dilatatum), vasey (Paspalum urvillei), guinea (Panicum maximum), and fingergrass (Chloris species).

On Lanai fledglings or immatures without spotted breasts were noticed in April, May, August, and October, 1976. Nesting in Hawaii is believed

to occur year-round (Berger 1972); the species probably breeds almost the entire year on Lanai.

House Sparrow (*Passer domesticus*). A native of Europe and northern Asia, nine House Sparrows were initially brought from New Zealand in 1871 and released in Honolulu (Berger 1972, Caum 1933). It is unclear whether there were further importations, but the bird is now fairly common in Hawaii. On Lanai the species was found near centers of human activity, abundant in Lanai City, in fair numbers at Manele-Hulopoe Bays, and at least present along the coast at popular fishing sites and beach homes (Figure 10).

House Sparrows are omnivorous, feeding on garbage, fruits from fig trees, grass seeds of *Amaranthus* species, and picking at fallen, dried kiawe pods.

In Hawaii the House Sparrow is undoubtedly multibrood and possibly a year-round nester (Berger 1972). Under the roof of a house in Lanai City, House Sparrows were noticed nesting in April, May, June, and October, 1976. Fledglings were seen in May, 1976 and August, 1975.

Red-crested Cardinal (*Paroaria coronata*). This species is found throughout much of South America, and initially was released only on Oahu, starting in 1928. Today it is found on the other islands (Berger 1972). Individual Red-crested Cardinals were seen at or near Naha on May 26, July 16, and October 29, 1976, and near the restrooms in the Manele-Hulopoe Bay area on May 12 and July 14, 1976 (Figure 9). The cardinals were adults, seemingly alone; in the July sighting at Naha the bird sang a brief song. These observations may indicate the incipient establishment of the Red-crested Cardinal on Lanai from the population on a neighboring island.

Cardinal (Cardinalis cardinalis). This bird is widely distributed in North America and south to British Honduras. Between 1929 and 1931 several releases were made on Oahu, Hawaii, and Kauai (Berger 1972, Caum 1933). Presently the species is found on all the main islands, common in some lowland areas and apparently moving upward into the mountains in recent years. On Lanai Cardinals were found from sea level to Lanaihale, fairly common to abundant in the coastal forest from Kaiolohia Bay to Naha, the Manele-Hulopoe area, Maunalei Gulch, Kanepuu, Lanai City, the pineapple fields containing fruits, and the mountain forest (Figure 9). On the mountain birds were heard and seen in valleys and ridges covered with native and introduced vegetation.

Cardinals were observed feeding on fruits of the mountain apple, guava, and pineapple, and seeds from dried kiawe pods.

Singing for this species on Lanai began in December, continued at a high level from January through June, and decreased in July, probably corresponding to the breeding season. An active nest, with a clutch of three eggs, was found in a kiawe tree in Maunalei Gulch on July 17, 1976. However, in 1976 fledglings and immatures were noted from April through July; in 1975 fledglings were seen in early August. On September 5, 1976 a male was noticed at Manele with its tail feathers undergoing molt.

House Finch (Carpodacus mexicanus frontalis). The House Finch is found throughout western North America and was brought to Hawaii prior to 1870, probably from San Francisco. It possibly escaped from captivity and now is established on all the main islands (Berger 1972, Caum 1933). House Finches were distributed over much of Lanai, but were found in appreciable numbers only at Lanai Airport, Kanepuu, and in the pineapple fields with fruits (Figure 9). Fair numbers of birds were also regularly

noted in the mountain forest, including the summit area. Probably because of the availability of food and water, good-sized flocks were occasionally seen in other sections of the island. In October, 1976 over 100 House Finches were observed in the vicinity of the Fish and Game water trough located in the grassland habitat along Keomuku Highway. This was the only time during this study that that many birds were in the area.

This species is primarily a seed or fruit eater, feeding on fruits from fig trees, papaya, gunpowder trees (Trema orientalis), and mango (Mangifera indica); seeds from horseweed (Erigiron species), ironwood, crimson sage (Salvia species), and dallis grass; and to some extent inch worms.

On Lanai increased singing was noticed from January through June. Courtship behavior, indicating breeding activities, were observed as early as February 3, 1976 and as late as July 10, 1976. No active nests were found during the study, but fledglings or juveniles were noted in late April, May, and June, 1976. Individuals in molt were seen on August 31, October 15, and November 10, 1975, and on September 8, 1976. The seasonal cycle of the House Finch on Lanai is similar to that found for the species on the University of Hawaii Manoa campus in urban Honolulu (Hirai 1975). On the campus singing was greater from January through June, nesting occurred from mid-February through August, and molting took place from late July-August until the end of October.

A good deal has been written concerning the coloration of male House Finches in Hawaii and the United States mainland (Hirai 1975). On Lanai males exhibited the range from dull yellow to bright red. Males in various sections of Lanai were seen and their hues noted and placed into one of three categories--yellow, orange, or red. There were a total of 138 sightings,

with 43 (31.2%) red-colored males, 44 (31.9%) orange-colored, and 51 (36.9%) yellow-colored.

The Lanai Bird Surveys

There were two types of detailed bird surveys--by driving and walking. The jeep-driven surveys were done along seven paved or unpaved roads, with stops at one or two mile intervals for 10-minute periods. During the stops, birds were counted if they were seen or heard calling or singing in the area. These road-type censuses were conducted generally in the morning hours but at times latter in the day; weather conditions were usually good. The purpose of these surveys was to provide a general picture of the avian composition in the different sections of Lanai. Table 3 gives information on the areas surveyed; Figure 11 shows their locations.

A strip-census method was used in the walking surveys. Transects were at least one mile long and birds noted along the routes were counted. Surveys were spaced throughout the day but usually done in the morning hours. Weather conditions generally were good. There were 13 transects, and, unlike the area covered in a jeep-driven survey, a walked-transect habitat was generally homologous in terms of vegetation. These surveys gave a more detailed view of bird diversity in the different habitats found on Lanai. Table 5 gives information on the areas surveyed and Figure 12 shows their locations on the island.

The purpose of this study was not to obtain absolute avian abundances but relative abundances and comparative indices. In this study the index used to measure bird species diversity was the Shannon-Weaver index

$$H' = - \sum_{i=1}^s p_i \log p_i \text{ (corrected for bias)}$$

where s is the number of species and p_i is the proportion of the total number of individuals consisting of the i th species (Poole 1974). This measure of

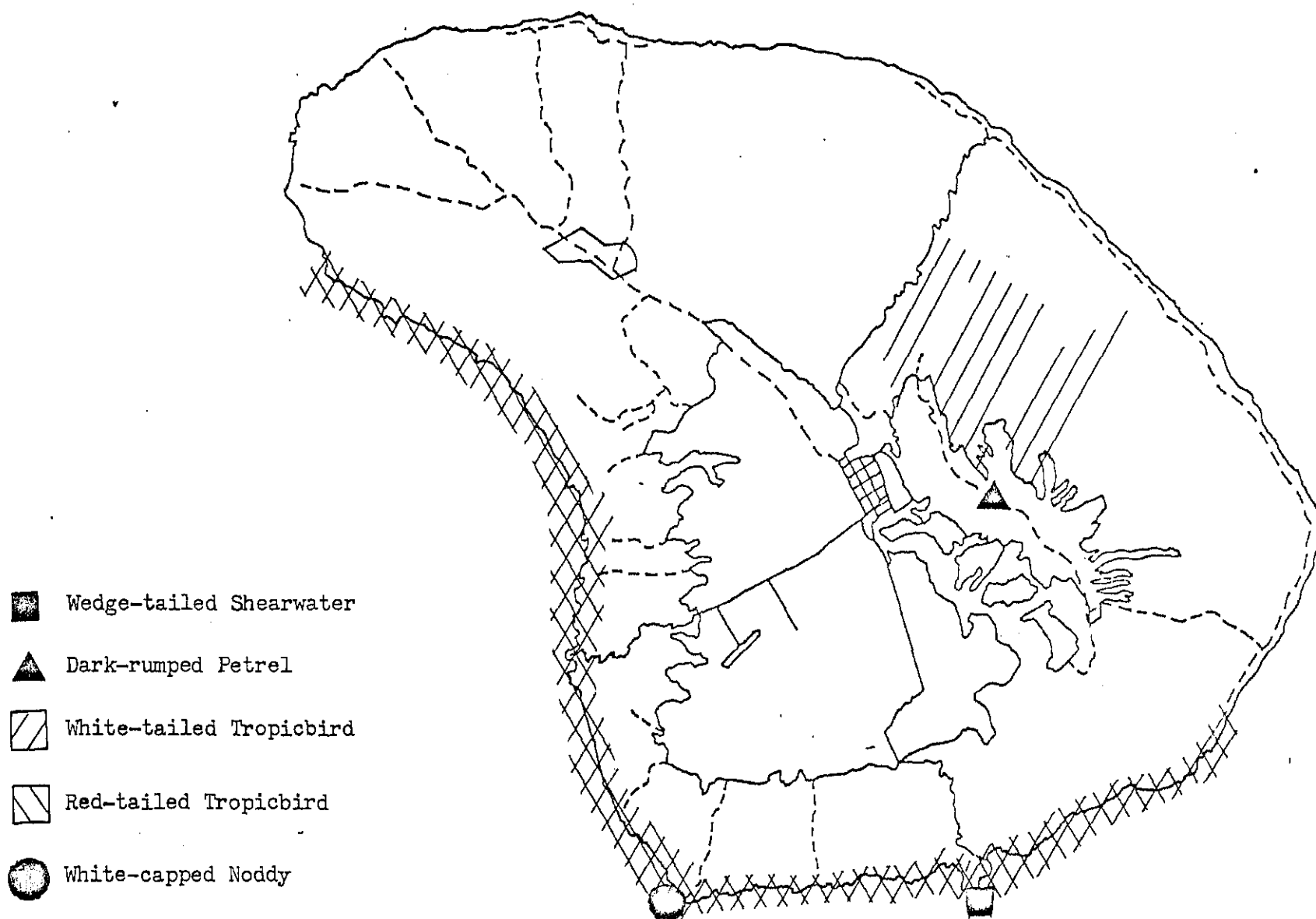


Figure 2. Distribution of the seabirds on Lanai.

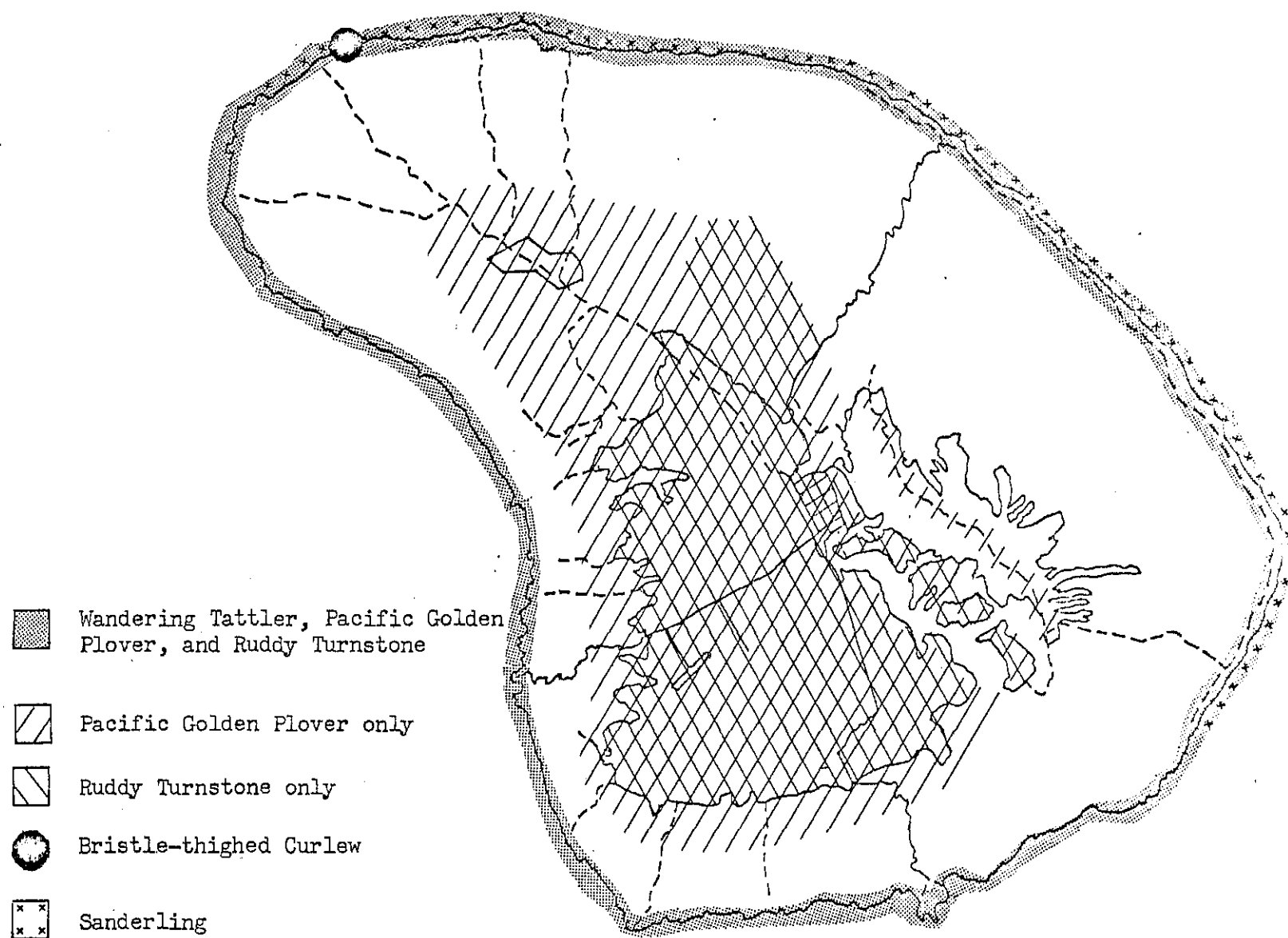


Figure 3. Distribution of the migratory shorebirds on Lanai.

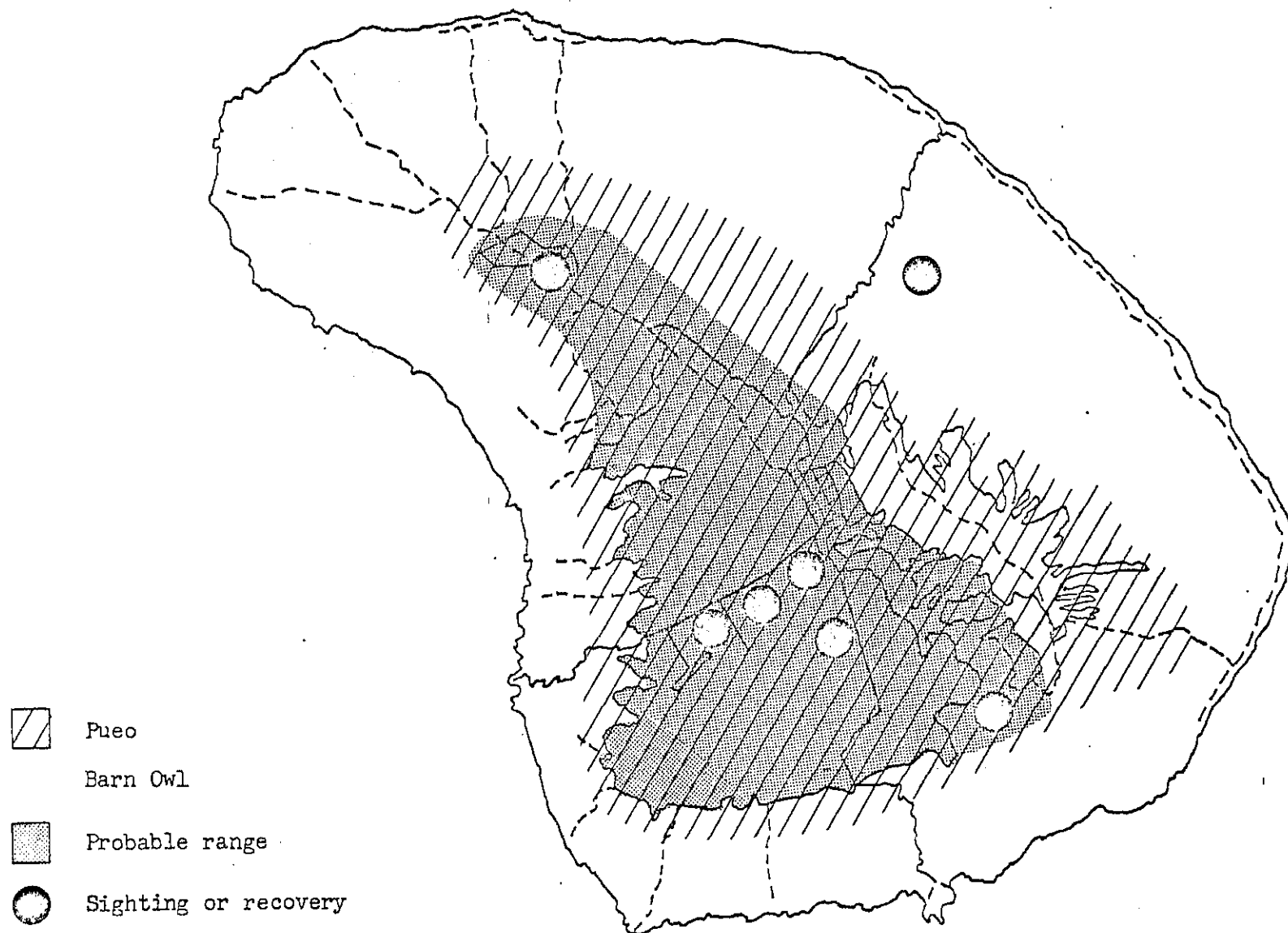


Figure 4. Distribution of the owls on Lanai.

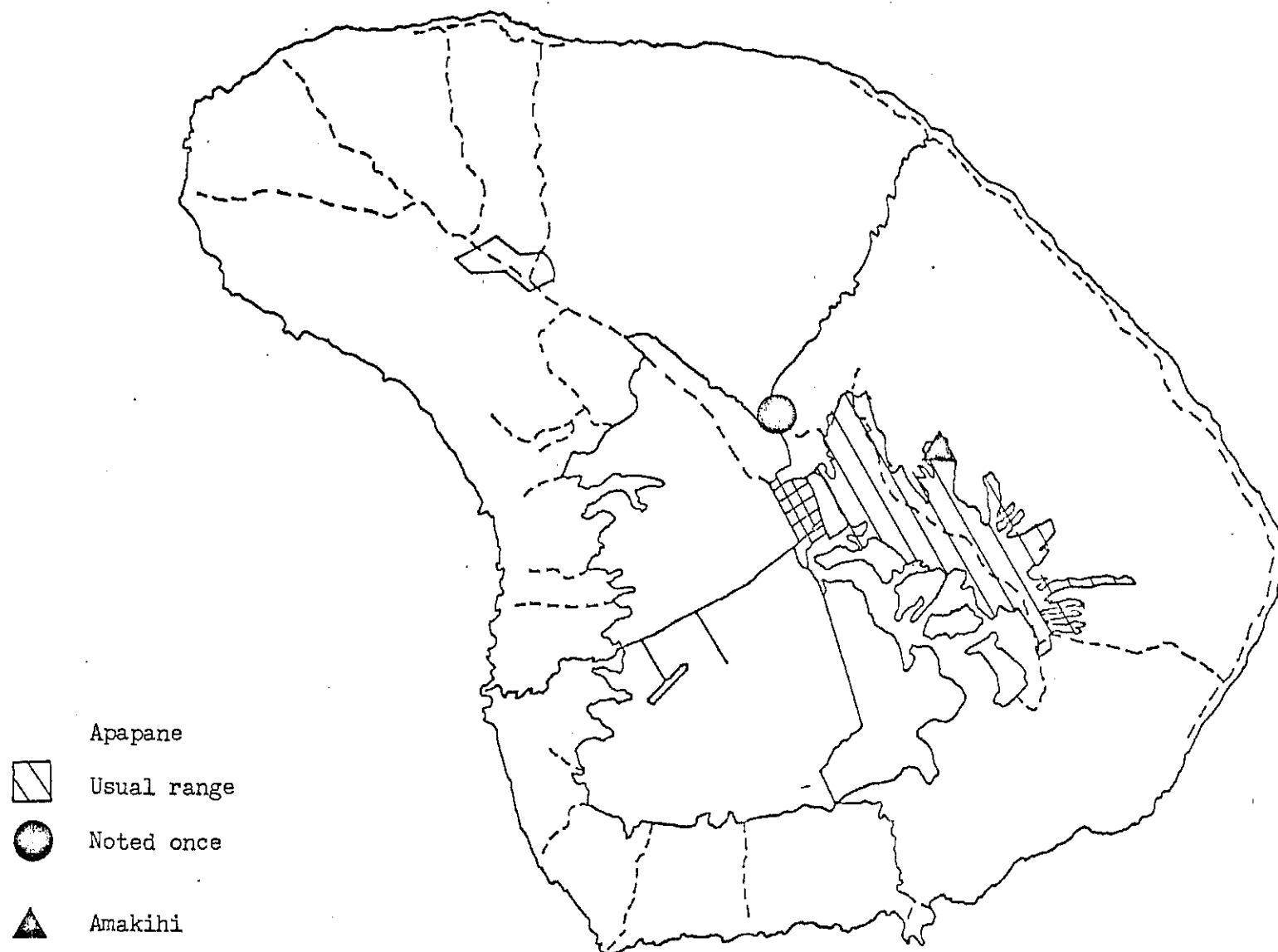


Figure 5. Distribution of the Apapane and Amakihi on Lanai.

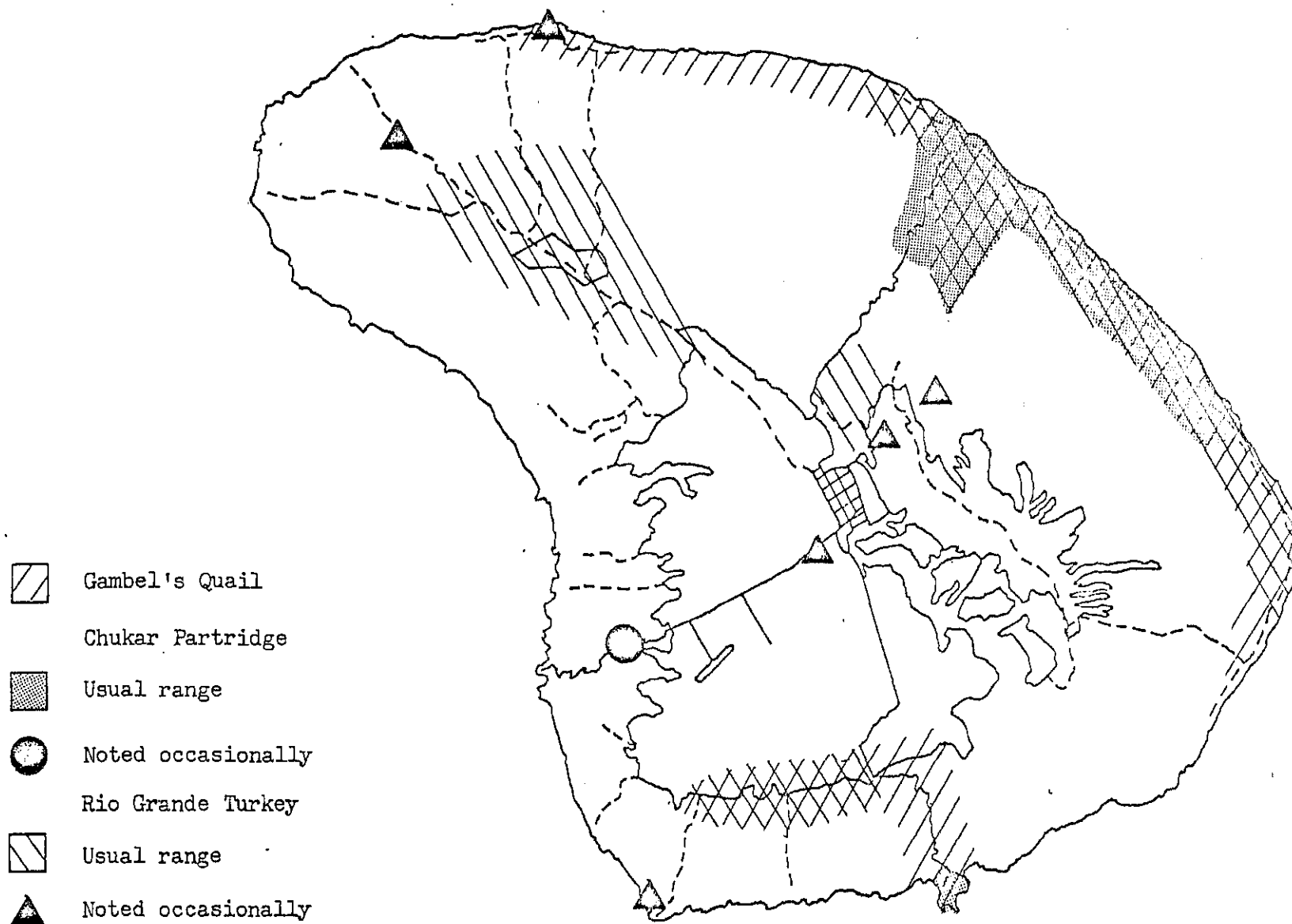


Figure 6. Distribution of the Gambel's Quail, Chukar Partridge, and Rio Grande Turkey on Lanai.

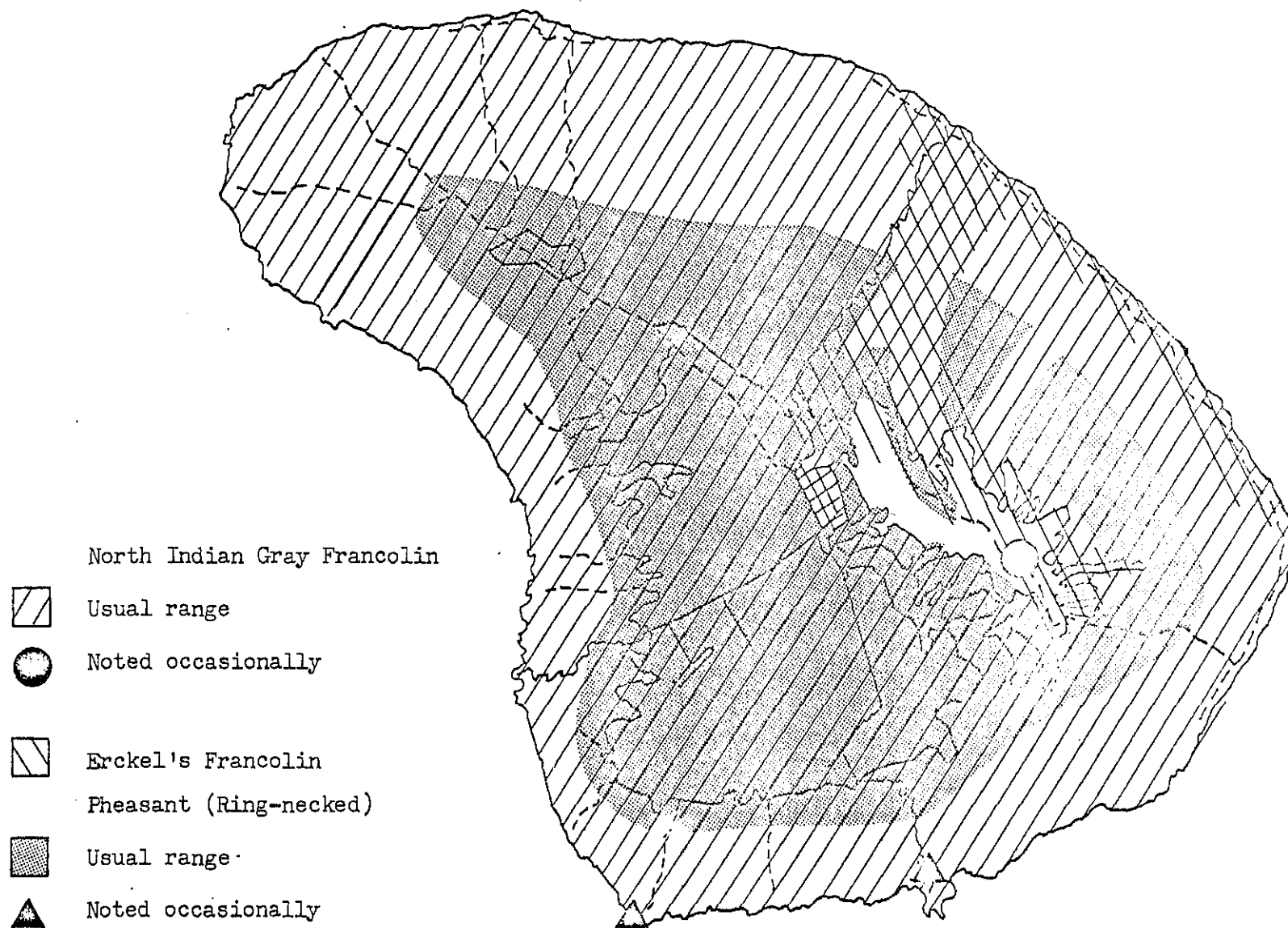


Figure 7. Distribution of the Francolins and Pheasant on Lanai.

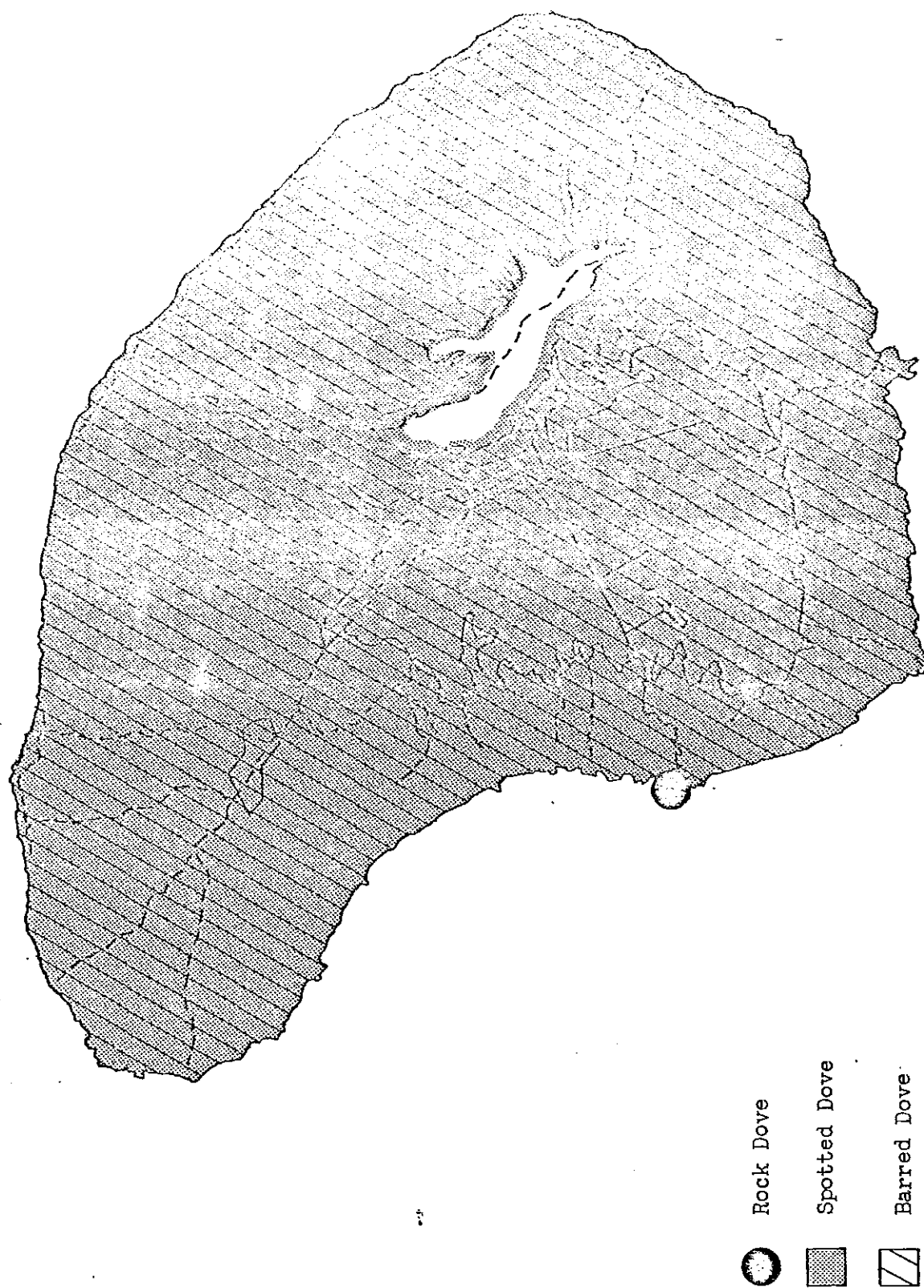


Figure 8. Distribution of the doves on Lanai.

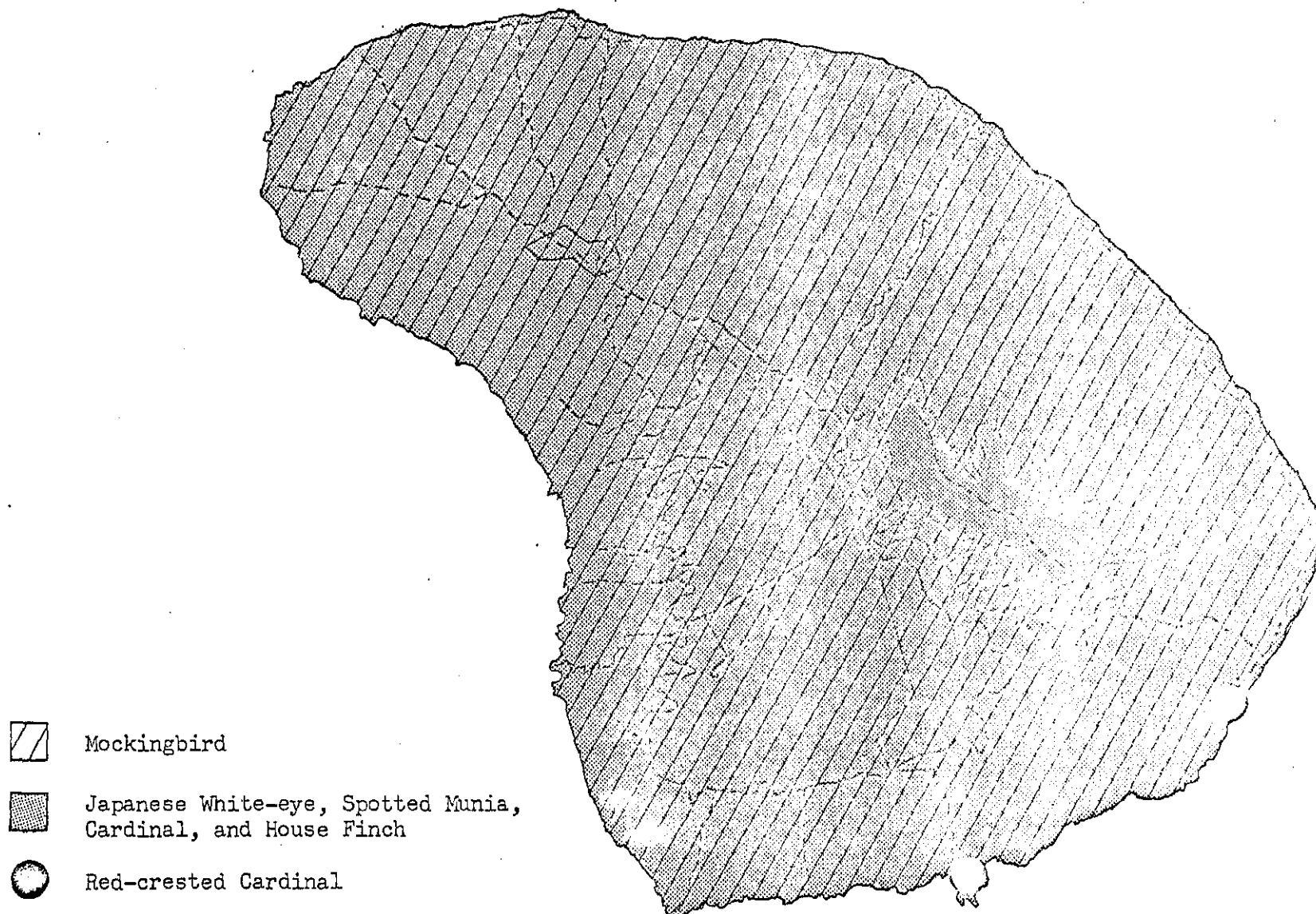


Figure 9. Distribution of the Mockingbird, Japanese White-eye, Spotted Munia, Cardinals, and House Finch on Lanai.

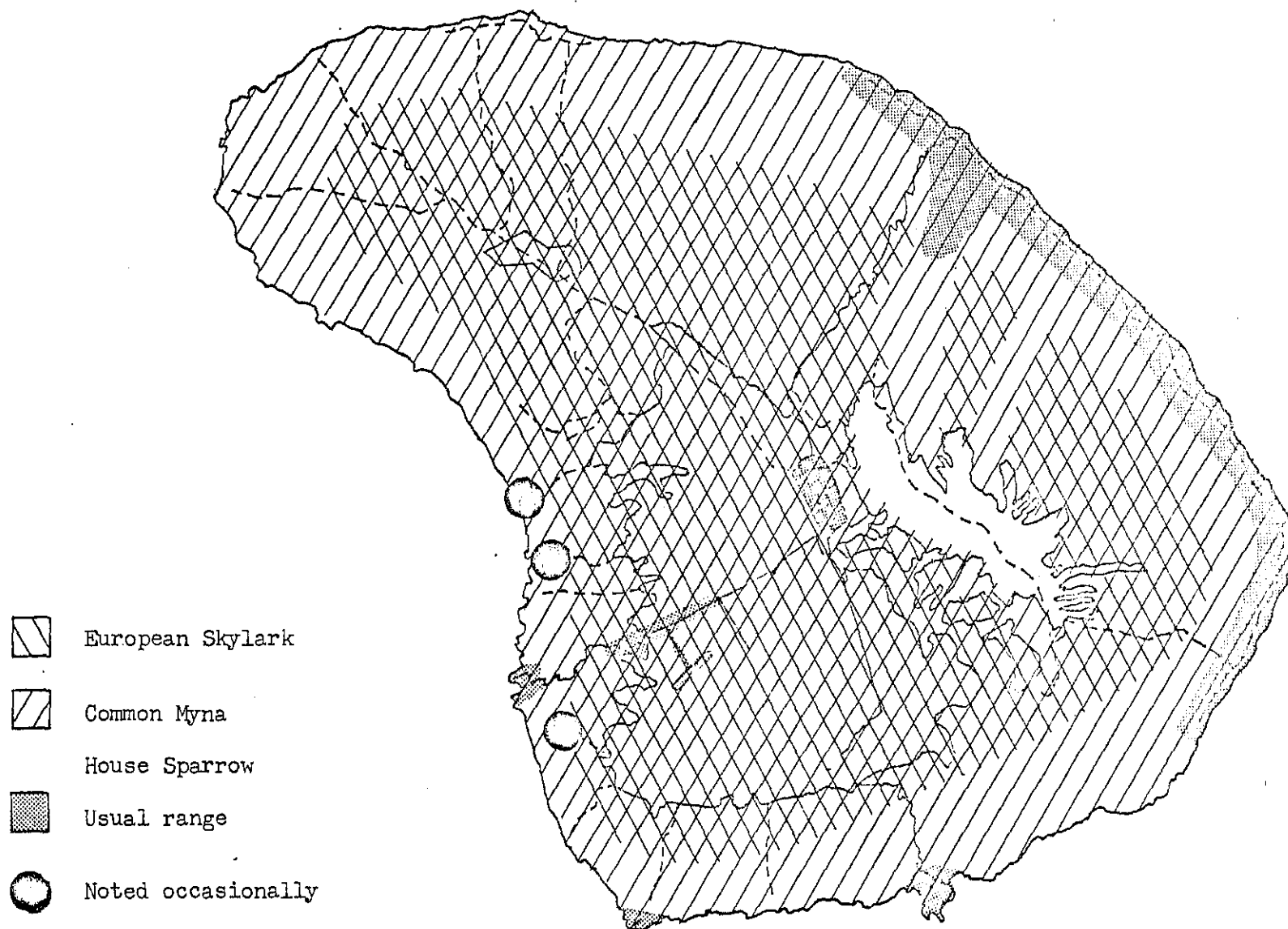


Figure 10. Distribution of the European Skylark, Common Myna, and House Sparrow on Lanai.

diversity takes into account not only the number of species but also the relative abundances of each species. Using this index, a community is considered more diverse if the species are equally common than if some species are very common and others rare. Statistically, values were compared by one-way analysis of variance and the Student-Newman-Keuls test, with a 0.05 significance level (Sokal and Rohlf 1969).

Results of the surveys by driving and walking are given in Tables 4 and 6, respectively. The birds are listed as they appeared in the species-accounts sections. The " \bar{X} /stop or mile" represents the mean number of individuals, or abundance, of a species per survey for every stop or mile covered. The relative abundances are also given (under "prop. total", based on the abundances in the tables. Because the abundance values for the birds in an area is calculated by combining the findings of all the surveys done there, the result is a composite picture of the bird community. Thus H' and number of species when derived from this information could be considered composite values. Mean values per census for H' , total number of individuals observed, and number of species were also calculated and are in the tables. For a surveyed area there was no significant difference between the composite H' and the mean H' (t-test, $P > 0.05$). "S.D." represents standard deviation and is given for the composite H' , and mean H' , number of birds observed, and number of species.

More diagrammatic presentations of the results are in Figures 11 and 12. Only those species with relative abundances equal to or greater than 0.10 are plotted separately; species with relative abundances less than 0.10 are grouped together in the final, solid bar of the graph. The composite H' is used in the graph.

Table 3. Areas on Lanai Surveyed by Jeep.

Area Surveyed	Distance Covered (miles)	Intervals Between Stops (miles)	No. of Stops	No. of Times Surveyed	Comments
Manele Road	8	1	9	5	From the city limits to the end of the paved road at Manele-Hulopoe. Five stops were in pineapple fields and four stops in koa haole-kiawe.
Kaumalapau Highway	6	1	7	5	From 0.5 mile from Lanai City to Kaumalapau Harbor. Three stops were in pineapple fields and four in koa haole.
Polihua Road	11	1	12	5	From one mile from Lanai City to Polihua Beach. Four stops were in pineapple fields, three in the native dry forest at Kanepuu, and five in wind-eroded sections-koa haole-kiawe-grass.
Keomuku Highway	8	1	9	5	From Koele to the end of the paved road at Maunalei. Four stops were in pineapple fields-pastureland and five stops in grass-kiawe-koa haole.
The "Naha Run"	13	1	14	7	From 0.5 mile from the end of the paved Keomuku Highway to Naha. Stops were in the coastal kiawe strip.
Munro Trail	10	1	11	7	From the cemetery to the pineapple fields on the Flats. Four stops were in native vegetation and five in mainly introduced flora.
Pineapple-field edge	34	2	18	4	From 0.5 mile from the west end of Lanai City to one mile from the east end of the city. Drove along the border of the pineapple fields and grass-koa haole.

Table 4. Result of the Jeep-driven Surveys.

Bird Species	Manele Road \bar{X} /stop prop. total	Kaunalapau Hwy. \bar{X} /stop prop. total	Polihua Road \bar{X} /stop prop. total	Keomuku Hwy. \bar{X} /stop prop. total	"Naha Run" \bar{X} /stop prop. total	Munro Trail \bar{X} /stop prop. total	Field edge \bar{X} /stop prop. total
1 W. Tropicbird		0.03 .002		0.10 .007		0.19 .019	0.01 .001
2 R. Tropicbird		0.11 .009					
3 Plover	0.07 .007	1.77 .142	0.93 .108	0.74 .051	0.49 .031		0.47 .050
4 Turnstone		0.11 .009			0.06 .004		
5 Curlew			0.02 .002				
6 Tattler					0.07 .004		
7 Sanderling			0.02 .002		0.11 .007		
8 Wcap. Noddy							
9 Pueo	0.03 .003		0.02 .002	0.02 .001		0.01 .001	
10 Apapane						0.05 .005	
11 Amakihi							
12 G. Quail	0.02 .002				0.17 .011		
13 G. Partridge							
14 G. Francolin	0.95 .090	0.51 .041	0.46 .053	0.32 .022	1.25 .079	0.03 .003	0.56 .060
15 E. Francolin				0.11 .008		0.05 .005	
16 Pheasant	0.25 .024	0.06 .005	0.13 .015	0.42 .029		0.05 .005	0.62 .066
17 Turkey					0.04 .002		
18 Rock Dove		0.34 .027				0.06 .006	
19 Spotted Dove	0.43 .041	0.23 .018	0.42 .049	0.77 .054	0.17 .011	0.09 .009	0.35 .037
20 Barred Dove	1.67 .159	0.86 .069	0.60 .069	3.13 .218	3.22 .204	0.09 .009	0.69 .074
21 Barn Owl							
22 Skylark		0.09 .007	0.54 .062	1.32 .092		0.06 .006	0.10 .011
23 Mockingbird	0.41 .039	0.09 .007	0.27 .031	0.20 .014	0.63 .040	0.25 .026	0.45 .048
24 White-eye	1.16 .110	1.77 .142	0.90 .104	1.15 .080	4.34 .275	5.11 .520	2.11 .225
25 Myna	3.22 .307	3.66 .295	3.06 .354	1.77 .123	1.23 .078	0.92 .094	2.85 .304
26 Spotted Munia	0.24 .023	0.20 .016	0.05 .006	0.73 .051	0.32 .020	0.93 .095	0.10 .011
27 House Sparrow	1.00 .095	0.94 .076		0.13 .009	1.13 .072		
28 Rcr. Cardinal					0.01 .001		
29 Cardinal	0.36 .034	0.05 .052	0.56 .065	0.36 .025	2.40 .152	0.57 .058	0.77 .082
30 House Finch	0.69 .066	1.00 .080	0.66 .076	3.11 .216	0.14 .009	1.36 .138	0.29 .031
Composite $\bar{H} \pm$ S.D. no. sp.	1.51 \pm .26 14	1.57 \pm .27 17	1.31 \pm .32 15	1.74 \pm .22 16	1.60 \pm .23 17	0.85 \pm .40 16	1.43 \pm .29 13
Mean $\bar{H} \pm$ S.D. no. birds no. sp.	1.33 \pm .39 10.5 \pm 4.8 10.4 \pm 2.0	1.49 \pm .25 12.4 \pm 2.7 10.4 \pm 1.8	1.20 \pm .33 8.6 \pm 5.0 11 \pm 1.9	1.48 \pm .24 14.4 \pm 10.3 11.8 \pm 1.9	1.62 \pm .12 15.8 \pm 2.5 12.4 \pm 1.0	1.01 \pm .08 9.8 \pm 2.9 9.6 \pm 2.0	1.38 \pm .07 9.2 \pm 1.9 11.0 \pm 1.6

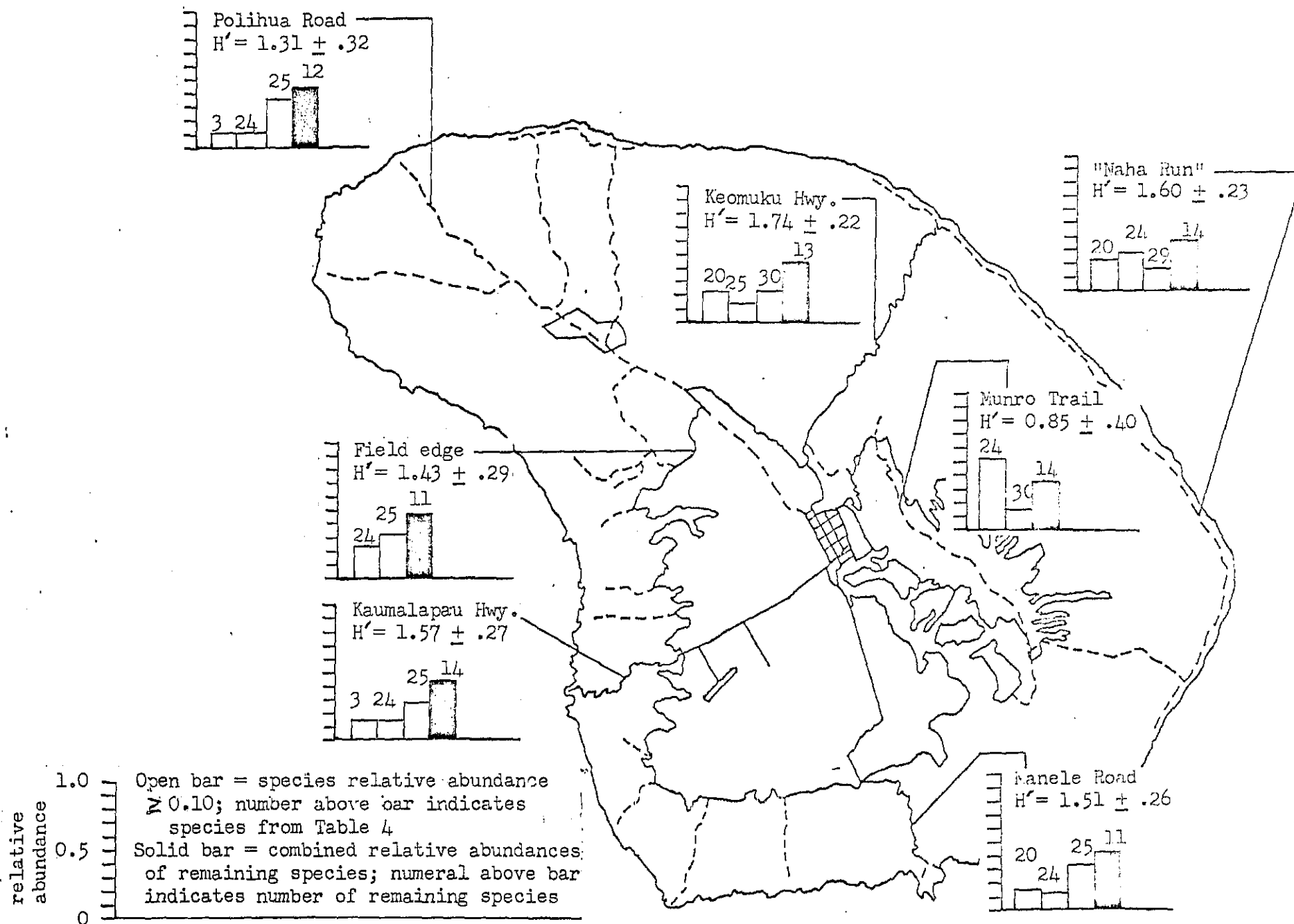


Table 5. Areas on Lanai Surveyed by Walking.

Area Surveyed	Distance Covered (miles)	No. of Times Surveyed	Comments
Lanai City	2	6	Urban area, including a nine-hole golf course.
Fields plowed under	1	4	Different pineapple fields were surveyed but all were plowed under.
Fields without fruits	1	5	Different pineapple fields were surveyed but all contained no fruits.
Fields with fruits	1 or 2	6	Different pineapple fields were surveyed but all contained fruits.
Manele-Hulopoe Bays	2	5	Small-boat harbor and beach-recreation centers, covered by kiawe.
Maunalei Gulch	2	6	From the gate across the road to the abandoned plant nursery; area covered by kiawe, but containing a number of water sources.
Kaiolohia Bay	1	5	From the end of the paved Keomuku Highway to Kaiolohia Bay, walking in the coastal kiawe strip and by a number of beach homes.
Kanepuu	2	6	Native dry forest section of Lanai.
Puualalea	3	6	Area covered by introduced molassas grass and guava, bordering the mountain forest.
Hulopoe Gulch	1	7	Mountain forest habitat, dominated by introduced eucalyptus, paperbark, and ironwood trees.
Kapohaku Gulch	1	4	Area mainly introduced flora but with native vegetation toward the summit; walked on a ridge in the gulch.
Puu Nene-Puu Alii	2	5	Mountain forest habitat, dominated by native uluhe, ohia-lehua, and koa
Hauola Trail North	2	5	Mountain forest habitat, dominated by native uluhe fern and ohia-lehua.

Table 6. Results of the Walked Surveys.

Bird Species	Lanai City		Fields plowed		Fields w/o fruits		Fields w/ fruits		Manele-Hulopoe Bays		Maunalei Gulch		Kaiolohia Bay	
	\bar{X} /mile	prop. total	\bar{X} /mile	prop. total	\bar{X} /mile	prop. total	\bar{X} /mile	prop. total	\bar{X} /mile	prop. total	\bar{X} /mile	prop. total	\bar{X} /mile	prop. total
1 W. Tropicbird	0.1	.001									1.5	.009		
2 R. Tropicbird														
3 Plover	12.9	.062	4.5	.064	0.2	.015	0.1	.001	0.5	.007			0.4	.003
4 Turnstone														
5 Curlew														
6 Tattler														
7 Sanderling														
8 Wcap. Noddy									0.3	.004				
9 Pueo	0.1	.001					0.2	.002						
10 Apapane														
11 Amakihi														
12 G. Quail									2.4	.033	3.4	.021	0.6	.004
13 C. Partridge									0.1	.001	1.3	.008		
14 G. Francolin	0.2	.001	1.2	.018	0.6	.045	4.7	.046	5.9	.081	11.2	.070	14.8	.099
15 E. Francolin											6.2	.038	0.4	.003
16 Pheasant			1.2	.018	3.4	.254	2.9	.029						
17 Turkey											1.7	.010	1.0	.007
18 Rock Dove	0.3	.002												
19 Spotted Dove	2.4	.012	3.0	.043			1.5	.015	0.1	.001	6.8	.042	5.0	.033
20 Barred Dove	12.1	.058	5.5	.078	0.6	.045	16.7	.164	6.4	.088	49.9	.312	66.2	.442
21 Barn Owl											0.1	.001		
22 Skylark	2.3	.011	1.2	.018	0.2	.015	0.2	.002						
23 Mockingbird	1.4	.007	0.2	.004			3.0	.029	2.9	.040	5.6	.035	5.2	.035
24 White-eye	10.8	.052	0.2	.004	3.2	.239	31.8	.312	4.2	.056	41.5	.259	12.8	.086
25 Myna	44.2	.213	46.5	.660	4.8	.358	5.6	.055	13.3	.182	7.1	.044	7.2	.048
26 Spotted Munia	50.3	.243	6.2	.089			11.2	.110	0.7	.010	4.4	.028	1.6	.011
27 House Sparrow	57.8	.278							22.1	.303	4.4	.028	22.6	.151
28 Rwr. Cardinal									0.1	.001				
29 Cardinal	5.4	.026	0.2	.004			3.8	.037	11.9	.163	12.9	.081	11.6	.078
30 House Finch	7.0	.034	0.2	.004	0.4	.030	20.5	.201	2.1	.029	2.3	.014	0.2	.001
Composite $H' \pm$ S.D.	1.86 \pm .06		1.21 \pm .15		1.30 \pm .22		1.88 \pm .08		1.92 \pm .10		2.04 \pm .09		1.76 \pm .09	
no. sp.	15		12		8		13		15		16		14	
Mean $H' \pm$ S.D.	1.68 \pm .17		0.82 \pm .50		0.90 \pm .30		1.69 \pm .10		1.75 \pm .16		1.86 \pm .26		1.65 \pm .16	
no. birds	207.5 \pm 51.1		70.5 \pm 59.9		13.4 \pm 7.6		101.8 \pm 42.0		73.0 \pm 11.4		159.1 \pm 45.1		149.6 \pm 48.9	
no. sp.	11.5 \pm 1.5		5.5 \pm 3.4		3.6 \pm 1.5		9.3 \pm 2.0		10.2 \pm 0.8		12.8 \pm 1.6		9.6 \pm 1.1	

Table 6. Results of the Walked Surveys (continued).

Bird Species	Kaneupuu		Puuaalealea		Hulopoe Gulch		Kapohaku Gulch		Puu Nene-Puu Alii		Hauola Trail North	
	\bar{X} /mile	prop. total	\bar{X} /mile	prop. total	\bar{X} /mile	prop. total	\bar{X} /mile	prop. total	\bar{X} /mile	prop. total	\bar{X} /mile	prop. total
1 W. Tropicbird			0.1	.002							2.0	.072
2 R. Tropicbird												
3 Plover	0.3	.004	0.2	.004								
4 Turnstone												
5 Curlew												
6 Tattler												
7 Sanderling												
8 Wcap. Noddy												
9 Pueo			0.1	.002					0.1	.002		
10 Apapane					0.7	.014	0.2	.003	2.1	.047	1.9	.069
11 Amakihi											0.2	.007
12 G. Quail												
13 C. Partridge												
14 G. Francolin	0.8	.010					0.8	.009	0.2	.004		
15 E. Francolin			0.4	.010							0.3	.011
16 Pheasant	1.0	.012	0.6	.016			2.8	.032	0.1	.002		
17 Turkey	0.1	.001	0.5	.013	1.3	.026						
18 Rock Dove												
19 Spotted Dove	0.6	.007	0.6	.014	1.0	.020	1.8	.021	0.1	.002	0.1	.004
20 Barred Dove	10.9	.129	0.7	.018					0.3	.007	0.1	.004
21 Barn Owl												
22 Skylark	1.9	.023	2.8	.071								
23 Mockingbird	1.3	.016	0.8	.020	0.1	.003	1.8	.021	0.4	.009		
24 White-eye	35.5	.421	10.3	.261	30.4	.612	56.8	.668	29.9	.669	14.8	.534
25 Myna	5.0	.059	2.3	.059	0.1	.003	2.8	.032			0.2	.007
26 Spotted Munia	5.8	.069	7.1	.181					3.6	.080	4.5	.162
27 House Sparrow												
28 Rcr. Cardinal												
29 Cardinal	5.1	.060	2.2	.057	6.6	.132	8.2	.097	4.0	.090	1.8	.065
30 House Finch	16.0	.190	10.8	.274	9.4	.190	10.0	.118	3.9	.087	1.8	.065
Composite $\bar{H}' \pm$ S.D.	1.71 \pm .11		1.77 \pm .15		1.08 \pm .14		1.14 \pm .13		1.07 \pm .18		1.34 \pm .21	
no. sp.	13		15		8		9		11		11	
Mean $\bar{H}' \pm$ S.D.	1.34 \pm .27		1.60 \pm .16		0.87 \pm .24		1.09 \pm .14		0.96 \pm .28		1.09 \pm .25	
no. birds	83.9 \pm 30.1		39.3 \pm 19.0		49.7 \pm 13.2		84.8 \pm 33.1		44.7 \pm 9.3		27.7 \pm 5.8	
no. sp.	9.0 \pm 1.4		10.3 \pm 2.0		4.6 \pm 0.8		6.2 \pm 1.0		5.8 \pm 1.5		6.4 \pm 0.6	

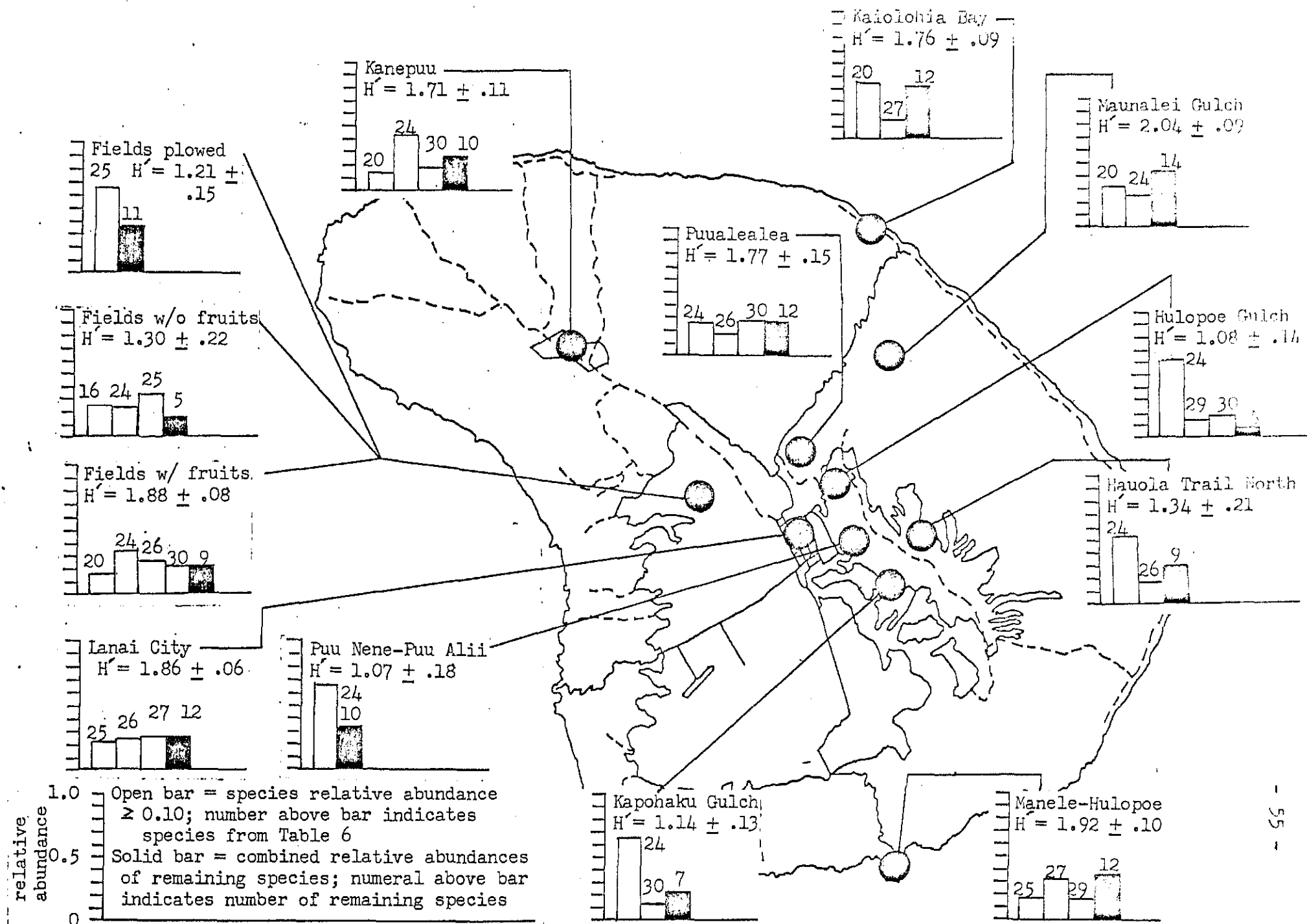


Figure 12. Results of the Walked Surveys.

Table 7. Multiple comparisons by the Student-Newman-Keuls test of the \bar{H}' means from the driven and walked surveys.

Jeep-driven surveys¹

area	Munro Trail	Polihua Road	Manele Road	Field edge	Keomuku Highway	Kaumalapau Highway	"Naha Run"
mean \bar{H}'	1.01	1.20	1.33	1.38	1.48	1.49	1.62

Walked surveys²

area	Fields plowed	Hulopoe Gulch	Fields w/o fruits	Puu Nene- Puu Alii	Hauola Trail North	Kapohaku Gulch	Kanepuu	Puualealea	Kaiolohia Bay	Lanai City	Fields w/ fruits	Manele- Hulopoe Bays	Maunalei Gulch
mean \bar{H}'	0.82	0.87	0.90	0.96	1.09	1.09	1.34	1.60	1.65	1.68	1.69	1.75	1.86

Surveyed areas arranged in order of increasing magnitude of the \bar{H}' s. Significant level = 0.05. Those areas underlined have \bar{H}' values that are not significantly different.

¹ \bar{H}' s initially tested by one-way anova ($F=4.96$, with 6/31 d.f., $P=0.005-0.001$)

² \bar{H}' s initially tested by one-way anova ($F=13.81$, with 12/57 d.f., $P<0.001$)

The diversity values (H') from the jeep-driven surveys were statistically compared (Table 7). Generally diversity in the seven sections of Lanai was found to be similar, probably the result of the surveyed areas containing comparable habitats (pineapple fields, grassland, kiawe-koa haole). The most significantly different areas were the mountain forest and the coastal kiawe belt from Maunalei to Naha. The "Naha Run" had high bird species diversity, the result of the ample food supply found in the thick kiawe forest and along the coastline, the good water sources (possibly the only ones on that side of the island), and beach homes and fishing sites, which open the region to such man-adapted species as the House Sparrow. Rather surprisingly, the mountain forest showed such low diversity, possibly the consequence of the past destruction of the forest and its small size and "poor" quality today. The loss of a number of the island native forest birds, the low numbers of the remaining Apapane and Amakihi, and the paucity of introduced species adapted to the forest probably contributed to the low H' value.

Similar conclusions were drawn from the analysis of the walked surveys. Diversity was high in the coastal kiawe areas of Lanai and low on the mountain. Rather high H' values were found in those coastal areas subjected to "improvements" by man--Maunalei Gulch with piped water sources, Manele-Hulopoe Bays and its small-boat harbor and recreational beach, and Kaiolohia Bay with numerous beach homes along the shore. The transects on the mountain, on the other hand, had H' values in the low to medium range. Two transects were in habitats considered native, a third in an introduced forest, and the fourth in a mixed, though largely introduced, area. Bird species diversity in the four mountain areas did not differ significantly from each other, although Apapane were more evident in the native than the introduced portions.

Other areas of human activities, such as Lanai City and the pineapple fields with fruits, had high diversity values. Low values were found for fields being plowed under and without fruits, but those tracts could be considered in man-produced "successional stages" toward a "climax" field with fruits. The dry native forest at Kanepuu showed medium range diversity, with its birdlife similar to that found in many other sections of Lanai. Except for the Pueo and an occasional migratory Golden Plover, no native birds were found there. Puualealea had a rather high diversity value. The area is located at the borders of the mountain forest, gulches, pastureland, and grassland and probably attracts many bird species from the other habitats, especially when the guava shrubs are fruiting.

The survey results (Tables 4 and 6 and Figures 11 and 12) reveal that the Japanese White-eye is the most common bird species over the entire island. The bird was present in relative abundances ≥ 0.10 in 15 of the 20 surveys, being the most common in eight of the censused areas, with abundances over 0.50 and even 0.60 in the mountain transects. Even in those surveyed areas where it was not plotted separately on the graphs in Figures 11 and 12, White-eyes were present in relative abundances between 0.05 and 0.10, except for the plowed pineapple fields where birds were rarely noted (relative abundance < 0.01). Spotted Munias, Cardinals, and House Finches were also distributed over Lanai but usually not in such abundance as White-eyes.

The Barred Dove was the only game bird found frequently in relative abundances over 0.05. In seven areas Barred Doves were noted in abundances over 0.10, and in six other surveys in numbers over 0.05, with relative abundances as high as 0.30 and 0.40 in Maunalei Gulch and Kaiolohia Bay, respectively. Doves were rarely noted, however, in the mountain forest.

Of the larger-sized game birds, only the North Indian Gray Francolin approached high relative abundances. The species was never common enough to be plotted separately on the graphs (in Figures 11 and 12) but was found in abundances between 0.05 and 0.10 in seven areas, usually in the coastal or lowland regions of Lanai.

It is interesting to note from the relative-abundance information how closely associated the House Sparrow is with man. The bird was absent from the surveys done in the mountain forest, Kanepuu, Puualealea, and even the pineapple fields, but found in rather high relative abundances, around 0.30, in urban Lanai City and much-used Manele-Hulopoe Bays. Mynas were also associated with man, but not to the extent of House Sparrows.

The native birds were rarely common, usually in relative abundances < 0.05 and often below 0.01. Only the Pacific Golden Plover was found in any frequency, over 0.05 in six areas and as high as 0.14 and 0.11 along Kaumalapau Highway and Polihua Road, respectively. Apapane were distributed over much of the mountain forest but were rare in the portions of the forest dominated by introduced flora (relative abundances ≤ 0.01) and somewhat more common in the native areas (relative abundances around 0.05). It would seem that the future well-being of the Apapane on Lanai is dependent on the maintenance and improvement of the native mountain forest.

The Treated Areas on Lanai

Three areas--the native dry forest at Kanepuu, the mountain forest, and the coastal kiawe strip from Maunalei to Naha--were aeri ally treated in a Lanai fruit fly eradication program in mid-April, 1976. Bird surveys were done in the areas before and after the treatments to assess possible affects on the bird populations. Kanepuu was censused by walked surveys and the other two areas by jeep-driven surveys. Different sections of the mountain forest

were censused during this study, but for the purpose of evaluating the spraying effects only the surveys done along the length of the Munro Trail were utilized. It was felt that these surveys would best reflect any changes in the avian populations found over much of the mountain habitat.

The results of the surveys done in the treated areas are given in Table 8. For a given area the findings of the surveys conducted before or after the treatment were combined to give a composite picture of the bird community. It was felt that comparisons of such composite pictures would better reveal any immediate and long-termed affects of the eradication program on the avian species than comparing just the surveys done immediately before and after the sprayings. Before-and-after composite H's were then calculated and statistically compared by a t-test method (in Poole 1974). In none of the areas did diversity significantly decrease after the treatments, probably meaning that the eradication program had little, if any, deleterious consequences on the avian populations in the treated areas. Whether repeated treatments of the areas would adversely affect the bird communities is of course unknown.

The Rodent-trapping Program on Lanai

Land mammals have had and to an extent still has an effect on the natural history of Lanai. Because of the introductions of a number of big game species, the island is now considered one of the better hunting areas in the State. Axis deer (Axis axis) were found in good numbers throughout the drier, coastal lands, along the edges of the pineapple fields, the mountain forest, and even on the outskirts of Lanai City. Because this mammal seems to be penetrating the mountain habitat, it constitutes presently the major threat to the maintenance of the island native forest. Small numbers of pronghorn antelopes (Antilocapra americana) were noted in the horse pasture

Table 8. Results of Surveys done in the Treated Areas.

Bird Species	Kanepuu		Munro Trail		"Naha Run"	
	before \bar{X} /mile total	after prop. \bar{X} /mile total	before \bar{X} /stop total	after prop. \bar{X} /stop total	before \bar{X} /stop total	after prop. \bar{X} /stop total
1 W. Tropicbird			0.16 .016	0.24 .025		
2 R. Tropicbird	0.7 .011					
3 Plover					0.50 .039	0.48 .028
4 Turnstone					0.07 .005	0.05 .003
5 Curlew						
6 Tattler					0.05 .003	0.09 .005
7 Sanderling					0.07 .005	0.17 .010
8 Wcap. Noddy						
9 Pueo			0.02 .002			
10 Apapane				0.12 .012		
11 Amakihi						
12 G. Quail					0.21 .014	0.12 .007
13 C. Partridge						
14 G. Francolin		1.7 .016	0.05 .005		1.11 .075	1.43 .083
15 E. Francolin			0.09 .009			
16 Pheasant	0.3 .005	1.7 .016	0.05 .005	0.06 .006		
17 Turkey	0.2 .003				0.02 .001	0.07 .004
18 Rock Dove				0.15 .015		
19 Spotted Dove		1.2 .011	0.14 .014	0.03 .003	0.13 .009	0.24 .014
20 Barred Dove	3.8 .062	18.0 .169	0.14 .014	0.03 .003	1.98 .134	4.88 .284
21 Barn Owl						
22 Sklark	1.3 .022	2.5 .024	0.05 .005	0.09 .009		
23 Mockingbird	0.5 .008	1.2 .011	0.37 .037	0.09 .009	0.63 .043	0.64 .037
24 White-eye	32.8 .535	38.2 .358	4.75 .478	5.58 .572	4.04 .274	4.74 .276
25 Myna	5.5 .090	4.5 .042	0.80 .080	1.09 .112	1.41 .096	0.98 .057
26 Spotted Munia	6.2 .101	5.5 .052	1.02 .103	0.82 .084	0.38 .026	0.24 .014
27 House Sparrow					1.54 .104	0.59 .034
28 Rcr. Cardinal						0.02 .001
29 Cardinal	4.5 .073	5.7 .053	0.50 .050	0.67 .069	2.45 .166	2.33 .136
30 House Finch	5.5 .090	26.5 .249	1.80 .181	0.79 .081	0.18 .012	0.09 .005
Composite $\bar{H} \pm$ S.D.	1.50 \pm .14	1.73 \pm .09	1.04 \pm .36	0.91 \pm .40	1.66 \pm .22	1.53 \pm .25
no. sp.	11	11	14	13	16	17
Number of surveys	3	3	4	3	4	3
one-sided t-test	t= 1.36, d.f.= 112, P= 0.1-0.05		t= 0.24, d.f.= 20, P= 0.45-0.40		t= 0.39, d.f.= 32, P= 0.35-0.30	

at Puu Mahana; the species is now on the non-hunting list because of recent declines. Feral goats (Capra hircus) were seen in some numbers on the steep cliff edges and deep canyons of gulches located on the northeastern side of Lanai. Mouflon sheep (Ovis musimon) inhabited the rugged kiawe and grassland coast of the southern and northwestern portions of the island. Of the smaller mammals, feral cats (Felis catus) were noted in many parts of the island, although it seems not as numerous as reported in the early 1900s. Unlike most of the other main islands, pigs (Sus scrofa) and small Indian mongooses (Herpestes auropunctatus) are not found on Lanai. Fuller accounts on the mammals are given by Armstrong (1973), Kramer et al. (1973), and Tomich (1969).

Rodents are generally found throughout Hawaii (Armstrong 1973, Tomich 1969). Polynesian rats (Rattus exulans) are believed to have accompanied the first Polynesians to Hawaii, with roof rats (Rattus rattus), Norway rats (Rattus norvegicus), and house mice (Mus musculus) being introduced with the coming of western man.

In 1976 a limited rodent-trapping program was conducted on Lanai to furnish information on the distribution and diet of these mammals. Snap-type traps were used, baited with coconut. Trap lines were placed in 11 locations on the island--five in the mountain forest, two each in the pineapple fields and the coastal areas, and one each in the dry native forest at Kanepuu and urban Lanai City (Figure 13, Table 9). Trap lines were maintained for two or three nights, depending on trapping success and time limitations during the study; snap traps were removed and not replaced when they contained rodents. The trapping done in February 1976 was along the entire 10-mile long Munro Trail, with traps set at 0.5-mile intervals. The other trappings were along one-mile transects, with traps set every 0.1 mile.

A total of 21 rodents were caught, 18 roof rats, 1 polynesian rat, and 2 house mice. No Norway rats were taken. The roof rats were obtained on the mountain, in Lanai City, and in the pineapple fields; the polynesian rat was trapped along the Munro Trail about 0.5 mile eastward of Hauola Trail East; and one mouse was caught along the beach coast near Halulu and the other in the pineapple field (Table 9).

From the limited trapping data, observations, and accounts by Tomich (1969), tentative conclusions can be made about rodent distribution on Lanai. Roof rats are probably abundant and widely distributed on the mountain, especially the wetter portions. Good numbers were indicated in the summit area. Roof rats are also probably found in at least fair numbers in pineapple fields containing fruits or left fallow for a few years and in Lanai City and other centers of human activity (such as the harbors). Several color types are known in Hawaii. On Lanai, 16 of the 18 roof rats trapped were classified as original wild types, with white bellies and gray-brown backs; the remaining two rats were mutant phenotypes, with gray bellies and gray-brown backs. The two mutants were obtained on the mountain, in areas where original wild types were found.

No Norway rats were taken but this rodent probably is associated with man in such places as Lanai City and the harbors. The polynesian rat is probably most abundant in abandoned pineapple fields, adjacent wooded or grassy gulches, and rare or absent in the lowlands, grasslands, and forested areas. The one individual obtained during this study was trapped in a transitional zone between the wetter mountain forest and the drier, open range. Mice are distributed over much of Lanai, only absent in the wet mountain forest. Long-time island residents have commented on occasional population explosions of mice in the coastal and lowland areas.

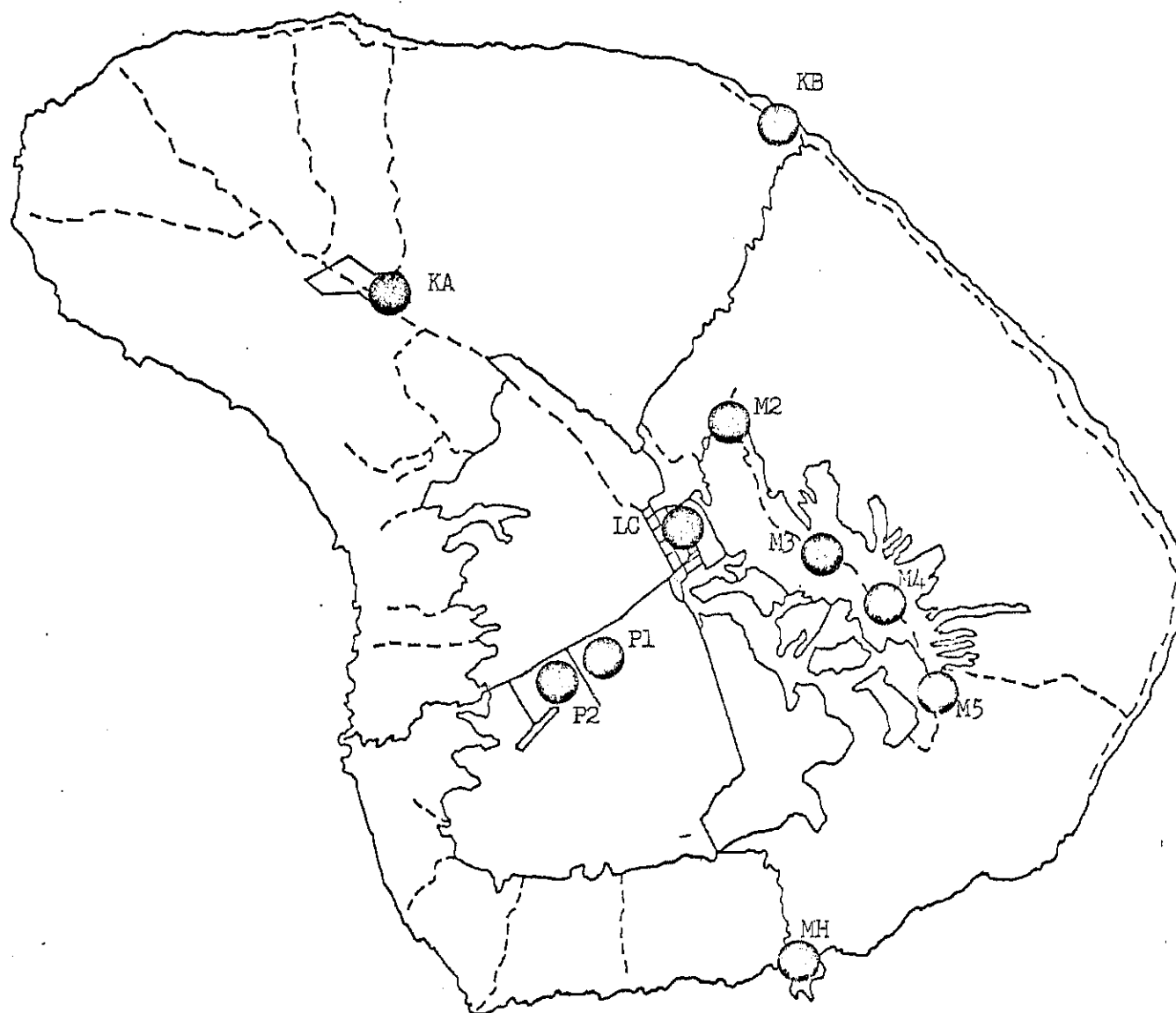


Figure 13. Rodent Trap Sites on Lanai. Trap site M1 is not shown but covers the length of the Munro Trail.

Table 9. The Rodent-trapping Program on Lanai.

Trap Site	Date began Date ended	No. Traps Set	Intervals between Traps (mile)	Rodents caught	Comments
M1	02-02-76 02-05-76	20	0.5	5 roof rats 1 polynesian rat	Mountain forest habitat, with introduced and native flora. Three roof rats were trapped near Koloiki Road and the remaining rodents were caught from Lanaihale to Haalelepaakai Puhielelu Ridge. Traps set along the Munro Trail.
M2	09-22-76 09-25-76	11	0.1	3 roof rats	Mountain forest habitat, mainly introduced flora. Traps set along the Munro Trail, near Koloiki Rd.
M3	09-22-76 09-25-76	11	0.1	2 roof rats	Mountain forest habitat, mainly native flora. Traps along the Munro Trail, in the Dark-rumped Petrel area.
M4	09-13-76 09-16-76	11	0.1	5 roof rats	Mountain forest habitat, mainly native flora. Traps along the Munro Trail, from Hauola Trail North to Hauola Trail East, including the summit.
M5	09-13-76 09-16-76	11	0.1	none	Dry mountain forest habitat and grassland. Traps along Munro Trail, in the area of Awehi Road.
KB	11-01-76 11-03-76	11	0.1	1 house mouse	Coastal kiawe belt from the end of the paved Keomuku Hwy. to Kaiolohia Bay.
MH	11-03-76 11-05-76	11	0.1	none	Coastal kiawe area between Manele and Hulopoe Bays..
KA	11-01-76 11-03-76	11	0.1	none	Dry native forest habitat at Kanepuu.
LC	11-03-76 11-05-76	11	0.1	1 roof rat	Urban Lanai City.
P1	11-05-76 11-07-76	11	0.1	none	Pineapple fields w/o fruits.
P2	11-05-76 11-07-76	11	0.1	2 roof rats 1 house mouse	Pineapple fields w/ fruits

Stomach contents from 17 roof rats and one Polynesian rat were examined. Most of the food was unrecognizable. No animal matter was discernible, with guava the only identifiable plant food. However, mice, and probably rats, feed on ripe pineapple fruits. Holes in fruits were often seen and on one occasion a mouse was seen feeding on the interior through a hole in the side of a pineapple. Also, under a native Clermontia plant (Clermontia species), located near the summit, piles of partially eaten buds were discovered, probably gathered and eaten by roof rats.

Conclusions

From August 1975 through the first weeks of November 1976 a field study of the birds on Lanai, Hawaii was done to provide information on avian distribution, relative abundance, and possible environmental affects caused by the United States Department of Agriculture Hawaiian Fruit Flies Laboratory Lanai eradication program. A limited rodent-trapping program was also conducted in 1976.

About 30 avian species nest on Lanai, with five more regular migrants to the island. Of the eight native nesting birds five were seabirds. There were fair numbers of White- and Red-tailed Tropicbirds and small colonies of Wedge-tailed Shearwaters, Dark-rumped Petrels, and White-capped Noddies. The Short-eared Owl, or Pueo, could be termed common on the island. Apapane were found in the mountain forest, in introduced and native vegetation, probably with a population size in the very low hundreds. Amakihi were noted only once and the population on Lanai may be on the verge of extinction. The Dark-rumped Petrel was rediscovered during this study, probably nesting in the mountain forest, but other native birds formerly found on the island are undoubtedly extinct.

Introduced birds are the most commonly seen species on Lanai and today the island is considered one of the better bird-hunting zones in the State. Many of the birds were intentionally brought in but a number of species probably became established on the island unaided by man. The Japanese White-eye is undoubtedly the most abundant bird on Lanai, found in good numbers from sea level to Lanaihale. The Barred Dove is probably the most common of the game birds; of the larger-sized game birds, however, the North Indian Gray Francolin is the widest distributed and most abundant.

The Shannon-Weaver index

$$H' = - \sum_{i=1}^S p_i \log p_i \text{ (corrected for bias)}$$

was used to measure bird species diversity in seven areas surveyed by driving and 13 transects censused by walking. Results indicated high diversity in the coastal kiawe areas, Lanai City, and pineapple fields with fruits, and low diversity in the mountain forest and fields being plowed or without fruits. Transects located on the mountain, in introduced or native forest, did not have significantly different diversities from each other, possibly the consequence of the past destruction of the forest and many of the native bird species.

Three areas--the dry native forest at Kanepuu, the mountain forest, and the coastal belt of kiawe from Maunalei to Naha--were aerially treated in mid-April 1976, in a preliminary test to eliminate the Oriental fruit fly. The results of survey work done before and after the treatments indicate no significant affect on the bird populations in the areas by just one such eradication test.

The limited rodent trapping program on Lanai suggests that the roof rat is found in numbers in Lanai City, the pineapple fields (especially those

tracts with fruits), and in the mountain forest to the very summit; the polynesian rat is at least present on Lanai; and the house mouse is probably widely distributed on the island, especially in the coastal and lowland areas but not in the mountain forest.

An examination of the stomach contents of 17 roof rats and one polynesian rat revealed no discernible animal matter and guava as the only identifiable plant food. Rodents also feed on ripe pineapple fruits, and on the mountain, on the buds of the native Clermontia.

Acknowledgements

This study was conducted under the direction of Andrew J. Berger on funds provided by the Hawaiian Fruit Flies Laboratory of the U.S. Department of Agriculture through the Department of Entomology of the University of Hawaii. Mahalo to so many people in Honolulu and on Lanai for their kindness and assistance during the period of this study. My appreciation to Dr. Roy Cunningham, Jo Cole, Terry Kahaleanu, and Dexter del Rosario of the Hawaiian Fruit Flies Laboratory, Donald Rietow and Duane Black of Koele/Lanai Company; William Kwon of the State Division of Fish and Game; and Phillip Schrader of Dole Company; to Bertwin Nakamura, Susan Takemoto, and Spencer Malecha. A special thanks to the Kim brothers--Ki Song, Ki Chun, and Ki Yong; Leighton M. Hirai; and my parents, Mr. and Mrs. Thompson Hirai. Most of all, to my wife, Kyong Nan, for her support and field assistance during our stay on Lanai.

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