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Breeding Ecology of Palila
and
'Amakihi Parasites

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42. A BREEDING ECOLOGY OF THE ENDANGERED PALILA (*PSITTIROSTRA BAILLEUI*) ON MAUNA KEA, HAWAI'I

43. A SURVEY SHOWING THE EFFECT OF ENVIRONMENT AND BEHAVIOR UPON PARASITE LEVELS IN THE HAWAI'I 'AMAKIHI (*LOXOPS VIRENS*) (AVES: DREPANIDIDAE)

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A SURVEY SHOWING THE EFFECT OF ENVIRONMENT AND BEHAVIOR UPON PARASITE LEVELS IN THE HAWAI'I 'AMAKIHI (*LOXOPS VIRENS*) (AVES: DREPANIDIDAE)

ABSTRACT

From 1972 through 1979 a field survey was conducted to determine what parasites were present in an 'Amakihi (*Loxops virens*) population from a dry forest on the island of Hawai'i. Fauna were collected from recently used nests and few avian parasites were found; most were nonparasitic arthropods associated with nests as saprophages, or as predators on other nest arthropods. Mites of the genus *Ptilonyssus* were found in the nasal cavity and seven other genera were identified from body washes. Avian pox lesions were found on five 'Amakihi, and in two instances the infections appeared severe enough to have caused death. Coccidia (*Isospora* sp.) were recorded from four birds, and all blood smears from 107 birds were negative for haematozoans.

Complete postmortems were carried out on 44 'Amakihi. Intestinal helminths were the most frequently encountered parasites, and their abundance varied significantly between host age classes. From 1972 through 1979 capillarids were present in nine of 20 postmortemed adults, but were not found in any juvenile birds. Four cases of cestode parasitism were all from adult specimens. Ecological factors are given which possibly explain the differing levels of parasite infection between young and adult birds.

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INTRODUCTION

Parasites and disease can act in diverse ways upon a group of organisms, and in many instances the effects are subtle and difficult to interpret because, among other factors, changing environmental conditions and diverse behavioral patterns of different host age classes have a profound influence upon parasite levels (Dogiel 1961; Bull 1964; Kennedy 1975; Holmes et al. 1977). Disease can be a primary factor of population regulation, although the overall importance is probably more closely related to its role in increasing the susceptibility of the host to other mortality factors (Bradley 1972; Esch 1977; Forrester et al. 1978). This view is often extended to predict that in times when food supplies are reduced, levels of parasite infection are greater (Esch et al. 1975). There are, however, few examples in which environmental productivity, information on host diet, and parasite levels have been monitored so as to document the interrelationship of the changing environment upon levels of parasites and diseases.

This present study was concerned with the effect of environmental and behavioral factors upon parasites and diseases in an endemic Hawai'i 'Amakihi (Loxops virens) population on Mauna Kea, Hawai'i. Although some attention has been given to the diseases of poultry and introduced birds in Hawai'i (Alicata 1969; Navvab Gojrati 1970; Lewin & Holmes 1971; Smith & Guest 1974), little work has been done on the native birds. Warner (1968) studied the presumed role that introduced avian malaria and pox played in the extinction of the Hawaiian avifauna, but no other information exists on levels of parasites in any native bird population. The questions to be answered in this study were: (1) what diseases and parasites were present in this bird population? and (2) what were possible explanations for different parasite levels between years and among different age groups? In this paper the parasitic fauna of 'Amakihi are described. It is also shown that parasite levels are not increased in years of low food resources, and different foraging strategies are correlated with differing levels of helminth infection.

MATERIALS AND METHODS

Study Area

This study was carried out on the island of Hawai'i, with the majority of work done on the southwestern slope of Mauna Kea; three intensive study sites were established at 1980, 2130, and 2290 m elevations (Fig. 1). The Mauna Kea study area is located in one of the last extensive dry-forest ecosystems in the Hawaiian archipelago, and is essentially a savanna, interrupted in places by bare lava, grassland, and scrub. The habitat is dominated by two tree species, māmane (Sophora chrysophylla (Salisb.) Seem.) and naio (Myoporum sandwicense Gray), and has a variety of shrub and ground cover plants (van Riper 1978). The main camp, at 2290 m elevation, was 6.6 km from the nearest paved road, and a 4-wheel drive vehicle was needed to reach it. There was no accessible housing or electricity and because of the remoteness, most bacterial and viral analyses were not feasible. The Mauna Loa study sites were all above 1500 m on the Strip Road of Hawaii Volcanoes National Park.

The Bird

The 'Amakihi is one of the most common birds on Mauna Kea and has been the subject of recent investigations concerning its breeding, ecology, and behavior (Baldwin 1953; Berger 1969; van Riper 1975a, 1975b, 1976a, 1977, 1978; Kamil 1978; Kamil & van Riper, in press). The bird is a small (approx. 15 g) passerine of the endemic honeycreeper family Drepanididae. Adult 'Amakihi utilize considerable nectar during the breeding season and through territoriality defend this resource; their diet also includes insects and various fruits (van Riper 1978). Nestlings and recently fledged young are fed regurgitated insects and nectar by parent birds; however, independent young subsist chiefly upon nectar (van Riper & Evenson, in prep.). Because of the 'Amakihi's abundance, its dietary requirements, and its sensitivity to levels of food availability, the species is ideal for study of the comparison of parasite levels in relation to changing behavioral and environmental conditions.

Collection Techniques

'Amakihi parasites were collected from 1972 through 1979 on Mauna Kea and during 1978-1979 on Mauna Loa. Nests from which young had recently fledged were placed in Berlese-Tullgren funnels for 48 to 60 hours, and the fauna collected in 70% ethanol with glycerine. From mist-netted 'Amakihi toe clips were made and thin blood smears taken; slides were fixed for 30 sec in absolute methyl alcohol then stained with Giemsa. Fecal material collected from live-caught birds was transported in saline water.

Dead 'Amakihi were either postmortemed immediately or preserved in 70% ethanol with glycerine. Ectoparasites were collected by shaking the bird in detergent and water for 2 min, removing the host, permitting the wash to stand for 1 hr, breaking the surface tension with 95% alcohol, then decanting; ectoparasites were preserved in 70% alcohol. All postmortemed 'Amakihi were necropsied according to the technique outlined by van Riper and van Riper (1980). Feet and facial lesions were excised, preserved in 10% formalin, and later examined for mites as well as avian pox inclusion bodies. Impression smears of organs were fixed in absolute methyl alcohol and stained with Giemsa. Intestinal coccidia were sporulated in 1% formalin. The location and numbers of all intestinal helminths were noted.

Cestodes were fixed in FAA and nematodes in alcohol; both were preserved in 70% ethanol with glycerine.

RESULTS

Nidicoles and Ectoparasites

Fauna from 46 'Amakihi nests were analyzed and few parasitic groups were found; most were associated with the nest as saprophages, or as predators on other nest arthropods. Only Ornithonyssus sylviarum (Parasitiformes: Macronyssidae) was parasitic to birds. There were, however, seven genera of parasitic Acarina collected from body washes, and nasal mites of the genus Ptilonyssus were found in two birds (Table 1). In one nasal flush the first nymphal instar of a scale insect (Coccidae: Homoptera) was found. It was no doubt an accidental visitor in the nares.

Avian Pox

Avian pox lesions were observed on only five of over 900 mist-netted 'Amakihi. The lesions of four birds were located on the face, while the other had swellings on the leg and toes. Histopathology of the lesions revealed inclusion bodies. Two of these birds apparently died of avian pox, because eyes and nares were completely covered with lesions. One of the birds was a female collected from the 2290 m study site on 27 March 1974. The bird was first observed in tall wet grass; its feathers were saturated and, as a result, it could not fly. The bird, collected from the ground by hand, had a prominent keel; it died shortly thereafter. Both opercula were occluded by scabs as was the left eye. Lesions extended into the oral cavity and the bird breathed with its beak open. This was during the height of the breeding season, yet no brood patch was evident and the gonads were regressed.

Blood Parasites

From live birds that were mist-netted, 131 peripheral blood smears from 107 individuals were taken. All were negative for haematozoans. Heart, liver, spleen, and lung impression smears were made on postmortemed birds and none contained blood parasites. It appears that haematozoa are absent from the high altitude 'Amakihi population on Mauna Kea.

Two cases of avian malaria developed in 'Amakihi that were taken to a lower elevation for behavioral studies. Three birds were removed from the 2290 m study area on Mauna Kea to Kamuela, Hawai'i, at approximately 760 m elevation on the southern slope of the Kohala Mountains, and were maintained in an indoor aviary. The first bird died after 18 days with no signs of malaria; the second died after 32 days; and the last died 45 days after exposure to mosquitoes at lower elevations. The last two that died had acute infections of *Plasmodium*, which had bizarre features in that the blood was obviously abnormal and contained numerous microcytes and other immature cells, which, in turn, exhibited unusually small and otherwise odd parasites. Laird (pers. comm.) found that the parasite resembled *Plasmodium elongatum*, but he believed the organism in question was a member of the "*Plasmodium relictum* complex."

Gastrointestinal Parasites

In December 1973 and January 1974 fecal samples were collected from 14 mist-netted 'Amakihi. While this material does not give an accurate picture of all the intestinal parasites present, the more prevalent species are detected. Nine of the birds showed no signs of being parasitized, three had capillarid eggs (one sample contained both capillarids and coccidia), while two had only coccidia.

During postmortem examinations a number of gastrointestinal parasites were found (Table 2). The helminth infection rate was 75% for all birds examined in 1972, 33% in 1973, and 44% in 1974. The most frequently encountered parasite was *Capillaria* sp., which was present in 33% of the examined birds. The infection rate of this parasite fell from 58% in 1972 to 33% in 1973, and was not detected in any of the 1974 birds.

Juvenile birds had a significantly lower infection level than did adults (Chi-squared = 7.77; degrees of freedom = 1; probability is less than 1%). Coccidia were found in four of the postmortemed 'Amakihi, but none were heavy infections. Sporulated oocysts, of the genus *Isospora*, ranged from 18 to 24 microns.

DISCUSSION

Malaria parasites are sometimes very localized (Garnham 1966), and this appears to be the case in Hawai'i. None of the 'Amakihi on the higher slopes of Mauna Kea, the Kohala Mountains, or Mauna Loa were found to harbor blood parasites. But the birds are susceptible as shown by the two individuals that contracted malaria when transferred to lower elevations. Warner (1968), after moving native birds to lower elevations on Kaua'i, also found that the birds became infected with malarial parasites. There are, however, native 'Amakihi populations that do survive at lower elevations. Individuals have been regularly observed in Mānoa Valley and Makiki Heights (O'ahu) below 200 m elevation, and on Hawai'i in the Kiholo and lower Hilina Pali areas. Berger (1972) found 'Amakihi at 76 m elevation in the Malamaki Forest Reserve on Hawai'i. Work is currently in progress to determine if the extant 'Amakihi populations that exist within vector range have developed resistance to the introduced malarial parasite in Hawai'i.

One disease which is present in the upper forests of Mauna Kea is avian pox. Descriptions of avian pox in endemic avifauna of Hawai'i are found in the early literature (Perkins 1893; Henshaw 1902; Munro 1944; Amadon 1950). More recently Warner (1968) appears to have shown the susceptibility of some native and introduced birds to this virus. The disease has probably been introduced by birds, such as the House Finch (Carpodacus mexicanus), which each year move to this high forest to breed (van Riper 1976b); I have found several House Finch with lesions on face and feet. Mosquitoes have been implicated as the primary mechanical carrier of pox infections, but the virus may also be spread directly by contact of susceptible birds with infected ones, by contact with contaminated objects, or by bird mites (Karstad 1971). The lack of mosquitoes in the higher forests of Mauna Kea may be why the incidence of avian pox (3%) recorded was so low. It would appear that in the absence of mosquitoes, avian pox is probably spread to the endemic birds of Mauna Kea either by direct contact with contaminated objects, or possibly by transovarial transmission (transmission from parent to offspring in the mite) of the virus by Ornithonyssus sylviarum.

The most frequently encountered 'Amakihi parasites were found in the gastrointestinal tract. Coccidia (Isospora sp.) were found in four birds, this being the first report in any native Hawaiian bird. Alicata (1969) reported coccidia in domestic chickens, Guest (1973) in Japanese White-eyes (Zosterops japonicus) from O'ahu, and Smith and Guest (1974) in 15.7% of all the introduced birds they examined in Honolulu. None of the 'Amakihi found in this study had heavy coccidia infections. Because coccidia are usually transmitted from one individual to another in food or water contaminated with feces (Todd & Hammond 1971), this parasite would probably not be found that frequently in wild-caught 'Amakihi.

The most abundant gastrointestinal parasites of the 'Amakihi were helminths. The overall helminth infection rate was positively correlated ($r = 0.425$) with the Mauna Kea rainfall pattern (Fig. 2). The amount of māmane flowering (therefore nectar production) was related to the rainfall pattern, in that greater flowering occurred in years of higher precipitation (van Riper 1975b). The parasitic helminth levels also increased in years of increased nectar (i.e., food) supplies (Fig. 2).

There are two possible explanations for these increased parasite loads in the 'Amakihi. The first is that with increased food resources, the birds are able to physically carry heavier parasite loads. If this is the case, it would suggest that the 'Amakihi host-parasite system is finely tuned and in dynamic equilibrium, being able to respond rapidly to changing environmental conditions. The second, and probably more likely, explanation is that in years of high rainfall there is a greater production of insects which act as intermediate hosts; and, because of the increased probability of encountering these intermediate hosts, parasite loading in the 'Amakihi increases. Both suggestions are only field hypotheses and need to be tested in a controlled laboratory situation.

Research on changing parasite fauna with age suggests that different age-groups carry heavier parasite loads because of differences in immunological response (Bull 1974), changes in structure (Kennedy 1975), behavior or diet (Dogiel 1961), and so also a change in the probability of infection. In the 'Amakihi a unique situation appears to exist in which young birds are behaviorally excluded from contact with intermediate parasite hosts, thereby preventing high levels of gastrointestinal helminth infections until later in life. This is brought about by the fact that breeding birds are highly territorial and exclude conspecifics from their territories (van Riper 1978). Because of this, the young are forced to continually move in order to procure food, and are, therefore, forced to subsist almost totally upon the higher energy source of māmane nectar (van Riper & Evenson, in prep.). As a result, the young birds take few insects (which act as nematode intermediate hosts), and thus gastrointestinal parasite levels may be kept at a minimum.

Where several parasitic species occur within the same host, their distribution may be restricted by competition with other species (Holmes 1961; MacKenzie & Gibson 1970). Differences in the species composition of helminth parasites in the 'Amakihi might suggest that interspecific competition is occurring. The decreased Capillaria sp. infection levels over the 3-year study period, complemented by increased cestode numbers, is suggestive of this (Fig. 2). Furthermore, all birds in which cestodes were found did not harbor capillarids. In the one individual that did have a mixed infection, the cestodes occupied the gut while nematodes were found only in the gizzard. However, as Kennedy (1975) has pointed out, conclusive evidence for interspecific competition for sites can only be proven by a comparison of the distribution of the species when they occur alone and together.

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TABLE 1. Parasites collected from 'Amakihi nests, body washes, and nasal cavities.

NIDICOLES	PARASITES
ORDER PARASITIFORMES	ORDER PARASITIFORMES
COHORT GAMASINA	COHORT GAMASINA
RHODACARIDAE - sp.	MACRONYSSIDAE - *Ornithonyssus sylviarum*
PHYTOSEIIDAE - *Amblyseius ovatus*	RHINONYSSIDAE - *Ptilonyssus* sp.
ORDER ACARIFORMES	ORDER ACARIFORMES
SUBORDER ACTINEDIDA	SUBORDER ACTINEDIDA
BDELLIDAE - *Spinibdella* sp. nr. *depressa*	HARPYRHYNCHIDAE - *Harpyrhynchus* sp.
CUNAXIDAE - sp.	SUBORDER ACARIDIDA
ANYSTIDAE - sp.	SUPERFAMILY ANALGOIDEA
ERYTHREIDAE - *Erythrites* sp.	ANALGIDAE - *Analges* sp.
SUBORDER ACARIDIDA	PROCTOPHYLLODIDAE - *Proctophyllodes* sp.
ACARIDAE - *Tyrophagus putrescentiae*	*Pterodectes* sp.
SUBORDER ORIBATIDA	TROUESSARTIIDAE - *Trouessartia* sp.
CYMBAEREMAEIDAE - *Scapheremaeus* sp.	XOLALGIDAE - gen. & sp.

TABLE 2. Numbers of 'Amakihi found with gastrointestinal helminth parasites on the island of Hawai'i from 1972 through 1979. A total of 44 birds was necropsied.

Age Class	No Infections	Single Infections		Mixed Infections	
		Only Cestodes	Only Nematodes	Cestodes and Nematodes Occurring Together	Cestodes in the Gut and Nematodes in the Gizzard
ADULT (n = 33)	12	4	14	0	3
JUVENILE (n = 11)	10	0	1	0	0

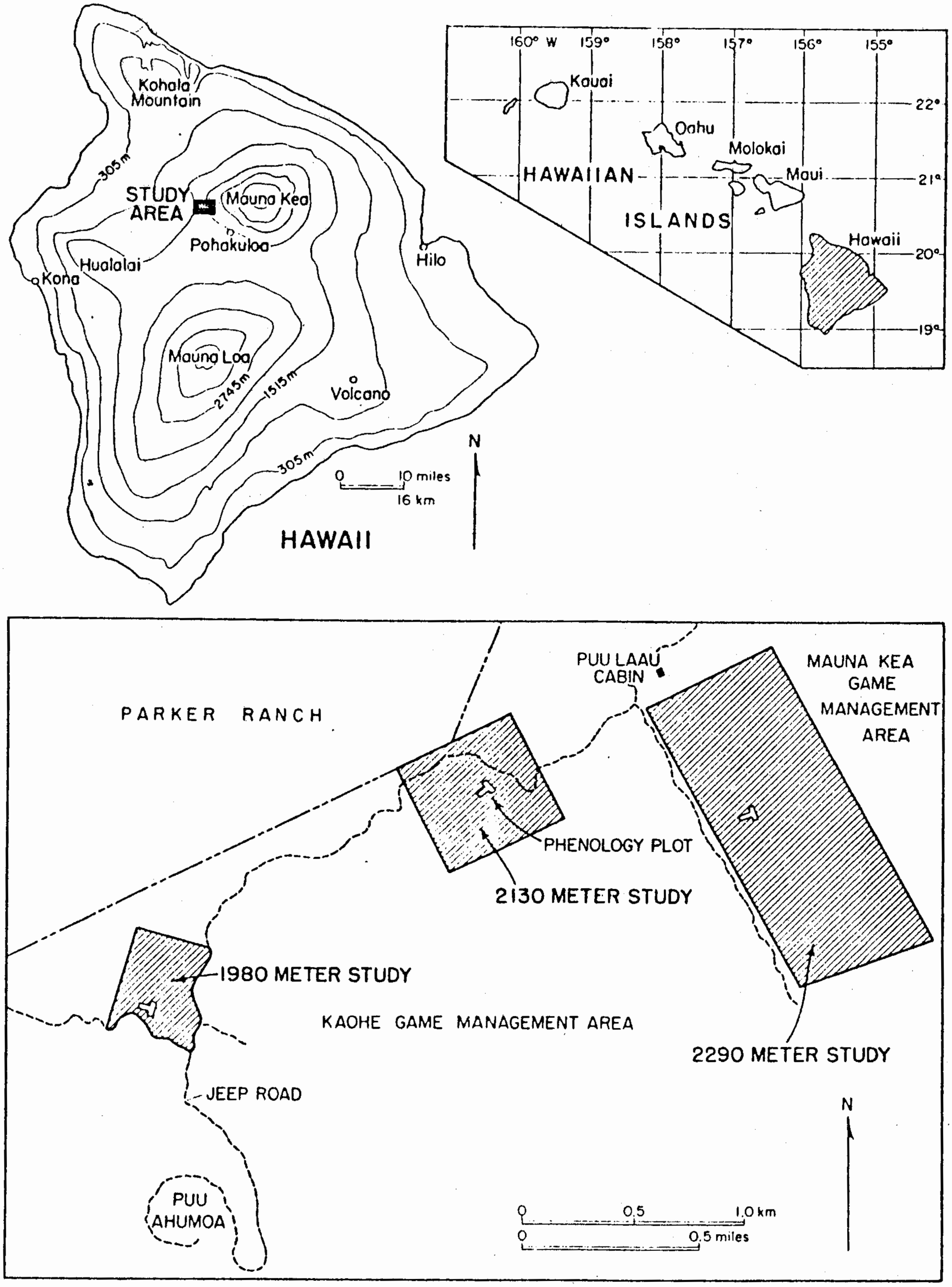

FIGURE 1. The study area on Mauna Kea, Hawai'i.

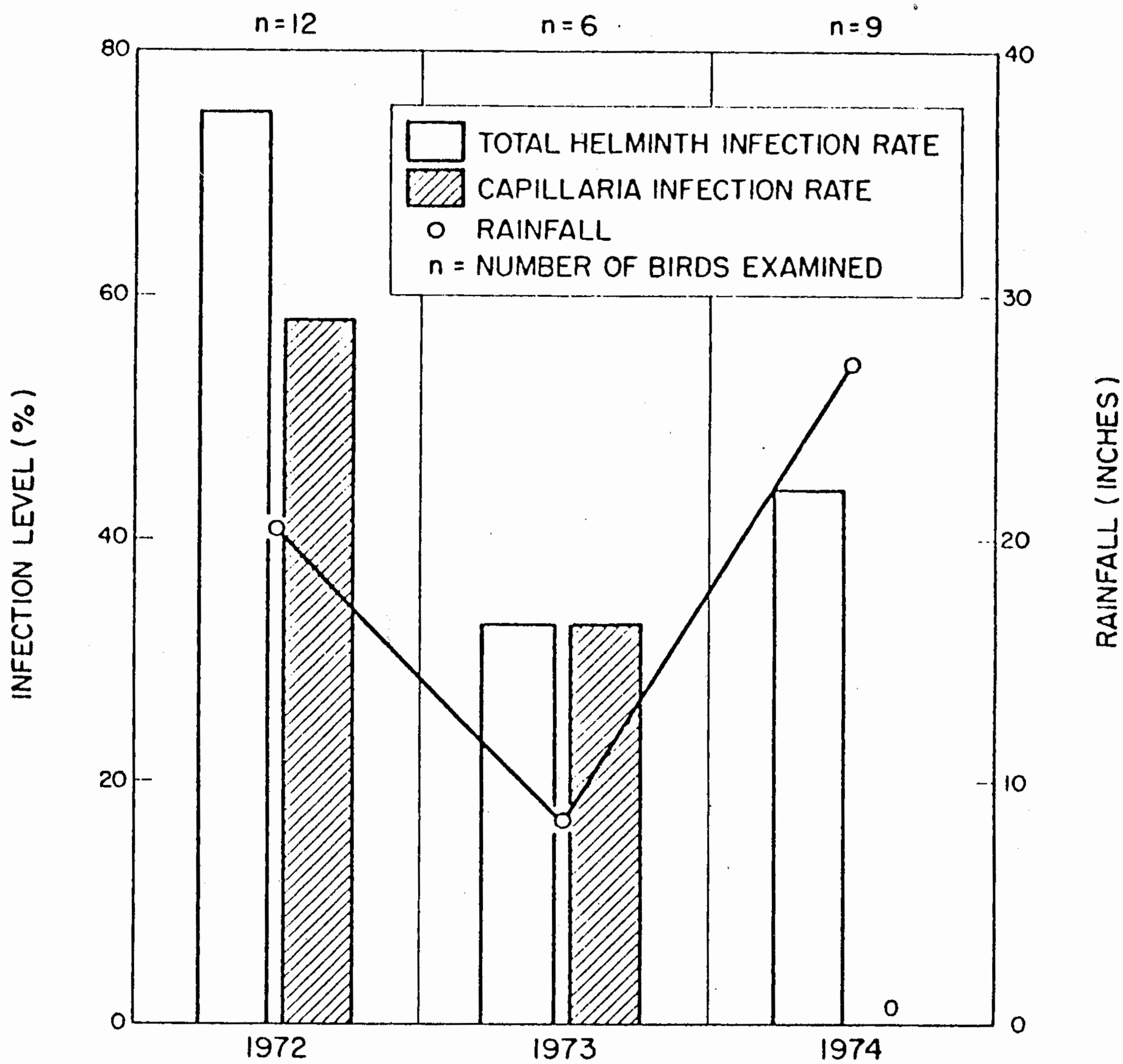

FIGURE 2. Helminth infection levels and yearly rainfall on Mauna Kea, Hawai'i.

GLOSSARY

Acarina	Spiders and mites.
arthropods	Insects, spiders, and mites.
capillarid	Intestinal parasitic roundworm.
cestode	Tapeworm.
coccidia	Intestinal protozoan parasites.
ectoparasite	External parasite.
instar	Developmental stage (e.g., first nymphal instar).
FAA	Formalin/Acetic Acid/Alcohol.
haematozoan	Blood protozoan parasite.
helminth	Parasitic gut flatworm.
histopathology	Tissue damage.
microcyte	Immature blood cell.
nematode	Roundworm.
nidicole	Nest-inhabiting organism.
operculum	Opening (as of the ear cavity).
passerine	Perching song bird.
saprophage	Organism which feeds on dead or decaying matter.