Pacific Insects 15 (1): 85-94 **20 May 1973**

ECOLOGICAL STUDIES OF *CTENOSCIARA HAWAIIENSIS* (HARDY) (Diptera: Sciaridae)[2]

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Abstract: The seasonal fluctuations of *Ctenosciara hawaiiensis* (Hardy) populations in two different ecosystems at the same elevation on Mauna Loa on the island of Hawaii are compared and correlated with fluctuations in rainfall, humidity, and temperature. Rainfall appears to be the most important extrinsic factor affecting seasonal changes in this species. There was a marked difference between the two populations which in part can be explained by observed differences in the ecosystems. *Ctenosciara hawaiiensis* is closely associated with *Acacia koa*, and the larvae live under the bark of dead branches. In culture, developmental time from oviposition to adult emergence ranged from 23-34 days at a constant temperature of 20°C.

The Sciaridae or dark-winged fungus gnats are a prominent element in many of Hawaii's ecosystems. The adults are small, usually dark flies commonly found around decaying plant and animal materials. The larvae are characterized by the shiny black head and the featureless, twelve-segmented, white, translucent body. Larvae generally feed on decaying plant and animal materials, animal excrement, molds and fungi; some feed on living plant tissues.

Hardy (1960) revised the Hawaiian Sciaridae and provided an excellent base for future studies. Seventeen species were recognized by Hardy, and approximately 40 species are now known from this island chain. None of the genera are endemic; however, many of the species are. Because these flies are easily transported by man and his activities, and Sciaridae in general are poorly known and difficult to identify, determination of endemic versus introduced species is an arduous task.

Ctenosciara hawaiiensis was selected as one of the species to be intensively investigated since it is relatively easy to identify, is common to all the sites being investigated and appears to be closely associated with one of the dominant elements of the plant community—*Acacia koa.*

The seasonal fluctuations of *C. hawaiiensis* populations in two different ecosystems at the same elevation on Mauna Loa are compared and correlated with fluctuations in rainfall, humidity, and temperature. Laboratory studies of *C. hawaiiensis* are reported and correlated with field observations. The investigation of Hawaiian Sciaridae is being continued as part of integrated ecosystem studies under the International Biological Program (IBP).

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1. Contribution No. 14. ISLAND ECOSYSTEMS IRP/IBP HAWAII. Partial results of grants to Bishop Museum from the National Science Foundation (GB-6761, GB-23075).
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METHODS

A modified Malaise trap (Gressitt & Gressitt 1962) was used to sample the sciarid populations. This is an interception trap designed to trap the insects as they fly. Presumably with this type of trap, it is easier to obtain indices of absolute population since it intercepts the insects more or less randomly. Julliet (1963) compared a Malaise trap with others and suggests that for larger Hymenoptera and some Diptera this trap is unbiased, but he found it unsatisfactory for Coleoptera and Hemiptera.

Malaise traps were set up in the Kilauea Forest Reserve (Transect-Profile 2, segment 11) and near the IBP weather station on the Mauna Loa Transect (Transect-Profile 1, segment 7). These two sites are being intensively studied by other researchers involved in the *Islands Ecosystems* IRP. Both of the traps are near IBP weather stations and are at approximately the same altitude, 1660 m. The ecosystems, however, are different. Kilauea Forest Reserve is a montane rain forest composed primarily of *Acacia koa*, *Metrosideros* and tree ferns (*Cibotium* species). The Mauna Loa site is in a mountain parkland ecosystem formed by *Acacia koa* tree colonies and *Styphelia-Dodonaea* tall-shrub communities, both in a matrix of subalpine grassland.

During the first six months, samples were taken continuously and collected weekly. After July 5, 1971, the sites were sampled on alternate weeks only, because it was not feasible to analyze the volume of material collected on a weekly basis.

Laboratory cultures were started from gravid females or larvae collected in the field and from adults reared from rotting wood. The adults or larvae were placed in glass shell vials (25 × 95 mm) containing an agar substrate. This is a modification of a culture method used by Metz and his students (Smith-Stocking 1936) for genetic studies of Sciaridae and is described below. It was initially reported in Steffan (1966).

Agar substrate : Mix 4.2 g of Bacto-Corn Meal Agar and 2.0 g of Bactoagar in 200 ml of distilled water. If excess fungal growth is detrimental to the sciarid culture, a plain Bacto-agar medium can be used. This is prepared by mixing 8 g of Bacto-agar in 200 ml of water. Heat mixture in a pan of boiling water for 10 minutes. Pour approximately 3 cm of this mixture into each vial, plug with cotton and autoclave for 15 minutes. Prepare slants by cooling vials in a diagonal position. Slant cultures are preferred as they provide more surface area for the larvae and adults so that they are easier to observe and manipulate.

Sprinkle chopped, sterilized straw over the agar surface prior to the introduction of adults or field-collected larvae to remove excess surface moisture and provide a suitable environment for oviposition and larval feeding. Eggs generally hatch within 2-6 days. Larvae are subsequently fed a mixture of finely chopped sterilized straw and Brewer's yeast every 2-3 days. The cultures are maintained in a constant temperature cabinet at 20°C.

RESULTS

Laboratory studies. During the past 5 years only 8 of the 28 laboratory cultures of *C. hawaiiensis* attempted were successfully carried through all stages and of these, only one yielded an F_2 generation. The F_3 generation died out. Other Hawaiian Sciaridae have been reared and maintained easily on the same medium. The difficulty in establishing cultures of *C. hawaiiensis* may be due to the habitat preferences of the larvae and ovipositing females. Larvae are found commonly under the bark of dead branches of *Acacia koa* and several other native trees, either fallen trees or broken branches on the ground. The larvae are most often in branches that still have the bark fairly tight against the wood with little organic debris. This habitat undoubtedly protects them from predators, parasites, and pathogens that would be abundant in the more normal sciarid larval habitat, i. e., loosely packed decaying organic substances. The female prefers to oviposit in deep crevices or under the bark. Straw was apparently not a suitable substrate since gravid females frequently die without ovipositing. Larvae tended to burrow into the agar whereas most other Hawaiian sciarid larvae remain on the surface.

Duration of the life cycle of *C. hawaiiensis* in the laboratory ranged from 23-34 days from oviposition to adult emergence. The preoviposition period was usually 3 days. The incubation period ranged from 4-5 days. Duration of the 4 larval instars ranged from 15-29 days and the pupal period ranged from 4-6 days.

This species is apparently unisexual, i.e., the progeny from one female are either all males or all females. Development does not appear to be synchronous as adults from one batch of eggs emerged over a 10-day period. Both in the laboratory and in the field, the larvae tended to be scattered throughout the substrate, contrasting with the gregarious behavior of some other species.

Seasonal fluctuations, Kilauea Site : Numbers of adult *Ctenosciara hawaiiensis* collected in the Malaise trap were relatively low throughout 1971, ranging from 0 to 26 per 7-day collection period (Fig. 1). The greatest adult activity occurred between January 25 and April 26 with two peak periods between January 25-March 1 and March 8-April 26. The numbers trapped subsequently were relatively low, increasing to a high of 20 during the week of August 30-September 6. There was also a high of 13 during the week of September 27-October 4 and again during the week of November 8-15.

Seasonal fluctuations, Mauna Loa Site : Numbers of adults collected showed very pronounced fluctuation (Fig. 2). The first and greatest increase began during the week of January 25-February 1 climbing from 13 to 131. The following week, 258 adults were captured. After a decrease to 219 during the week of February 1, the catch rose to 281, the highest of the year. During the next four weeks, the numbers of adults collected dropped to 46. Two similar cycles occurred in mid-April and early June but with a lesser magnitude. During the summer dry season, the catch dropped to a weekly low of 7. After July 5, the collections were made on alternate weeks only and this undoubtedly affected the results. Three additional cycles were observed in early September, mid-October, and late December.

Comparison of Kilauea and Mauna Loa populations : C. hawaiiensis adults were always more abundant at the Mauna Loa site than at Kilauea (Fig. 3). During the 55-week period, 3,084 adults were trapped at Mauna Loa versus 353 at Kilauea. At the period of peak adult activity during the week of February 15-22, 281 adults were trapped at the Mauna Loa site versus 23 at Kilauea. The two populations approached each other in relative abundance only during the dry seasons.

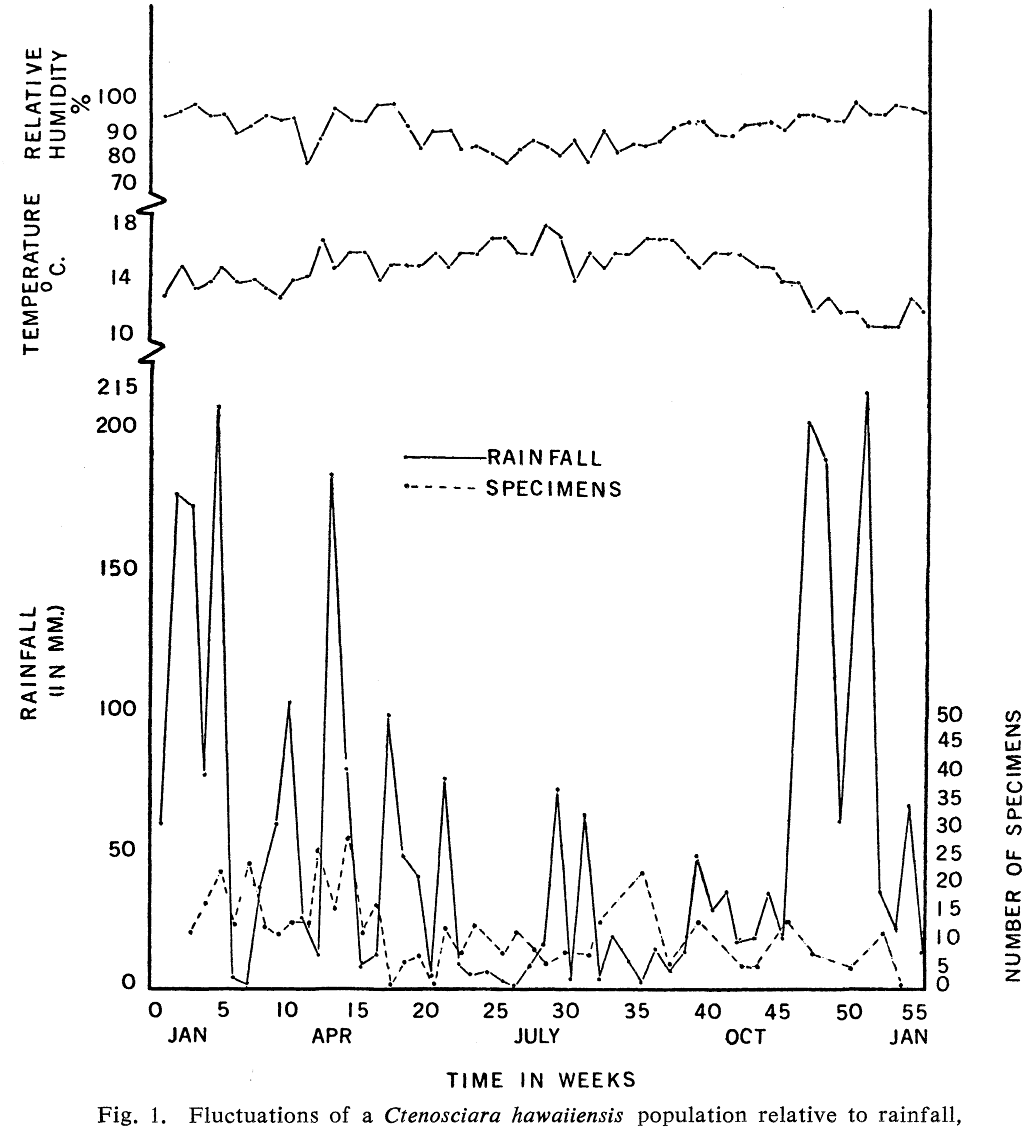

Fig. 1. Fluctuations of a *Ctenosciara hawaiiensis* population relative to rainfall, temperature and relative humidity, Kilauea Forest Reserve.

DISCUSSION

Seasonal fluctuations, Mauna Loa Site : Rainfall appears to be the most important extrinsic factor affecting seasonal changes in *C. hawaiiensis* populations. There were three cycles of adult activity during the first half of the year.

The first cycle, January 25-March 15, began about three weeks after a period of high rainfall in January, The following week the population dropped slightly, corresponding to a decrease in rainfall three weeks earlier. The population reached a high dur-

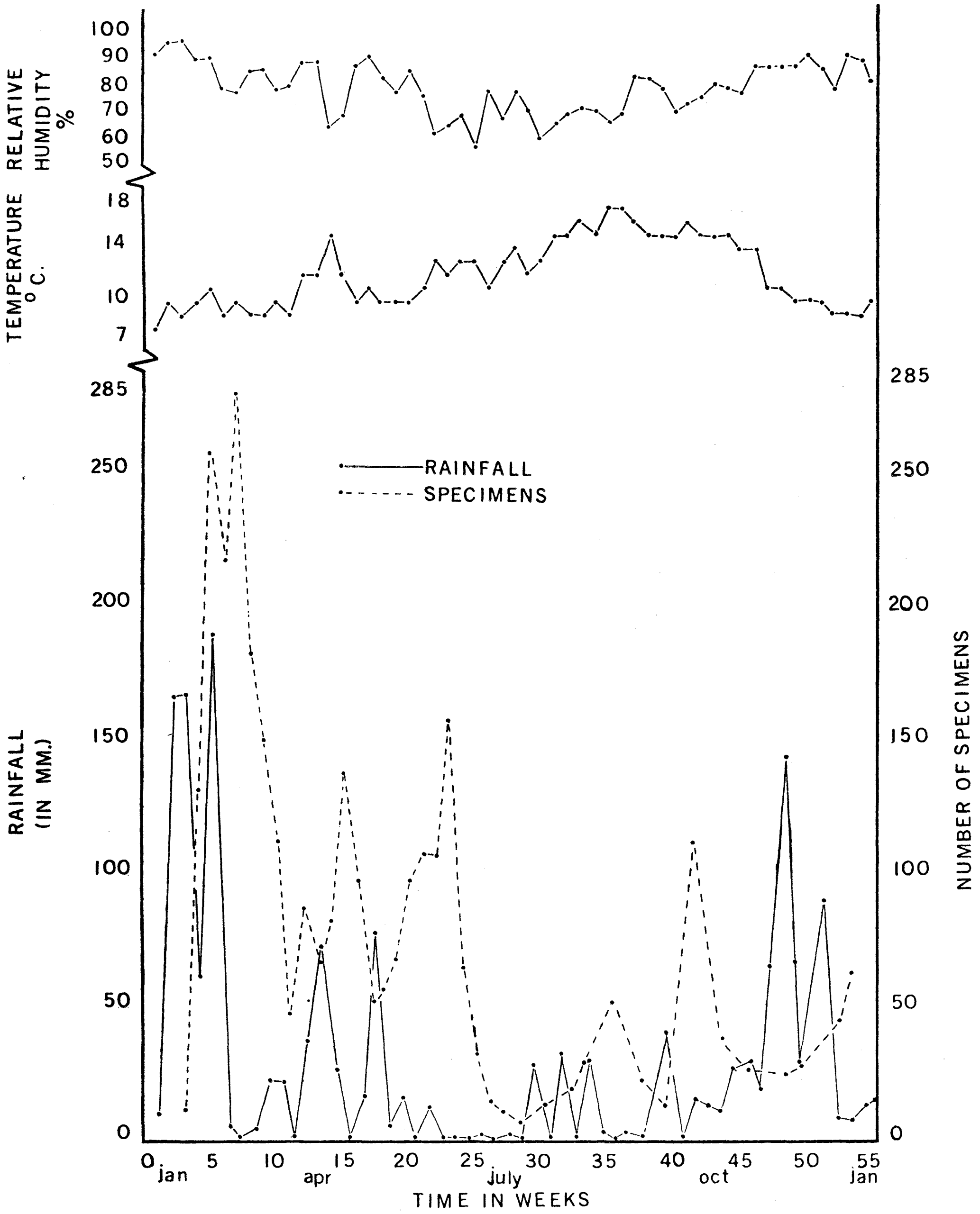

Fig. 2. Fluctuations of a *Ctenosciara hawaiiensis* population relative to rainfall, temperature and relative humidity, Mauna Loa Strip Road.

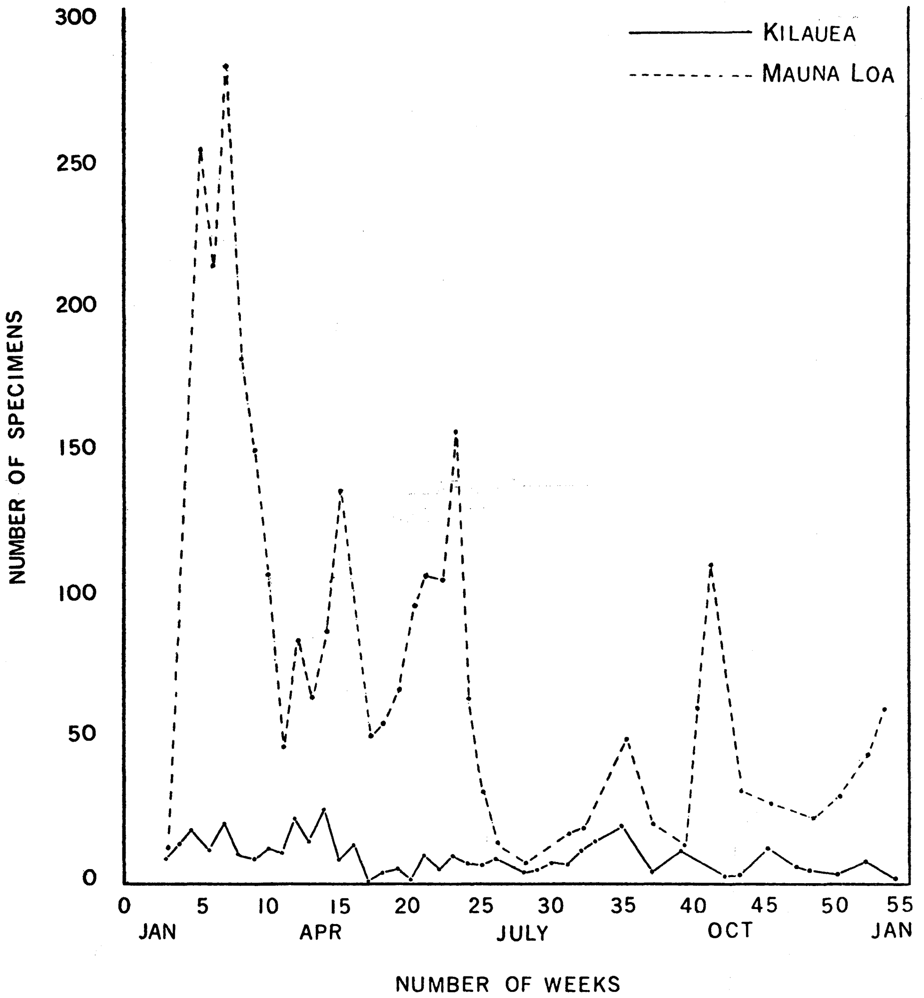

Fig. 3. Comparison of *Ctenosciara hawaiiensis* population fluctuations, Mauna Loa Strip Road and Kilauea Forest Reserve.

ing the week of February 12–22 when the catch rose to 281, the greatest of the year. Again this can be correlated to the highest rainfall of the year which occurred three weeks earlier. The rapid decrease in adult activity the following week was preceded three weeks earlier by a similar but greater decrease in rainfall.

The next two cycles in mid-April and early June were almost identical but about half the magnitude. Again the fluctuations could be correlated with fluctuations in rainall three weeks earlier, the only discrepancy being in the last cycle. The first peak occurred about 4 weeks after the week of peak rainfall. Rainfall then decreased sharply and remained at a relatively low level. However, the activity of the adult *C. hawaiiensis* after dropping only slightly, increased sharply. Since the population of *C. hawai-*

iensis was still fairly high, the relatively low level of rainfall probably was sufficient to provide another period of favorable growth.

This species is very sensitive to rainfall fluctuations. The usual three-week delay in response, i.e., activity of adults as expressed in Malaise trap captures, possibly represents the developmental time of *C. hawaiiensis*. This is about one week shorter than its developmental time in the laboratory, but the difficulty in colonizing this species indicates that our laboratory conditions are far from optimal and this may well be reflected in a lengthened developmental period.

There were again three cycles of adult activity during the second half of the year. The first and second were responses to increases in rainfall three weeks prior to each

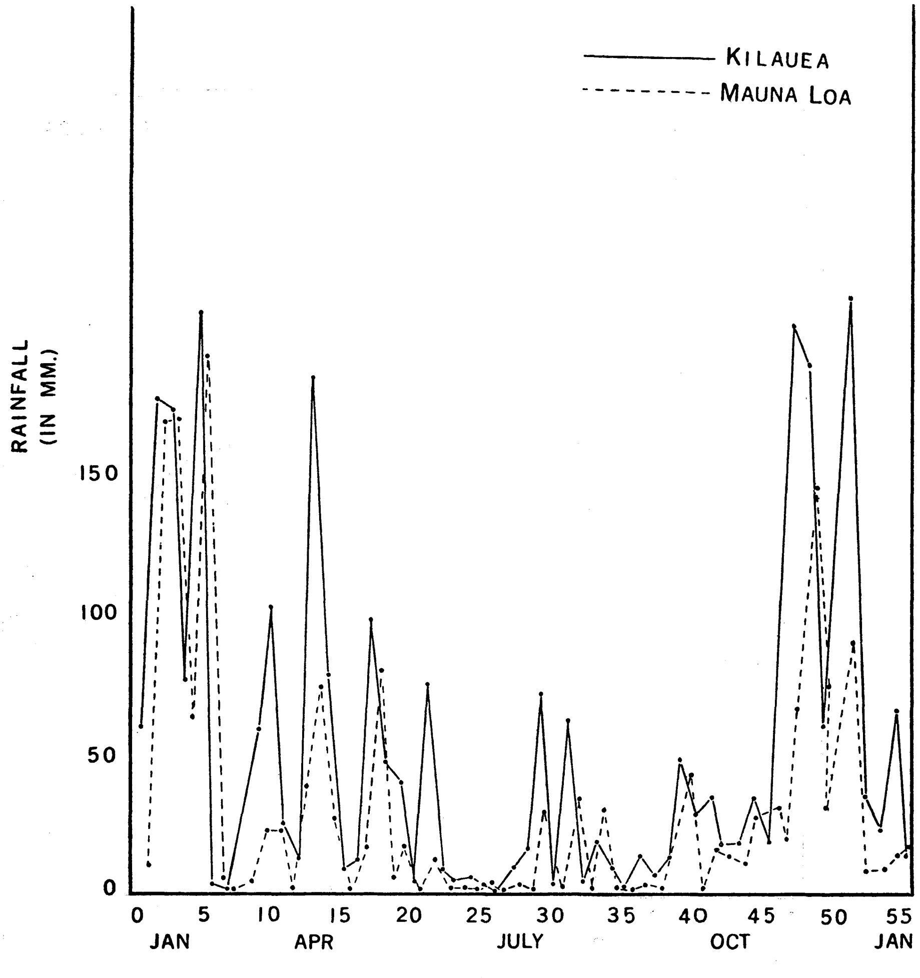

Fig. 4. Comparison of weekly rainfall, Mauna Loa Strip Road and Kilauea Forest Reserve.

peak. For the final cycle, the initiation was later and the magnitude was much less than expected. To some extent the fluctuations may have been dampened by the alternate-week sampling method, but even taking that into consideration, the numbers of adult *C. hawaiiensis* were lower than expected.

Fluctuations of relative humidity roughly corresponded to those of rainfall but the activity of adults, as reflected in the Malaise trap collections, was not as closely correlated as it was to fluctuations of rainfall. Since most of the life of *C. hawaiiensis* is in a confined, protected area, the availability of moisture under the bark of dead koa branches would have been a more appropriate indicator of moisture availability.

Temperature undoubtedly influences the development and activity of *C. hawaiiensis* but is not the limiting factor it would be in more temperate areas. A closer correla-

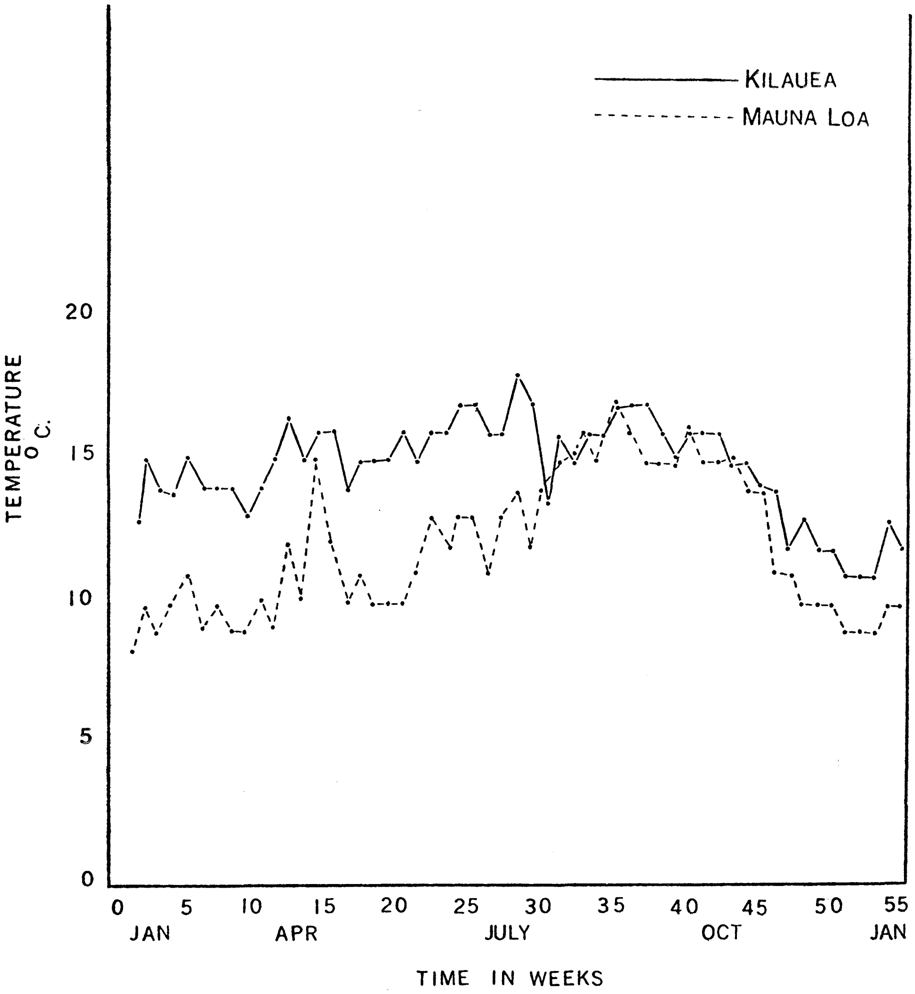

Fig. 5. Comparison of mean weekly temperatures, Mauna Loa Strip Road and Kilauea Forest Reserve.

tion of adult activity would be expected if the temperatures of the microenvironment under the bark were recorded.

Seasonal fluctuations, Kilauea Forest Reserve Site : Fluctuations of *C. hawaiiensis* populations were about 1/10 the magnitude of those at the Mauna Loa site ; however, they did reflect similar responses. Rainfall, relative humidity, and mean weekly temperatures were generally greater at the Kilauea site. It therefore appears that some factors were suppressing the population of *C. hawaiiensis* at Kilauea. The differences in the magnitude of the flucutations are shown in Fig. 3.

Comparison of Kilauea and Mauna Loa populations : As explained earlier, the two sites,

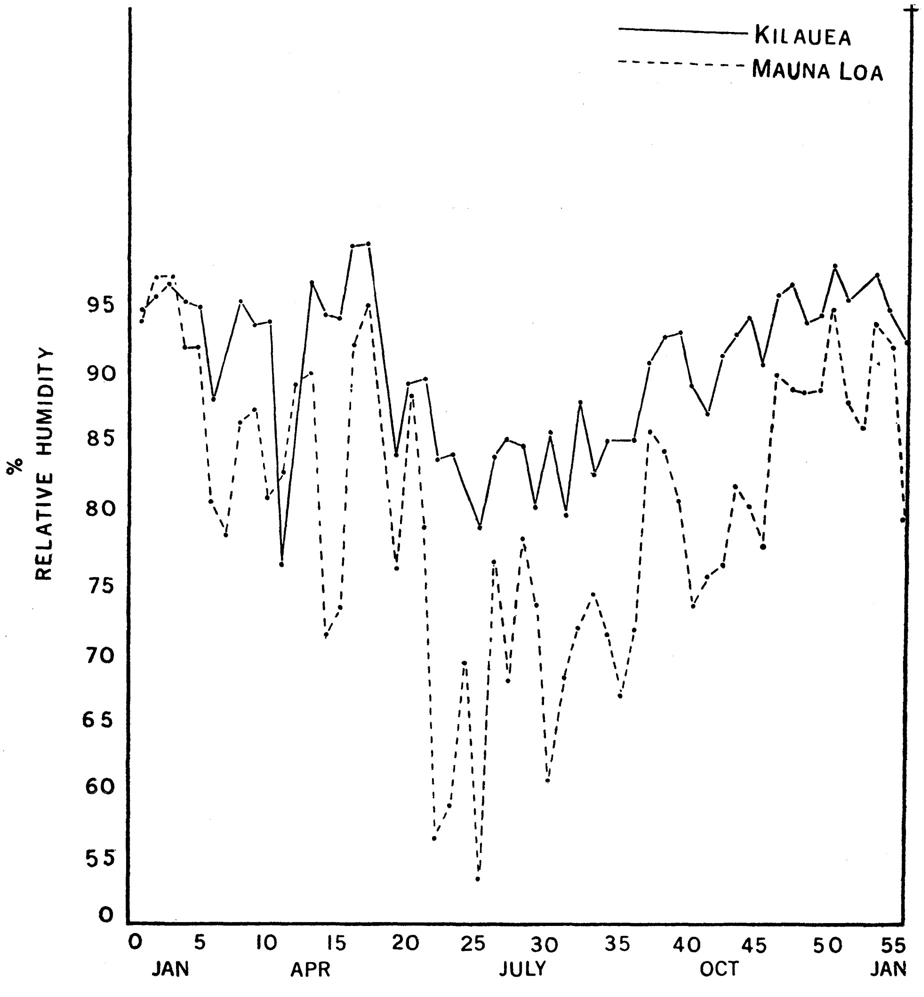

Fig. 6. Comparison of mean weekly relative humidity, Mauna Loa Strip Road and Kilauea Forest Reserve.

although at the same elevation and only a short distance apart, are very different ecologically. Kilauea is a rain forest and usually wet, while Mauna Loa is a mountain parkland ecosystem with more dry periods. Comparison of rainfall and relative humidity between the two sites (Figs. 4 and 6) reveals that both are usually higher at the Kilauea site. Sciaridae reared in the laboratory are very susceptible to excess moisture although this aspect has not been investigated quantitatively. Excess moisture may favor the spread of epizootics of fungal or bacterial disease. Mean weekly temperatures are usually lower at the Mauna Loa site (Fig. 5) and this may indicate that lower temperatures are more favorable for development of *C. hawaiiensis*. Availability of food and shelter may be an important factor in the differences in the relative abundance of *C. hawaiiensis* at the two sites. *C. hawaiiensis* larvae are usually found under the bark of fallen koa trees and branches and seem to prefer branches where the bark is still tightly against the wood. This probably provides them some protection from predators and parasites and provides a more suitable microclimatic niche. Fallen koa trees with a great number of dead branches are very typical of the Mauna Loa site, but they are not prominent at the Kilauea site.

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