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Technical Report 29

MITES (CHELICERATA: ACARI) PARASITIC ON BIRDS IN HAWAII VOLCANOES NATIONAL PARK

Technical Report 30

DISTRIBUTION OF MOSQUITOES (DIPTERA: CULICIDAE) ON THE EAST FLANK OF MAUNA LOA VOLCANO, HAWAI'I

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RECOMMENDATIONS

Mosquito populations in Hawaii Volcanoes National Park are directly related to the number of breeding sites available. While it would be impractical to even consider treatment of the dominant natural breeding sites (tree-holes, etc.), it is possible to reduce the number of artificial breeding sites available. The following measures should be taken:

1. Reduce the number of open containers which presently act as breeding areas in the forests of the Park (e.g., rain barrels, water troughs, discarded bottles and cans).

2. Properly screen all water storage areas (water tanks) to prevent entry of mosquitoes.

3. Make Park Service personnel aware of this problem so when they come upon standing water, it can either be eliminated or reported to the resource manager for proper action.

4. During construction activity breeding sites are frequently created. One of the contractual obligations should be that all standing water be eliminated. The construction area should be monitored by the resource manager for compliance.

Treatment involving toxic agents is not recommended at this time and it is doubtful that populations of mosquitoes will reach levels at which such treatment will be indicated.

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INTRODUCTION

There have been four species of blood-feeding mosquitoes introduced into the Hawaiian Islands. Two of these, Aedes aegypti (Linnaeus, 1762) and A. albopictus (Skuse, 1895), are day-biters; the other two, A. vexans nocturnus (Theobald, 1903) and Culex quinquefasciatus Say, 1823, are night-biters. Four additional predatory species have been introduced for biological control (Hardy 1960): Toxorhynchites amboinensis (Doleschall); T. brevipalpus Theobald; T. inornatus (Walker); and T. theobaldi (Dyar & Knab). Of these four predators, only T. amboinensis appears to have become well established (Steffan 1968).

Culex quinquefasciatus has been implicated in the transmission of filariasis (Wuchereria bancrofti), dog heartworm (Dirofilaria immitis), avian malaria, and fowl pox and may possibly be implicated in transmission of several viral agents including Japanese B-type encephalitis (Hardy 1960). Aedes albopictus is a vector of dengue fever, dog heartworm, and Japanese B-type encephalitis (Hardy 1960) and is listed as a minor vector of avian malaria (Plasmodium sp.) by Boyd (1949). Aedes aegypti is the major vector of yellow fever as well as transmitting dengue and avian malaria (Boyd 1949; Hardy 1960). Aedes vexans nocturnus is a vector for dog heartworm, fowl pox (experimentally), and various encephalides (Joyce & Nakagawa 1963). The vector potentials listed above have resulted in a surveillance of these species in areas around human habitation by the Vector Control Branch, Hawaii State Department of Health. Their distribution in unpopulated areas of Hawai'i is largely unknown, with the exception of work by Warner (1968) concerning C. quinquefasciatus on the island of Kaua'i.

Five species of mosquitoes are known from the island of Hawai'i. Of the four blood-feeding species, three are currently reported: A. albopictus, A. aegypti, and C. quinquefasciatus. However, no specimens of A. aegypti were recovered during the current study. The fourth species, A. vexans nocturnus, first reported in the Hawaiian Islands in 1962, has not yet been recovered on Hawai'i. The predatory Toxorhynchites amboinensis has been reported from Hawai'i but was not recorded during the present study;

MATERIALS AND METHODS

Twenty-one sample stations were established (Fig. 1) ranging from sea level to 6000 feet (2000 m). They are part of two transects along an elevational gradient. One transect in rain forest environments (sample stations 1-10) runs from Hilo to the Kīlauea

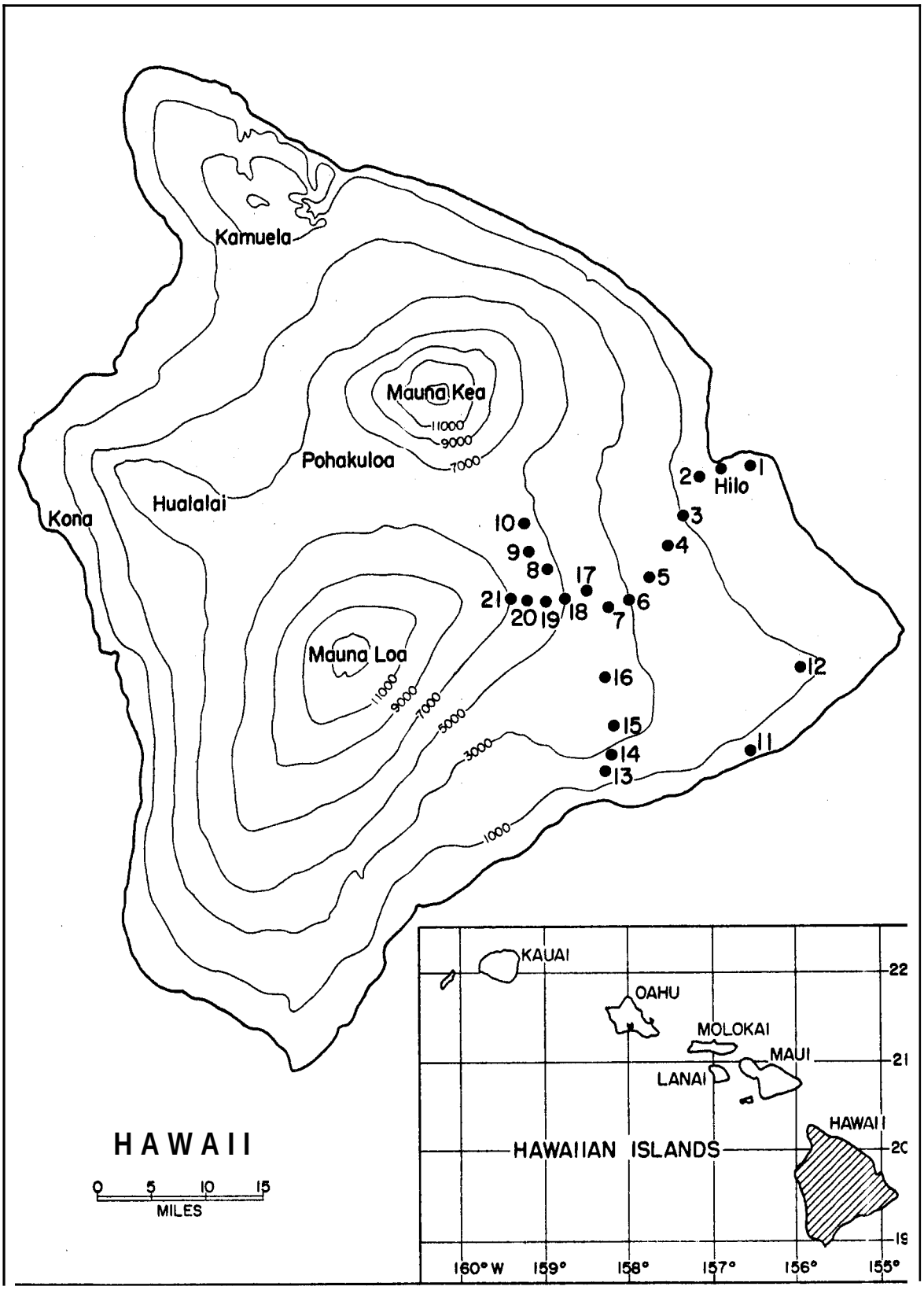

FIGURE 1. Locations of sample stations on east flank of Mauna Loa volcano. Numbers refer to Table 2.

Forest Reserve; the other in dry seasonal forest (sample stations 11–21) runs from Kalapana to the top of the Mauna Loa Strip Road. Sampling was done at monthly intervals from November 1977 through March 1979.

Artificial oviposition sites consisting of three each of coconuts, #10 metal cans, and Styrofoam containers were provided at each station. Containers were checked for eggs, larvae, and pupae each month, and the contents of one of each type container removed for examination in the laboratory. Potential natural oviposition sites (ground pools, hāpu'u stumps, tree-holes, leaf axils, ect.) were located at each station and checked monthly for larval activity.

Monitoring of adult populations of Culex quinquefasciatus for the island of Hawai'i is carried out on a continuing basis by the Vector Control Branch, Hawaii State Department of Health, using a series of 30 light traps operated 24 hours per day. Counts from these traps were made available for this study. Supplemental trapping at each of the 21 stations was done on a monthly basis from November 1977 to March 1978, using standard New Jersey Mosquito Light Traps, both unbaited and with a CO_2 attractant. Due to poor results and loss of traps, this sampling method was discontinued in April 1978. Biting-collections were made on a monthly basis for both C. quinquefasciatus and Aedes albopictus. Additional biting collections for C. quinquefasciatus were made by volunteers during July and December 1978 and February 1979.

RESULTS

Larvae and Pupae

Larvae and pupae of Culex quinquefasciatus were recovered from artificial oviposition sites at stations from sea level to 5000 feet (1650 m) (Tables 1 & 2). Breeding populations were present at Station 1 (sea level), Station 7 at 3500 feet (1200 m), and Station 18 at 4000 feet (1350 m) during the entire study period.

Station 9 at 4500 feet (1500 m), located on Keauhou Ranch, had a breeding population present during all months for which data was available. During the months from February through May and July 1978, the artificial oviposition sites at this location were destroyed by activities of cattle and pigs. Sampling of natural oviposition sites at Station 9 revealed larvae present in a tree-hole during March, April, and July. Thus, larvae were not observed at Station 9 for only two sample periods, February and May.

Stations 5 and 15 at 2700 feet (900 m) showed larval activity, but not on a continuous basis. The relatively constant strong winds, relatively low rainfall, and few natural oviposition sites available at Station 15 tend to limit mosquito activity. Larvae were collected here during the months of January through March, corresponding with the annual period of increased rainfall (December through April). Vegetation at Station 15 consisted primarily of grasses, scattered shrubs, and trees ('ōhi'a and koa). Lava substrate at this station was too porous to maintain ground pools sufficient for larval development. Ground pools were observed at this station only during the period December 1978 through February 1979, when there was unusually heavy rainfall resulting in flooding over a major portion of the island. Potential natural oviposition sites could not be located at Station 15.

A situation similar to that at Station 15 was encountered with regard to rainfall, vegetation, and natural oviposition sites at Station 14 (600 m). Here C. quinquefasciatus larvae were taken only in February and March–1978.

Station 5 was located in a rain forest with an abundance of potential natural oviposition sites, including ground pools, hāpu'u stumps, and tree-holes. However, C. quinquefasciatus larvae were recovered from this station only during September and October 1978.

Culex quinquefasciatus larvae were recovered on an irregular basis from artificial oviposition sites at stations from 450 feet to 1800 feet (150 m–500 m), but were observed regularly in natural oviposition sites at all stations except Station 14, as previously noted.

Although C. quinquefasciatus larvae were recorded only once in the artificial oviposition sites provided at Station 10 at 5000 feet (1650 m), other records are available from higher elevations on the island of Hawai'i. Swezey and Williams (1932) reported egg rafts from a rain barrel at 5500 feet (1850 m) on Mt. Hualalai and larvae in a pool at 6000 feet (2000 m) at Nauhi, Mauna Kea. Komatsu (1966) reported both egg rafts and larvae from concrete pools at the Pōhakuloa Nēnē Farm at 6000 feet (2000 m). While these records do not indicate a permanent breeding population of C. quinquefasciatus, results of larval samples in the current study indicate a permanent population at 4500 feet (1500 m).

Larvae and pupae of Aedes albopictus were recovered from artificial oviposition sites and in "natural" oviposition sites, primarily discarded cans, tires, and human refuse, up to 900 feet (300 m) for all months of the study. Recovery of A. albopictus larvae at Station 4 at 1800 feet (600 m) and Station 5 at 2700 feet (900 m) was associated with areas of human activity (construction equipment). Larvae were present at these elevations only for the period of the activity and were not recovered from

artificial oviposition sites during sampling either prior to or following such activiity. No A. albopictus larvae were recovered at stations above 2700 feet (900 m).

Eggs

Egg rafts were-collected from 50-gallon water drums located at Station 18 (Kipuka Ki) from November 1977 through October 1978, at which point the drums were removed by the National Park Service. Culex quinquefasciatus was the only mosquito species ovipositing at this station. During this period 46 egg rafts were removed from the drums. A mean of 171 eggs/raft was calculated with a range of 91 to 273 eggs/raft. No annual variation in numbers of eggs per raft was observed and monthly mean values ranged from 146 to 193 eggs/raft.

Four C. quinquefasciatus egg rafts were removed from artificial oviposition sites at Station 15 (Kipuka Nēnē) in January 1978. A mean of 177 eggs/raft was calculated for this collection with a range of 130 to 213 eggs/raft.

Egg rafts were collected from ground pools near sea level from November 1977 through October 1978. During this period 52 egg rafts were collected. A mean of 179 eggs/raft was calculated for this collection with a range of 120 to 260 eggs/raft.

Thus there was no significant difference in numbers of eggs per raft with elevation from sea level to 4000 feet (1350 m) in the present study ($t = 1.67$; $df = 96$; $P > 0.05$). No egg rafts were recovered at stations above 4000 feet in the current study.

Eggs of Aedes albopictus were not sampled during the present study.

Adults

Results of light traps operated by the Vector Control Branch, Hawaii State Department of Health, at localities indicated in Figure 2, are given in Table 3. These traps were primarily operated in areas of human activity and at elevations below 2700 feet (900 m). These results show a population of Culex quinquefasciatus present in all localities sampled on a year round basis, although more numerous from April through September. As expected, species of Aedes were not taken in light traps.

In this study, standard New Jersey Mosquito Light Traps were used along the Mauna Loa transects (Fig. 1) and sampled monthly from November 1977 through April 1978. Results from these traps were negative when used either with a CO_2 attractant or without an attractant.

Culex quinquefasciatus adults were frequently observed at lower elevation stations, and eggs, larvae, and pupae were

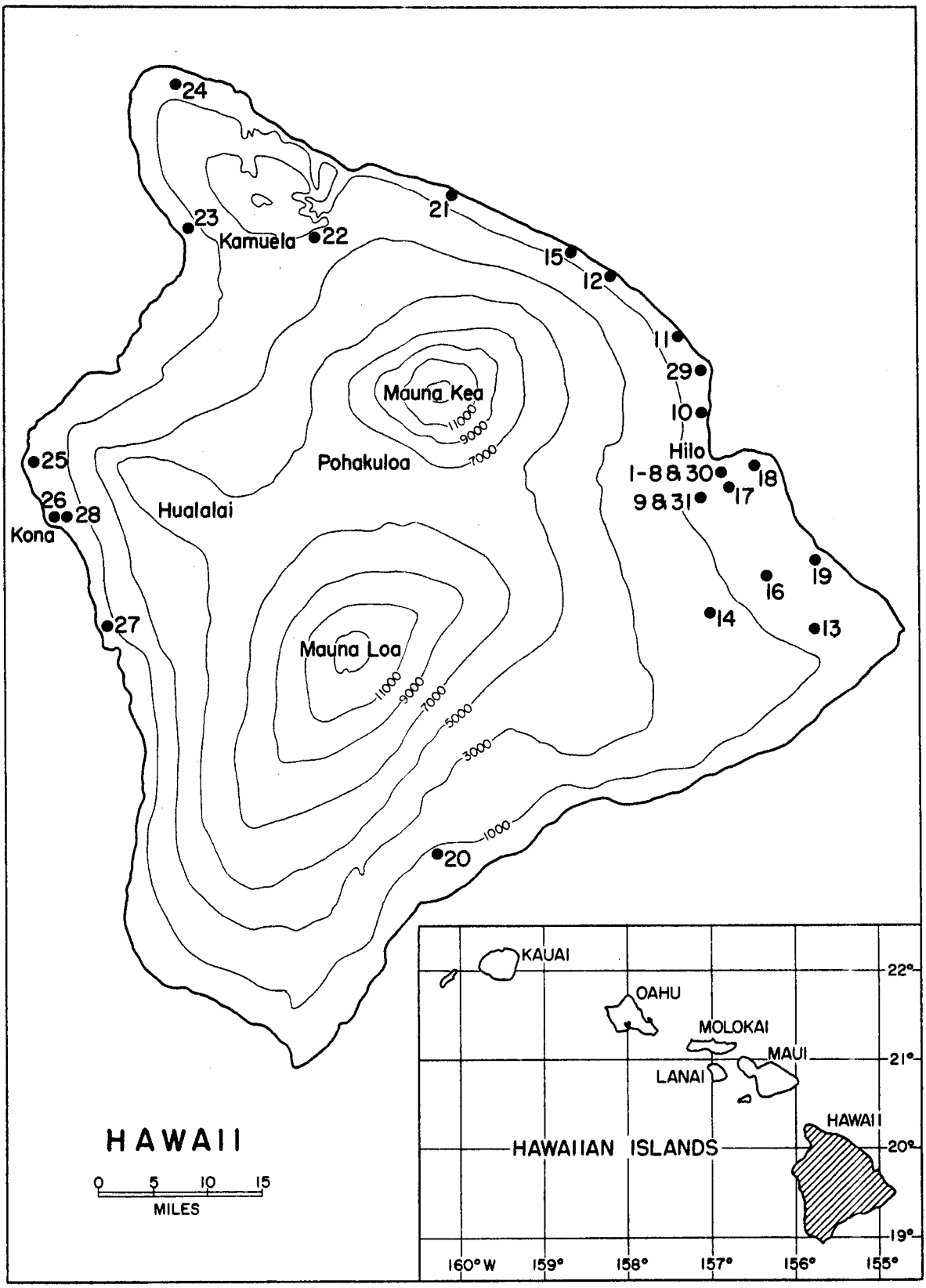

FIGURE 2. Locations of light traps operated **by** Vector Control Branch, Hawaii State Department of Health. Numbers refer to Table 2.

sampled. Both male and female C. quinquefasciatus were observed regularly at Station 18 (Kipuka Ki, 1350 m) in the vicinity of oviposition sites.

Biting collections at all stations during this same period were negative for C. quinquefasciatus. Biting collections of A. albopictus were made in early morning and with positive results at stations up to 900 feet (300 m). Bites ranged from 15 to 30 in a 10-minute period with no significant variation observed for the study period although higher numbers tended to occur in the warmer summer months.

Adult females of A. albopictus were observed biting in December 1977 and January 1978 at Station 18 (Kipuka Ki) and one female at Kīlauea Forest Reserve in April 1978.

DISCUSSION

Based on studies conducted on Kaua'i, Warner (1968) indicated that distribution of Culex quinquefasciatus is restricted to elevations below 2100 feet (700 m). Results of the current study on Hawai'i present a considerably different picture. Collections of eggs, larvae, and pupae indicate breeding populations of C. quinquefasciatus present for the entire year at elevations up to 4500 feet (1500 m). Adults of C. quinquefasciatus were observed monthly at Station 18 (Kīpuka Ki) with an elevation of 4000 feet (1350 m). Distribution of C. quinquefasciatus was, however, uniform throughout its altitudinal range but varied corresponding to degree of volcanic activity in the study area on the east flank of Mauna Loa volcano. Stations in the present study below 3300 feet (1100 m) were located in areas with a relatively uniform vegetation cover and with many available oviposition sites. Above this elevation, irregularities in patterns of lava flows from recent eruptions have resulted in the formation of kīpukas (pockets of undisturbed vegetation surrounded by relatively barren lava flows). Within the kīpuka, there are oviposition sites for mosquitoes and vegetation providing both food and roosting sites for bird and mammal hosts. Predictably, C. quinquefasciatus activity observed in this study was concentrated in these kīpukas.

This phenomenon is well illustrated by the larval collections at Stations 18 and 18a. Station 18 was located in Kīpuka Ki at an elevation of 4000 feet (1350 m). Vegetation cover consisted of koa and 'ōhi'a trees with an understory of pūkiawe and grasses. C. quinquefasciatus were recorded from this station in experimental oviposition sites as well as natural sites, including hāpu'u stumps, tree-holes, and ground pools. The major breeding sites at this station were tree-holes. Station 18a was located on exposed lava with grasses and low koa trees some 150 feet (50 m) outside of Kipuka Ki. As shown in Table 1, no larvae were recovered from artificial oviposition sites provided. Additionally, no natural breeding sites could be located in the

immediate vicinity of Station 18a and there was minimal indications of any host activity although 150 feet (50 m) distant at Station 18 there was a stable breeding population of C. quinquefasciatus and considerable host concentration.

A similar situation was observed for other kīpukas in the study area. Distribution of C. quinquefasciatus at elevations above 3300 feet (1100 m) coincided with the presence of kipukas caused by volcanic activity. This distribution, combined with the increased bird and mammal activities associated with the kipuka, would appear to increase the vector potential of even a small population of C. quinquefasciatus.

Taylor and Maffi (1978) indicate that ground pools, ditches, and large artificial containers were the principal breeding sites for C. quinquefasciatus in the South Pacific. In contrast, the main—natural breeding sites for C. quinquefasciatus at Station 18 were tree-holes. This was observed also at other stations. Lack of permanent ground pools due to the porous nature of the lava substrate precludes this as a breeding site at most of the stations above 3300 feet (1100 m). Standing water in tree-holes and hāpu'u stumps at stations located in kipukas is abundant and serves here as the main natural breeding sites. Additional breeding of C. quinquefasciatus was observed in large oil drums and water troughs placed in the kīpukas by the National Park Service.

Aedes albopictus on the east flank of Mauna Loa volcano was primarily associated with human activities and restricted to elevations below 900 feet (300 m). Although there were three females observed biting at elevations of 4000 feet (1350 m) and 5000 feet (1650 m), no permanent populations appeared to exist and these incidents were in areas associated with human activity.

Thus, patterns of distribution for C. quinquefasciatus given by Warner (1968) for Kaua'i do not appear on Hawai'i. The current study suggests that the "mosquito-free sanctuary" above 1800 feet (600 m) for Hawaiian birds does not exist on the east flank of Mauna Loa. In fact, due to the concentrating mechanism of the kīpuka at elevations above 3300 feet (1100 m), the birds and mosquitoes live in close association providing an ideal situation for transmission of avian malaria and other such diseases among the endemic and introduced birds.

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TABLE 1. Collection record of mosquito larvae from the sampling stations along the two transects on the east flank of Mauna Loa volcano (A = Aedes albopictus larvae; C = Culex quinquefasciatus larvae; * = Oviposition sites disturbed, no data; 1 = Station not yet established).

Station	Elev. (m)	Location	1977 Nov.	Dec.	1978 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	1979 Jan.
1	0	Hilo Airport	AC	AC	C	C	C	C	C	C	C	AC	C	C	C	C	C
2	150	Hilo Zoo	1	1	--	--	--	--	A	A	A	A	A	A	A	A	A
3	300	Lower Kūlani	A	A	A	A	A	AC	A	--	A	AC	AC	AC	A	--	A
4	600	Upper Kūlani	--	--	--	A	--	--	--	--	--	--	--	AC	AC	A	--	A
5	900	Lower Volcano	--	--	--	A	--	--	--	--	--	--	A	C	C	C	--	A
6	1050	Upper Volcano	--	-	--	C	--	--	--	--	--	--	--	--	--	--	--	--
7	1200	Avian Disease Lab.	C	--	C	C	C	C	C	C	C	C	C	C	C	AC	C	C
8	1350	Lower Keauhou	--	--	--	--	--	--	--	--	--	C	--	C	--	--	--	--
9	1500	Upper Keauhou	C	C	C	*	*	--	--	C	*	C	C	C	C	C	*	C
10	1650	Kīlauea Forest €&serve	--	--	--	--	--	--	--	--	--	C	--	--	--	--	--	--
11	0	Kalapana	1	1	A	A	A	AC	A	A	A	A	A	A	A	A	A	A
12	300	Keaouhana Forest	1	1	A	A	A	A	A	A	A	A	A	A	A	A	A	A
13	600	Lower Ailina Pali	--	--	--	--	--	--	--	*	*	--	*	*	--	--	--	--
14	600	Hilina Pali	--	--	C	C	--	--	--	*	*	C	*	*	--	--	--	--

TABLE 1--Continued.

Station	Elev. (m)	Location	1977 Nov.	Dec.	1978 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	1979 Jan.
15	900	Kīpuka Nēnē	--	C	C	C	--	--	--	*	*	--	*	*	--	--	--
16	1050	Kokoolaau	--	--	--	--	--	--	--	*	*	C	--	--	--	--	--
17	1200	Kīlauea Military C	--	--	--	--	--	--	--	*	*	--	--	--	--	--	--
18	1350	Kīpuka Ki	C	C	C	<	C	C	C	C	--	C	C	C	C	C	*
18a	1350	Kīpuka Ki (lava)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
19	1500	Strip Road (AA)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
20	1650	Ke oku Flow	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
21	2000	Top of Strip Road	--	--	--	--	--	--	--	*	*	--	--	--	--	--	--

TABLE 2. Collection record of mosquito larvae by elevation on the east flank of Mauna Loa volcano (A = *Aedes albopictus* larvae; C = *Culex quinquefasciatus* larvae; * = Oviposition sites disturbed, no data; — = No larvae present),

Elev. (m)	1977 Nov	Dec	1978 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	1979 Jan
0	AC	AC	AC	AC	AC	AC	AC	AC	Ac	Ac	Ac	AC	AC	AC	AC
150	—	—	—	—	—	A	A	A	A	AC	A	A	A	A	AC
300	A	A	A	A	A	AC	A	A	A	AC	AC	AC	A	A	A
600	—	—	—	A	—	—	—	*	*	C	AC	AC	*A	A	A
900	—	—	C	AC	C	—	—	*	*	A	*C	*C	C	—	A
1050	—	—	—	C	—	—	—	—	—	—	—	—	—	—	—
1200	C	C	C	C	C	C	C	*C	*C	C	C	C	AC	C	C
1350	C	C	C	C	C	C	C	C	*	C	C	C	C	C	*C
1500	C	C	C	*	*	*	*	*C	*	C	C	C	C	*	C
1650	—	—	—	—	—	—	—	—	—	C	—	—	—	—	—
2000	—	—	—	—	—	—	—	*	*	—	—	—	—	—	—

TABLE 3. Total number of adult *Culex quinquefasciatus* collected per month from light traps on the island of Hawai'i (* = trap malfunction).

Map Number	Locality	1977 Nov.	Dec.	1978 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	1979 Jan.
1	Kapiolani	19	30	55	15	11	33	104	54	184	80	17*	16	23	32	11*
2	Kea'au	104	181	97	35	241	751*	980	205	373	1941	323	361	147	184	36
3	Waiakea	11	10	4	1	7*	14	25	52	15	27	14	18	24	8	3*
4	Hilo Wharf	9	4	25	8	3	1*	5	7	33	13	8	30	14	14	2*
5	Old Airport	13	10	7	1	2	1*	0	0	2	3	1	0	1	1	3
6	Pi'ihonua	8	3	0	6	2	3	16	6	9	0	2*	13	13	8	3
7	Keaukaha	8	11	17	2	6*	22	70	103	21	113	16*	92	13	76	21
8	Kaumana	5	11	12	3	11	18	42	12	27	95	32*	7*	1*	*	0
9	Municipal Golf Course	86	46	33	9	19	152	348	409	461	980	507	531	91	167	22
10	Kalaniana'ole	23	17	27	82	76	193	42	43	360	237	25	26	51	51	44*
11	Hakalau	14	7	27	0*	10	29	13	25*	13	2	3	1	1*	0	4*
12	Laupahoehoe	22	41	67	2	4	4	7	2	12	0	4	31	24	42	17*
13	Pahoa	0	6	4	0	5	63	98*	31	119	257	65	117	6*	0	14
14	Mt. View	4	10	15	3	7	37	24	25	83	82	15	57	18	a	11
15	'O'okala	72	45	31	16	15	21	11	21	44	34	48	476	86	21	23*
16	Kea'au	95	343	263	67	523	121	52	7	20	57	53	74	24	38	7

TABLE 3--Continued.

Map Number	Locality	1977 Nov.	Dec.	1978 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	1979 Jan.
17	J. Serain	73	15	56	3	5*	42	170	36	91	234	117	11*	0*	84	63*
18	Hilo Airport	141	70	74	6	362	1040	1617	649	428*	2428	272	456	461	399	79
19	Okamoto Store	21	34	28	3	44	249	247	105	51	237	92	182	144	189	35
20	Pāhala	0	3	0	0	12	4	0	0	0	0	0	4	7	7	2
21		2	0	0	0	5	2	2	0	0	1	0	0	0	3	0
22	Waimea Airport	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
23	Kawaihae Harbor	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0
24	Kohala Hospital	2	1	1	1	1	2	1	0	0	26	0*	0	0	6	2
25	Keāhole Airport	1	0	4	2	1	10	47	98	176	75	52	1	2	25	17
26	Kailua School	0	0	0	0	0	3	8	15	27	10	3	0	2	2	2
27	Kona Health Center	3	1	6	5	3	8	22	35	26	14	11	5	7	10	16
28	Kona County Garage	1	2	6	5	4	9	28	40	31	33	26	7	5	16	20
29	Pepe'ekeo	82	64	36	6	414	156*	290	433	467	402	319	105	413	716	264*
30	U, H. Hilo	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0
31	C. Granat	24	55	57	11	21	19	discontinued----------								
Total for Island		843	1020	952	293	1814	3015	4269	2413	3074	7381	2025	2621	1578	2111	721