Breeding habits of vector mosquitoes of filariasis and dengue fever in Western Samoa¹⁾

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Abstract: Extensive surveys were undertaken in Western Samoa during the period 1969 to 1971 on breeding habits of the confirmed and suspected vectors of subperiodic *Wuchereria banorofti* and of *Aedes (Stegomyia) aegypti*, the vector of dengue fever.

Ae. (S.) aegypti breeds predominantly in artificial water containers around houses. A negligible number was found breeding in tree holes. This mosquito occurs throughout the country, even in the remote and inland areas. *Ae. (S.) polynesiensis* breeds in a wide range of both artificial and natural containers, but seems to prefer the latter, and is the only species breeding in crab holes. Since the above two species are often found breeding together, the single-larva-per-container survey method tends to underestimate the population of either one. *Ae. (S.) upolensis* is a forest mosquito, and its larvae were collected only once in a tree hole.

The only species found breeding in the leaf axils of *Freycinetia* is *Ae. (Finlaya) samoanus*; and in taro (*Colocasia* sp.) and pineapples, *Ae. (F.) oceanicus*. Both species can also breed in the *Pandanus* axils. This plant serves the only breeding habitat for *Ae. (F.) tutuilae*.

INTRODUCTION

In Western Samoa, subperiodic banoroftian filariasis had been one of the main communicable diseases of public health importance.

Confirmed vectors of the filariasis are *Aedes (Stegomyia) polynesiensis*, *Ae. (Finlaya) samoanus* and *Ae. (S.) upolensis*. *Ae. (F.) tutuilae* is suspected to be a vector (Ramalingam and Belkin, 1965; Ramalingam, 1968), and *Ae. (F.) oceanicus* was reported to transmit subperiodic filariasis in Tonga (Hitchcock, 1971). Some studies on breeding

habits of *Ae. polynesiensis* were undertaken in American Samoa by Jackowski (1954) and in French Polynesia by Bonnet and Chapman (1956, 1958); and these were reviewed by Iyengar (1965). In Western Samoa, systematic studies on the breeding habits of the vectors have been reported only by Ramalingam (1965, 1968).

During the period July 1969 to December 1971, the authors were engaged in the studies on biology, distribution and control of the filariasis vectors, with preliminary studies in 1968, and supplementary studies in 1972 and 1973. In this report, breeding habits of the filariasis vectors and their distribution in the country are presented, together with those of *Ae. (S.) aegypti*, the main vector of dengue fever.

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METHODS

In most surveys, twenty to thirty larvae, or sometimes more, of the third or fourth stage, if enough number present, were collected from each breeding site. In leaf axils of plants, those collected from one bundle of the same kinds of plant were usually pooled in a bottle. Identification was made according to the keys by Belkin (1962) and Ramalingam (1965).

Efforts were concentrated to collect larvae from the water containers near residential areas or plantations; and those breeding either in containers located far from human activities or in non-container habitats, were rarely collected. Sometimes no collections were made from the very common habitats of *Aedes* larvae, such as coconut shells, even if they were found. Therefore, the number of the breeding sites shown in Table 1 does not reflect the frequency of the positive sites in the country.

Special surveys were made on water-collecting drums, canoes, crab holes and leaf axils of *Pandanus* plant. Methods of such surveys were described in the relevant chapter.

RESULTS

1. Mosquito species found during the survey

A total of 70,132 larvae were collected from 876 breeding sites. During the survey, the following ten species in three genera were found.

Aedes (*Stegomyia*) *aegypti*
Ae. (*S.*) *polynesiensis*
Ae. (*S.*) *upolensis*
Ae. (*Finlaya*) *samoanus*
Ae. (*F.*) *tutuila*
Ae. (*F.*) *oceanicus*
Culex (*Culex*) *pipiens fatigans*
Culex (*C.*) *annulirostris*
Culex (*C.*) *sitiens*
Toxorhynchites spp.

The breeding species in each habitat are summarized in Table 1, and the details are mentioned below.

2. Breeding species in each habitat

Artificial water containers.

Drums: In Western Samoa, iron drums

with the capacity of 44 imperial gallons, or 200 litres, are widely used for storing water, especially in the villages which have no facilities of pipe water supply. *Ae. aegypti*, *Ae. polynesiensis* and *Culex p. fatigans* breed in the drums. Two of the above three, or even three, were sometimes found breeding together in a drum (Suzuki and Hirshman, 1977).

Special surveys on drums were made by checking all the drums in 15 villages of Upolu Island, 9 villages with pipe water supply, and 6 without it, during the period March to June 1970. As shown in Table 2, in the villages with no water supply, 31.8% of the houses possess one or more drums, and the number of the drums with larvae was as high as 50.5 per 100 houses. On the contrary, in the villages with pipe water supply, only 5.6% of the houses possess drum(s), and the number of the drums with larvae was 2.4 per 100 houses.

Canoes: A special survey was made on canoes in six coastal villages of Upolu Island. Every canoe was checked for holding water and harbouring mosquito larvae. Out of 74 canoes checked, 18 or 24% held water, but none of them harbouring larvae. It should be pointed out that breeding of larvae in canoes is rather rare, but larval population in each positive canoe is usually very high.

Natural water containers excluding leaf axils.

Tree holes: Water collections in tree stumps, tree hollows and trunks of fallen trees are included in this category. Out of 162 trees holes in Table 1, 98 were of coconut trees, 42 of breadfruit trees, and 22 of the other kinds of trees.

As shown in Table 1, the predominant species in tree holes is *Ae. polynesiensis*. In one occasion, a hole on a *Pandanus* plant was found harbouring *Ae. polynesiensis*, but no *Ae. (Finlaya)* larvae, which are common in the leaf axils of *Pandanus* plant. *Ae. aegypti* larvae were collected from two trunks and one hole of coconut trees in the close proximity of houses. They were associated with *Ae. polynesiensis*. One *Ae. upolensis* larva was collected from a tree hole in a deep forest of Pitonuu Village of

Table 1 Prevalence of mosquito species in various habitats of Western Samoa

Habitat	No. of sites with larvae	No. of larvae collected	No. of each species						
			<i>Aedes polyne-siensis</i>	<i>Aedes aegypti</i>	<i>Aedes upolensis</i>	<i>Aedes samoanus</i>	<i>Aedes tutuilae</i>	<i>Aedes oceanicus</i>	<i>Culex</i> spp.
Artificial water containers and collections									
Drum	113	6582	779 (11.8%)	3479 (52.9%)	0	0	0	0	2324 (35.3%)
Tyre and motor parts	37	4622	1110 (24.0%)	1066 (23.1%)	0	0	0	0	2446 (52.9%)
Canoe	6	695	488 (70.2%)	0	0	0	0	0	207 (29.8%)
Tin can	10	231	226 (97.8%)	1 (0.4%)	0	0	0	0	4 (1.7%)
Concrete pool	8	235	140 (59.6%)	0	0	0	0	0	95 (40.4%)
Miscellaneous	6	280	123 (43.9%)	0	0	0	0	0	157 (56.1%)
Sub-total	180	12645	2866 (22.7%)	4546 (36.0%)	0	0	0	0	5233 (41.4%)
Natural water containers and collections (Excluding leaf axils)									
Tree hole	162	7314*	7290 (99.7%)	12 (0.2%)	1 (0.01%)	0	0	0	9 (0.1%)
Coconut shell	40	3283	2502 (76.2%)	0	0	0	0	0	781 (23.8%)
Crab hole	59	1068	1068 (100 %)	0	0	0	0	0	0
Rock hole	5	152	76 (50.0%)	0	0	0	0	0	76 (50.0%)
Miscellaneous	3	27	27 (100 %)	0	0	0	0	0	0
Sub-total	269	11844	10963 (92.6%)	12 (0.1%)	1 (0.008%)	0	0	0	866 (7.3%)
leaf axils of plants									
<i>Pandanus</i>	299	26899	53 (0.2%)	0	0	18557 (69.0%)	2252 (8.4%)	6037 (22.4%)	0
<i>Freycinetia</i>	18	717	0	0	0	717 (100 %)	0	0	0
Taro	105	17914	3 (0.02%)	0	0	2 (0.01%)	0	17909 (99.97%)	0
Pineapple	5	113	0	0	0	0	0	113 (100 %)	0
Sub-total	427	45643	56 (0.1 %)	0	0	19276 (42.2%)	2252 (4.9%)	24059 (52.7%)	0

* *Toxorhynchites* spp. (2 larvae, 0.03 %) were excluded from the breakdown.

Savaii Island.

In the rainy season, many tree holes hold water and allow mosquito larvae to develop, but in the dry season, the holes readily get dry; consequently no larvae can develop any more, although dormant eggs may still be present. This is especially true in the

tree holes of the village area, which are not covered by dense forests but rather exposed.

The follow-up checks of 15 tree holes along the northern coast of Upolu Island, which held water on February 1970, showed the following results: Average number of holes with water was 14.3 in March, 11.5 in April,

Table 2 Results of special survey of water-collecting drums in Western Samoa

Type of village	No. of villages under survey	No. of houses under survey	No. of houses with drum (s)	Total no. of drums	Total drums with larvae	No. of drums with larvae per 100 houses
With no pipe water supply	6	192	61(31.8%)	344	97(28.2%)	50.5
With pipe water supply	9	413	23(5.6%)	39	10(25.6%)	2.4
Overall	15	605	84(13.9%)	383	107(27.9%)	17.7

7.0 in May, 10.0 in June, 8.5 in July, 6.0 in August, 6.0 in September, 11.0 in October, 15.0 in November, 7.0 in December, and 10.0 in January 1971.

Similar survey showed that, of 22 tree holes holding water when registered in April 1972, the average number of the holes with water decreased to 19.5 in May, to 15.3 in June, and to 14.0 in July.

Crab holes: *Ae. polynesiensis* is the only species breeding in crab holes.

A special survey on crab holes were made in six coastal villages of Upolu and Savaii Islands. About two litres of water, (if water was less than two litres, as much water as collectable), was pumped up from each hole with a plastic tube connected to a bottle and a suction pump. Water was more easily pumped up when tide was high, presumably because water level in the hole fluctuates with tide. The distance from the ground surface to the water level was usually one to six feet, when measured along the crooked hole.

As shown in Table 3, mosquito breeding was found only in two villages, Mulinuu and Moataa, both with sandy beach under co-

conut trees. The proportion of positive crab holes to those with water was 68.0% in Mulinuu and 37.5% in Moataa.

Salinity of the water from 21 crab holes in Mulinuu and Moataa was examined by titration method with silver nitrate. The maximum and average contents of sodium chloride in water from positive holes were 0.74% and 0.18%, respectively, while those from negative holes were 1.82% and 0.63%, respectively. *Ae. polynesiensis* can breed in slightly salty water, up to 0.74% of sodium chloride, but can not breed in more salty water. This might be one of the reasons, if not all, that breeding of *Ae. polynesiensis* in crab holes is limited to some areas, although crab holes are distributed extensively along the coast.

Leaf axils of plants.

Pandanus plant: *Pandanus* plant is common in and around every village in Western Samoa, and of economic importance for making baskets and mats.

Ae. samoanus, *Ae. tutuilae* and *Ae. oceanicus* are the most common species breeding in *Pandanus* axils. A small number of *Ae. polynesiensis* (0.2%) were also found.

Table 3 Results of special survey on crab holes for breeding of *Ae. polynesiensis* larvae

Village	No. of holes examined	No. of holes with water	Holes with larvae		
			Number	Proportion to total holes examined	Proportion to holes with water
Mulinuu	60	25	17	28.3%	68.0%
Moataa	30	16	6	20.0	37.5
Vaiala	30	4	0	0	0
Samea	6	1	0	0	0
Faailoloo	10	9	0	0	0
Lalovi	10	2	0	0	0

In each *Pandanus* plant, the leaf axils are located from approximately one foot to six feet above the ground. The breeding species in each axil were vertically not even. In this connection, a special survey was made in *Pandanus* plant in three villages of Upolu Island. As shown in Table 4, it was found that *Ae. tutuilae* prefers upper axils of a plant.

During the control trial of larvae by DDT spraying to leaf axils of *Pandanus*, it was found that the prevalence of *Ae. tutuilae* in the axils was much higher in the post-control surveys than in the pre-control surveys. It can be understood that *Ae. tutuilae* larvae prefer newly-grown axils located in the upper part of a plant which are apparently not contaminated with insecticide applied before.

Seasonal prevalence of the breeding species in leaf axils of *Pandanus* was studied on a triweekly basis in 23 registered plants during the period July 1970 to June 1971, covering a whole year. As shown in Table 5, no remarkable seasonal prevalence was observed

so far, except a slight increase in *Ae. Samoanus*, at the expense of *Ae. tutuilae* and *Ae. oceanicus*. It should be pointed out that the plants under observation during the year round period were undergoing growth and developmental changes.

Freycinetia plant: *Freycinetia* is a creeping plant common in forested area of both Upolu and Savaii Islands of Western Samoa. Each leaf axil of the plant holds a small amount of water enough to harbour only one or two mosquito larvae. Since each plant, sometimes even 10 to 20 meters high, has a numerous axils, the total number of mosquito larvae which can breed in one plant of *Freycinetia* may be tremendous.

All the larvae collected from *Freycinetia* axils were *Ae. samoanus*.

Taro and giant taro: Taro plant, *Colocasia* sp., as well as giant taro, *Alocasia* sp., is planted in and around every village in Western Samoa. These are essential staple food for the people of the country. The axils of taro and giant taro hold water and very often harbour mosquito larvae. Usually

Table 4 Vertical distribution of mosquito larvae in leaf axils of *Pandanus* plants

Location of axils from the top	No. of axils under survey	Total no. of larvae collected	Relative prevalence of each species (%)			Average no. of larvae per axil
			<i>Aedes samoanus</i>	<i>Aedes tutuilae</i>	<i>Aedes oceanicus</i>	
1st- 3rd	170	883	45.9	20.7	33.4	5.2
4th- 6th	142	503	51.3	5.0	43.7	4.2
7th- 9th	50	176	34.1	2.8	63.1	3.5
10th-12th	18	76	43.4	2.6	53.9	4.2
13th-15th	18	25	56.0	0	44.0	1.4
16th-18th	6	8	12.5	0	87.5	1.3
Overall	404	1671	46.1	12.9	41.0	4.1

Table 5 Results of a whole year survey of mosquito larvae in the 23 registered *Pandanus* plants

Date	No. of surveys made	Total no. of larvae collected	Relative prevalence of each species (%)			
			<i>Aedes samoanus</i>	<i>Aedes tutuilae</i>	<i>Aedes oceanicus</i>	<i>Aedes polynesiensis</i>
Jul-Sep 1970	5	2775	79.1	9.2	11.7	0
Oct-Dec 1970	4	1991	83.6	11.9	4.5	0
Jan-Mar 1971	4	1491	88.3	7.9	3.8	0
Apr-Jun 1971	5	2042	94.0	2.9	3.0	0.1
Overall	18	8299	85.5	8.1	6.4	0.02

more larvae are found in the axils of giant taro than those of taro, because of its capability to hold more water. Since no difference of breeding species between two kinds of the plants was observed, the results were combined.

Almost all the mosquito larvae (99.97 %) in the leaf axils of taro and giant taro were *Ae. oceanicus*. A small number of *Ae. polynesiensis* and *Ae. samoanus* were also collected. It is open to question whether *Ae. samoanus* really breeds in the axils, since the larvae used to stick to the inside wall of collecting pipette and might be contaminated to the other collecting bottles.

Pineapple plant: It is rather difficult to find water in leaf axils of pineapple plant enough to harbour mosquito larvae, since they are planted in the sun and their axils are small.

Only *Ae. oceanicus* larvae were found in the axils.

DISCUSSION

1. Breeding habits and distribution of *Stegomyia* mosquitoes

In Western Samoa, the larvae of *Aedes* (*Stegomyia*) mosquitoes breed in artificial and natural containers or collections, but rarely in leaf axils of plants.

It can be concluded that in Western Samoa *Ae. aegypti* is the preferable breeder in artificial containers, especially drums, tyres and motor parts in the close proximity of houses. They were found all over the country, not only in the populated and civilized town area such as Apia, but also in the rural and inland areas of Savaii Island.

Ae. polynesiensis seems to be a plastic species, breeding in a wide range of both artificial and natural containers, but preferable breeder in natural containers. They are the only species breeding in crab holes, and are the predominant breeder in tree holes, coconut shells, rock holes, canoes and tin cans. They were collected also from leaf axils of *Pandanus* and taro plants, but the number was very small.

Since *Ae. aegypti* and *Ae. polynesiensis* breed together in such habitats like drums and tyres, the single-larva-per-container

survey method tends to underestimate the population of either one.

Adult density of *Ae. polynesiensis* is rather high all over the country, except in the inland high altitude areas far from human activities, where neither artificial containers nor coconut trees are present. Its density is extremely high in the coastal areas with positive crab holes, sometimes reaching the density of 400 to 500 mosquitoes per man hour on human bait. In such areas, crab holes may play a major role producing the adult population of *Ae. polynesiensis*.

Unlike the other two *Stegomyias*, *Ae. upolensis* larvae were rarely collected, partly because the present collections were made mainly in the close proximity of human activities. This species is undoubtedly a forest mosquito. The role of *Ae. upolensis* in actual transmission of the filariasis is open to question, since man-mosquito contact might be much less than *Ae. polynesiensis* or *Ae. samoanus*.

2. Breeding habits and distribution of *Finlaya* mosquitoes

In Western Samoa, all the three *Aedes* (*Finlaya*) mosquitoes are exclusive breeders in leaf axils of plants, and each species has their favourite plant(s). *Ae. samoanus* larvae are the only species breeding in *Freycinetia* axils. They also breed in *Pandanus* axils, but abundantly only on Upolu Island. *Ae. tutuilae* larvae breed only in *Pandanus* axils, preferring young axils located in the upper part of the plant. This species is the minority of the three *Finlaya* mosquitoes. *Ae. oceanicus* larvae breed in taro, pineapple and *Pandanus* plants.

As mentioned above, *Pandanus* axils harbour, in general, three *Finlaya* mosquitoes, i.e. *Ae. samoanus*, *Ae. tutuilae*, and *Ae. oceanicus*. However, the breakdown of the three species in the axils is geographically inconsistent.

As shown in Table 6, *Ae. samoanus* was found predominantly in the *Pandanus* axils of Upolu Island, being 74.0 % of the total larvae collected. In Savaii Island, only 4.4 % was *Ae. samoanus*, and *Ae. oceanicus* was predominant (77.2 %). In addition, in the northern parts of Savaii, no *Ae. samoanus* larvae have ever been collected from the

Table 6 Geographical distribution of four species of mosquito larvae in leaf axils of *Pandanus*

Island	No. of bundles of <i>Pandanus</i> plants under survey	Total no. of larvae collected	Relative prevalence of each species (%)			
			<i>Aedes polynesiensis</i>	<i>Aedes samoanus</i>	<i>Aedes tutuilae</i>	<i>Aedes oceanicus</i>
Upolu	261	24981	0.16	74.0	7.8	18.0
Savaii	28	1578	0.8	4.4	17.6	77.2
Apolima	5	172	0	0	9.9	90.1
Manono	5	168	0	0	6.5	93.5
Overall	299	26899	0.2	69.0	8.4	22.4

axils so far ; and in the eastern and southern Savaii, *Ae. samoanus* larvae were present in the axils, but much less than *Ae. oceanicus* larvae. In two small islands of Apolima and Manono, which are located between Upolu and Savaii, no *Ae. samoanus* larvae were collected from the axils, *Ae. oceanicus* being predominant.

In Tutuila Island of American Samoa, which is located east of Upolu, it was reported by Ramalingam (1965, 1968) that *Ae. samoanus* larvae were never collected from *Pandanus* axils, although they were abundant in *Freycinetia* axils.

Therefore, the distribution of *Ae. samoanus* larvae in *Pandanus* axils seems geographically not gradual but patchy ; that is, from east to west, negative in Tutuila, positive and predominant in Upolu, negative both in Manono and Apolima, positive but scarce in the southern and eastern parts of Savaii, and negative in the northern parts of Savaii.

Taking into consideration that *Ae. samoanus* larvae breed in *Freycinetia* axils wherever the plant grows, it is presumed that the original breeding sites of *Ae. samoanus* might be *Freycinetia* axils and only the ecological or physiological colonies which have adapted to *Pandanus* can breed in their axils.

3. Role of *Freycinetia* and *Pandanus* axils in producing adult population of *Ae. samoanus*

As far as larvicidal application concerns, it is essentially needed to know what habitat plays a major role for producing adult population. In this connection, the following observations on the density of

female *Ae. samoanus* may be informative.

(1) High density of *Ae. samoanus* was observed in inland villages which are located more than 100 meters away from the coast, than in coastal villages. Average density of *Ae. samoanus* per man hour was 61.0 in 47 stations of coastal villages ; and 169.8 in 37 stations in inland villages.

(2) High density of *Ae. samoanus* was also observed in the stations close to forests, than those far from the forests. Average density per man hour was 159.5 in 54 stations less than 500 meters away from forests ; and 17.9 in 30 stations more than 500 meters away from forests. (In this case, the "forests" mean the areas marked as "bush" on the 1:20,000 map of Western Samoa.)

(3) Although no or scarce breeding of *Ae. samoanus* was observed in *Pandanus* axils of Savaii Island, density of *Ae. samoanus* was higher in Savaii, which is covered, in general, by more dense forests than Upolu Island. Average density per man hour was 502.3 in 14 stations of Savaii, while 108.9 in 84 stations of Upolu.

(4) Even in the northern parts of Savaii, where no *Ae. samoanus* breeds in *Pandanus* axils, high density of *Ae. samoanus* was recorded.

Taking the above observations into consideration, it can be presumed with reasonable certainty, if not definitely, that, for producing adult population of *Ae. samoanus*, *Freycinetia* might play a major role, at least in the areas less than 500 meters away from forests. Unfortunately, most of the villages of Western Samoa are located in the above-mentioned areas. It should be pointed out that *Freycinetia* axils are one of the most

difficult habitats to be treated by larvicide, because the plant grows in forests and the axils are found as high as 20 meters above the ground.

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摘 要

西サモアにおけるフィラリア症および
デング熱媒介蚊の発生源に関する知見

1969年から1971年に至る間、南太平洋西サモア国において、フィラリア症の媒介蚊 (*Aedes (Stegomyia) polynesiensis*, *Ae. (S.) upolensis*, *Ae. (Finlaya) samoanus*) およびデング熱の媒介蚊 (*Ae. (S.) aegypti*) の発生源について、広範な調査を行なった。*Ae. aegypti* は家屋周辺の人工容器から発生し、樹洞からの発生はきわめてわずかであった。この種は、内陸部や僻地も含め、西サモア国の全域で発生が認められた。*Ae. polynesiensis* は、人工および自然容器の両方に発生が認められるが、後者をより好むようである。カニの穴にはもっぱらこの種だけが生息する。上述の両種は、同一の発生源に共存することが多く、したがって、いわゆる“一発生源一匹採集法”による調査では、どちらの種も分布を過少評価するおそれがある。

Ae. upolensis は森林の蚊であり、その幼虫は樹洞から1度採集されたにすぎない。

Freycinetia の葉鞘からは、*Ae. samoanus* のみが発生し、タロとパイナップルの葉鞘からは、*Ae. oceanicus* のみが発生する。この両種は、また、*Pandanus* の葉鞘からも発生するが、*Ae. tutuilae* は、*Pandanus* の葉鞘が唯一の発生源である。