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Seasonal abundance, diel biting activity and parity of *Aedes polynesiensis* Marks and *A. samoanus* (Grünberg) (Diptera: Culicidae) in Samoa

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Abstract

The seasonal abundance, biting cycle, age composition and survival of females of *Aedes polynesiensis* Marks and *A. samoanus* (Grünberg), the major vectors of subperiodic bancroftian filariasis, were studied in Samoa. *A. polynesiensis* density was low during the high rainfall months and increased immediately following them. *A. samoanus* density showed no clear relation to rainfall. *A. polynesiensis* was active throughout the day, with peaks indoors and out at 08.00–09.00 h and 16.00–18.00 h. The nulliparous and parous populations showed similar patterns of activity. The biting cycles of 2-parous and 3- plus 4-parous females were asymmetric with time. *A. samoanus* was active throughout the night, with highest activity at 23.00–01.00 h. A minor peak at 19.00–20.00 h was more pronounced among older females than among younger ones. Night biting by *A. polynesiensis* and day biting by *A. samoanus* were rare. The parous proportion of *A. polynesiensis* ranged from 36·3 to 59·5% and the epidemiologically significant 3- plus 4-parous proportion ranged from 1·0 to 6·7%. The parous proportion of *A. samoanus* was 37·9–49·7% and the 3- plus 4-parous proportion 1·4–2·6%. The proportions found to be parous in both vectors were generally higher in the cool than the warm season, suggesting higher daily survival during that period.

Introduction

Although filariasis due to subperiodic *Wuchereria bancrofti* is one of the most important public health problems in Samoa, there are only two reports on the ecology of the vectors, *Aedes polynesiensis* Marks and *A. samoanus* (Grünberg), by Ramalingam (1968) and Suzuki & Sone (1974). Two of the objectives of the WHO Samoa Filariasis Research Project were to study the ecology and bionomics of the vectors and conduct vector control trials to determine the most effective and feasible methods of control that would supplement drug administration. Mass administration of diethylcarbamazine citrate (DEC-C) leaves a residual human population showing low levels of microfilaraemia in the peripheral blood (Desowitz & Southgate, 1973). It has been shown that these carriers can result in infective larvae developing in the local vector mosquitoes (Bryan & Southgate, 1976; Samarawickrema *et al.*, 1985*a*). The studies reported here were carried out between December 1977 and May 1979.

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Materials and methods

Study area

Samoa is the large and westerly part of the 483-km (300-mile) long Samoan archipelago in central Polynesia. It lies between 13 and 15°S and 171 and 173°W. The islands are of volcanic origin with most of the coastal areas surrounded by coral reefs. The central part of the two major islands, Upolu and Savai'i, is mountainous, the highest point of the former, where the study was carried out, being 1090 m (3600 ft) and its area about 1100 km^2. The population of Upolu is about 109 000. The people live in villages, most of which are situated along the coast. Their houses are open and without walls.

Samoa has a tropical rain forest climate with two seasons, a wet and warm season from December to May and a relatively drier and cooler season from June to November. However, the seasonal variation in temperature is slight, with a mean annual temperature in the coastal area of 27°C. The mean relative humidity ranges from 80 to 85% during the year. Rainfall varies considerably with location and time. The annual rainfall in the north-westerly part of Upolu is about 2300 mm (90 in.).

Four villages were selected on Upolu within easy reach of the capital, Apia (Fig. 1). Two of the villages are coastal, Vailu'utai 30 km west and Luatuanu'u 15 km east of Apia on the main trunk road running along the northern coast. Coconuts are grown as a cash crop and home gardens are planted with banana, breadfruit and cocoa. Luatuanu'u is surrounded by a natural barrier consisting of a mountain range behind. Vaipapa is a small village isolated within a vast coconut plantation situated about 4 km inland from Vailu'utai. Lalomauga is an inland village 35 km south-east of Apia situated at the foot of a mountain with dense jungle adjacent. Breadfruit, banana and coconut are cultivated.

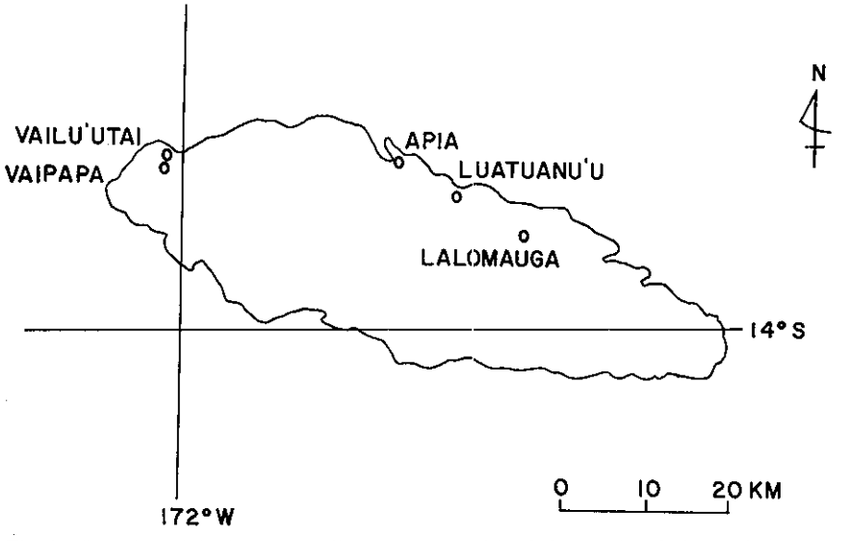

Fig. 1.—Location of the four study villages on Upolu island, Samoa, in relation to Apia.

Mosquito collections

Biting catches of ten minutes at each site.—Mosquitoes landing on a man were collected for a period of ten minutes at a given site. Collections were made in the mornings from 08.30 to 10.30 h and in the afternoons from 16.00 to 18.00 h for *A. polynesiensis* and at night from 19.30 to 21.30 h for *A. samoanus*. Two collecting teams, each consisting of a collector and the bait, worked simultaneously in each half of the village.

The teams worked in pairs, one team collecting inside the house and the other outdoors, either in the bush when present, or under the shade of a tree within 50 m of the house. Mosquitoes collected at each site were placed in separate paper cups. After ten minutes of catching, the teams moved to another house and a corresponding outdoor site. Each team worked in six sites at a time. Thus, in a typical survey, collections were made in 12 houses and in 12 corresponding outdoor sites evenly distributed through the village. Night-time catches for *A. samoanus* were made indoors only in 24 houses. One morning catch and one afternoon catch were carried out each month in Vailu'utai and Vaipapa, while one morning catch and one night-time catch were carried out in both Luatuanu'u and Lalomauga from December 1977 to November 1978.

Twelve-hour daytime and twelve-hour night-time biting catches.—Catches from shortly before 06.00 to 18.00 h (daytime) and from shortly before 18.00 to 06.00 h (night-time) (*cf.* Haddow, 1954) were carried out once a month at a single selected site in Vailu'utai and Luatuanu'u. In each team, one man captured mosquitoes landing on the other who was stripped to the waist and remained seated. During the daytime catch, one team worked inside a house while another was in the bush less than 50 m away. During the night-time catches, no outdoor collections were made and both teams collected inside the house. The catches commenced in December 1977 and continued until May 1979 in Vailu'utai and until December 1978 in Luatuanu'u.

Dissection

The *A. polynesiensis* females taken in the daytime catches and *A. samoanus* and *Culex quinquefasciatus* Say females taken in the night-time catches were dissected for filarial infections, the results of which are published elsewhere (Samarawickrema *et al.*, 1987). Five to fifteen specimens from each site in the ten-minute catches or each hour from 12-h catches were dissected by the senior author for age grading by the Polovodova method of counting the number of dilatations in the ovarioles (Detinova, 1962). Before carrying out these dissections routinely, it was confirmed with both laboratory-bred and wild-caught females of *A. polynesiensis* and wild-caught females of *A. samoanus* that a single complete blood-meal resulted in oogenesis and that, following oviposition, a dilatation was formed at the site of the former follicle.

Analysis

For the analysis of the activity cycle of *A. polynesiensis*, only Vailu'utai data were considered since the density of this species in Luatuanu'u was consistently low. By dissection of a sample from each hourly catch or of the total catch when this was small, the proportions of nulliparous, 1-parous, 2-parous and 3- plus 4-parous females in the sample were found, as well as the total number caught, and the total numbers of females in each age group were estimated. The Williams' means of the hourly values were calculated for the monthly 12-h catches carried out during the year. The data from Luatuanu'u were analysed similarly to give the activity cycle of *A. samoanus*.

Results

Mosquitoes collected

The numbers collected per man-hour of the two vector species in the 10-min catches per site at different times in the four villages and in the 12-h daytime and 12-h night-time catches in two villages are given in Table I. *A. polynesiensis* was the predominant species taken in all four villages in the morning and afternoon (10-min) catches. Its density was highest in Vailu'utai and Lalomauga and lowest in Luatuanu'u. The outdoor density was six to eight times higher than the indoor density in Vailu'utai and twofold higher in Lalomauga. The afternoon catch was higher than the morning catch in Vailu'utai but not in Vaipapa. In the night-time collections, *A. samoanus* was the predominant species, constituting about 75–80% of the total mosquitoes taken in both Luatuanu'u and Lalomauga.

TABLE I. *Number of* Aedes polynesiensis *and* A. samoanus *taken per man-hour on human bait in 10-min catches in four villages and in 12-h catches in two villages*

	10-min catches				12-h catches			
Village	Catch time*	*A. polynesiensis*		*A. samoanus*	Catch Time*	*A. polynesiensis*		*A. samoanus*
		Indoors	Outdoors	Indoors		Indoors	Outdoors	Indoors
Vailu'utai	M	11·9	66·3	0	D	4·6	28·8	0
	A	16·9	138·0	0	N^2	0·6	—	2·7
Luatuanu'u	M	4·5	10·5	0	D	3·4	8·2	0
	N^1	0·8	—	79·2	N^2	0·6	—	38·6
Vaipapa	M	10·5	13·6	0		—	—	—
	A	10·0	13·0	0		—	—	—
Lalomauga	M	21·8	48·0	0		—	—	—
	N^1	4·9	—	75·4		—	—	—
Totals		2090	6147	1971		1789	7732	11873

* M, Morning (08.30–10.30 h); A, Afternoon (16.00–18.00 h); N^1, Night (19.30–21.30 h); N^2, (18.00–06.00 h); D, Day (06.00–18.00 h).
— = Not carried out.

In the 12-h catches, the numbers of the two species varied widely in the two villages despite both of these being situated by the coast. There were consistently high numbers of *A. polynesiensis* in Vailu'utai and high numbers of *A. samoanus* in Luatuanu'u throughout the year.

Seasonal abundance

The mean monthly numbers per man-hour from the morning 10-min collections in the four villages in relation to rainfall are shown in Fig. 2. The rainfall patterns in the four villages followed similar trends and are averaged in the figure. There was high rainfall during January and March followed by a relatively dry period until October and November. Broadly, the density of *A. polynesiensis* was low at times of high rainfall and increased immediately thereafter. Thus, there was an increase in density in February and April and again in December in all four villages. While the densities decreased during the dry months in Vailu'utai and Vaipapa, that in Lalomauga remained high. This was probably due to the numerous tree holes there serving as breeding sites during dry months. Rainfall appeared to have little effect on the densities of *A. samoanus*, which breeds in leaf axils of plants belonging to the Pandanaceae.

Diel biting activity

A. polynesiensis commenced biting at daybreak and continued throughout the day until dusk, with a slight peak at 08.00–10.00 h and a rather more pronounced one at 16.00–18.00 h (Fig. 3). Indoor and outdoor trends of biting were similar. The nulliparous population and the whole parous population followed the same pattern of activity as the total population, suggesting that the peaks were composed of similar proportions of nulliparous and parous females. The 2-parous and especially the 3- plus 4-parous fractions displayed more marked morning and evening peaks.

Only 62 *A. polynesiensis* females were taken in Vailu'utai and 41 in Luatuanu'u after nightfall (between 19.00 and 06.00 h). These constituted 1·1 and 2·6%, respectively, of the total number of *A. polynesiensis* collected during the year in all the 12-h catches in each village. Although these numbers would theoretically increase the opportunity to pick up an infection, they were too low to contribute to transmission significantly.

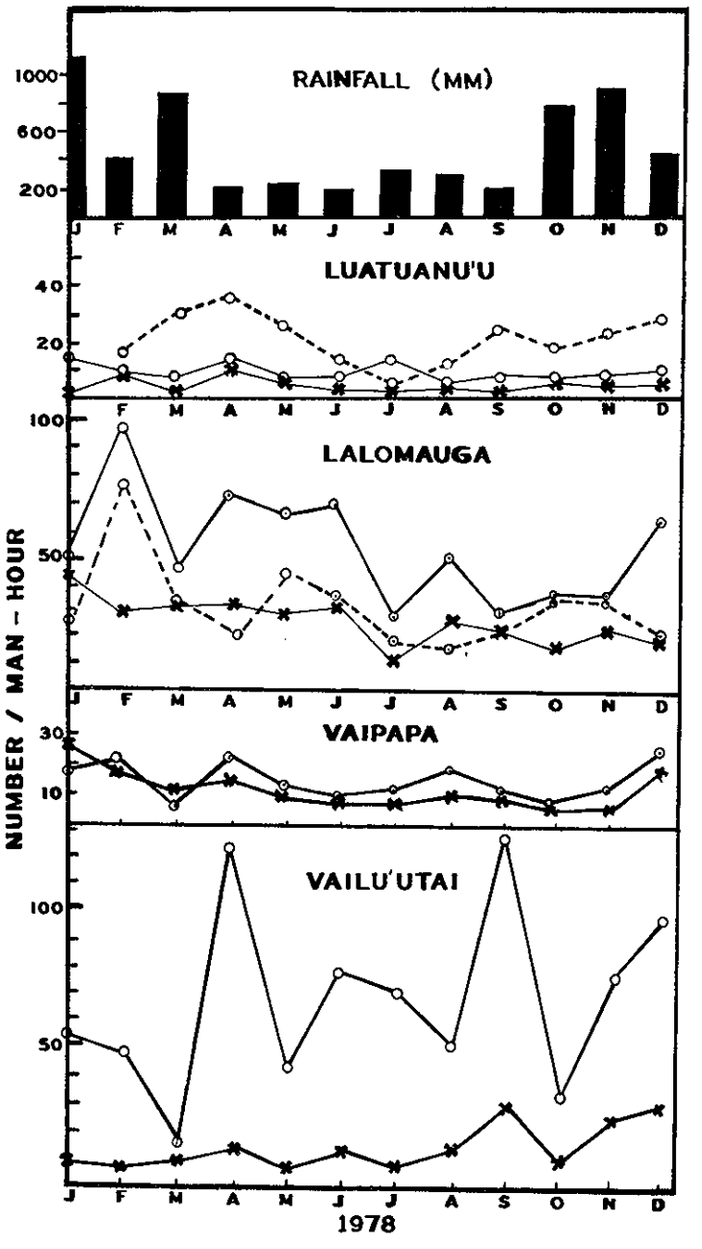

Fig. 2.—Mean monthly numbers of females per man-hour from 10-min catches in the mornings (*Aedes polynesiensis*) (solid line) and at night (*A. samoanus*) (broken line) in the study villages in relation to rainfall. (○———○, Outdoors ×———×, indoors.)

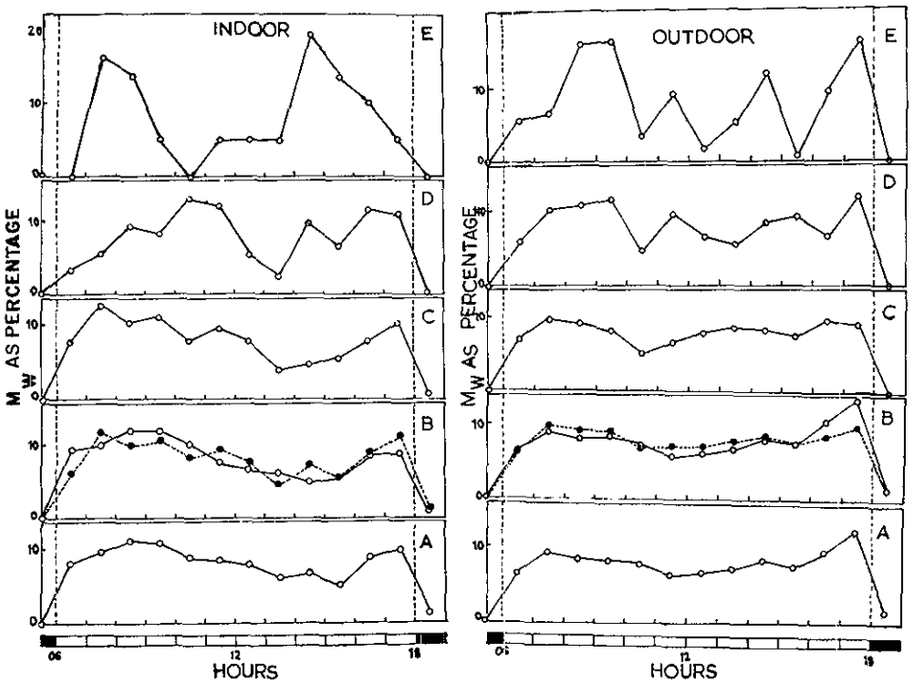

Fig. 3.—Biting cycle of *Aedes polynesiensis* females indoors and outdoors at Vailu'utai; (*A*) total population; (*B*) nulliparous (solid line) and parous females (broken line); (*C*) 1-parous; (*D*) 2-parous; (*E*) 3- plus 4-parous females. (M_W = Williams mean.)

A. samoanus showed continuous activity throughout the night with peak biting at 23.00–01.00 h (Fig. 4). There was also a minor peak at 19.00–20.00 h. The nulliparous and 1-parous populations exhibited the same trends, although the nulliparous peak was one hour later at 01.00 h. The minor peak at 19.00–20.00 h became progressively more pronounced in older mosquitoes. It would appear that a higher proportion of parous females was active during this hour than is indicated in the curve for the total parous population. Only ten females of *A. samoanus* were taken at Luatuanu'u and none in Vailu'utai during the day.

Age composition

During the twelve-month period from December 1977 to November 1978 5341 *A. polynesiensis* females were age graded; 2584 (48·4%) were from the four villages in the 10-min catches at different sites and 2757 (51·6%) from the two coastal villages in the all-day (12-h) catches. Monthly data for each village and the warm and cool seasons are given in Table II. Those for Vailu'utai and Luatuanu'u include the numbers both from 10-min catches and all-day catches. Except for the indoor collections in Vailu'utai, the percentage parous in the villages was higher in the cool than in the warm season. The population was oldest in Vaipapa where breeding sites were limited to 200-litre (44 gal) drums and coconut shells. The proportions of potentially infective 3-parous and older females (Samarawickrema *et al.*, in press) ranged in all villages between 1·0 and 7·1% indoors and between 2·1 and 4·5% outdoors.

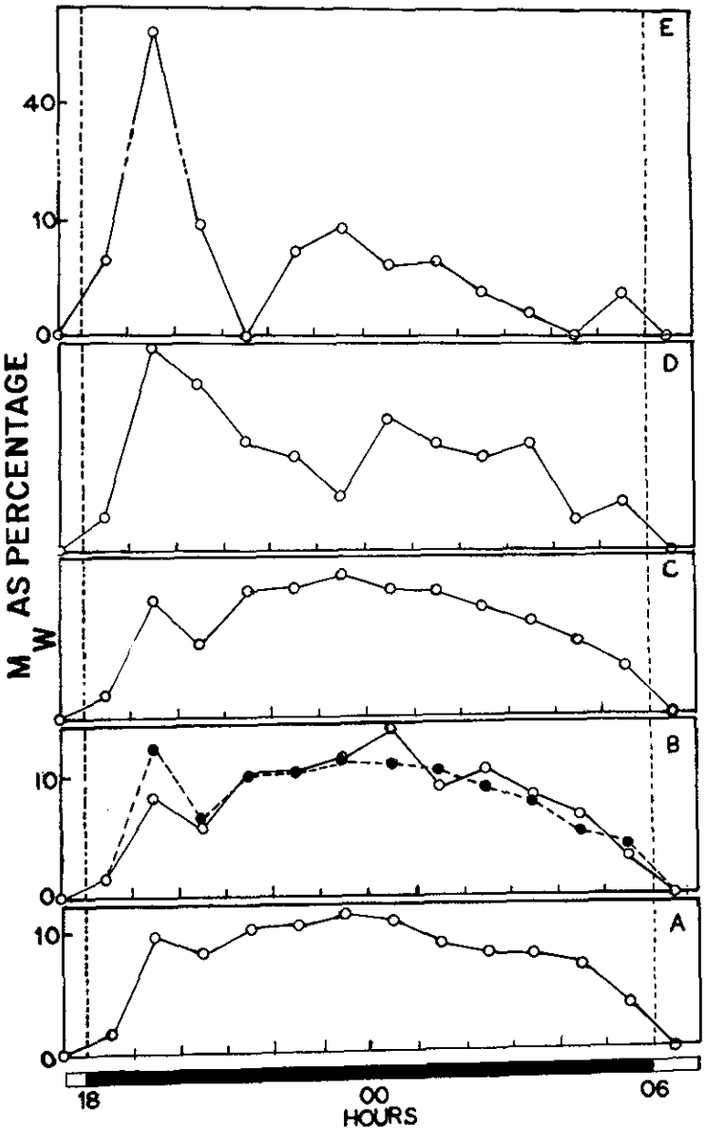

Fig. 4.—Biting cycle of *Aedes samoanus* females indoors at Luatuanu'u; (*A*) total population; (*B*) nulliparous (solid line) and parous females (broken line); (*C*) 1-parous; (*D*) 2-parous; (*E*) 3- plus 4-parous females. (M_W = Williams mean.)

TABLE II. *Age composition of females of* Aedes polynesiensis *taken in the four study villages during the warm season (December 1977–May 1978) and the cool season (June–November 1978)*

Season	Indoors						Outdoors					
		% in age group:						% in age group:				
	No. diss.	N	1	2	3	4	No. diss.	N	1	2	3	4
Vailu'utai												
Warm	226	47·3	33·6	12·4	5·8	0·9	759	55·7	28·1	11·7	3·7	0·8
Cool	339	48·6	36·4	13·0	1·8	0·2	1162	53·7	31·2	11·4	3·5	0·2
Luatuanu'u												
Warm	207	56·5	30·4	10·1	3·0	0·0	320	56·6	26·9	12·2	4·1	0·2
Cool	195	50·2	33·8	13·1	2·7	0·0	468	53·2	32·7	11·3	2·2	0·6
Vaipapa												
Warm	96	49·0	37·5	12·5	1·0	0·0	118	50·8	33·9	11·9	2·5	0·8
Cool	79	40·5	48·1	10·1	1·3	0·0	122	48·8	31·9	16·4	2·5	0·8
Lalomauga												
Warm	173	63·5	26·0	8·7	1·2	0·6	318	63·8	24·5	8·5	2·8	0·3
Cool	172	47·7	34·9	14·5	2·3	0·6	301	50·5	31·9	14·6	3·0	0·0

A total of 3413 *A. samoanus* females was age graded, 1091 (32·0%) of which were taken in the 10-min catches in Luatuanu'u and Lalomauga, and 621 (18·2%) and 1701 (49·8%) taken in all-night catches in Vailu'utai and Luatuanu'u, respectively. The results totalled for the two seasons are given in Table III. The age composition showed higher rates of parity during the cool season than the warm one in all three villages.

TABLE III. *Age composition of females of* Aedes samoanus *taken indoors in three villages during the warm season (December 1977–May 1978) and the cool season (June–November 1978)*

Season	No. dissected	% in age group:				
		N	1	2	3	4
Vailu'utai						
Warm	138	56·5	34·8	6·5	2·2	0·0
Cool	405	51·9	36·0	10·6	1·5	0·0
Luatuanu'u						
Warm	758	62·1	27·8	8·4	1·4	0·3
Cool	1307	61·6	29·2	7·7	1·4	0·1
Lalomauga						
Warm	223	59·6	27·8	10·8	1·8	0·0
Cool	376	50·3	36·2	10·9	2·1	0·5

Survivorship

From the age-composition data, the probability of survival over one day (p) for successive gonotrophic cycles of four days' duration was calculated using the methods of Davidson (1954) and Macdonald (1957). The range of probability of survival through two gonotrophic cycles of *A. polynesiensis* taken indoors and outdoors in the four villages is given in Table IV. On the whole, the survival was the same in the four villages. There was also no difference in the survival of females caught indoors and out. The data comparing the seasonal populations suggest slightly better survival in the cool season in three of the four villages than in the warm season.

Similar estimates were made for *A. samoanus* in Vailu'utai, Luatuanu'u and Lalomauga, and the range of probability of survival through two gonotrophic cycles is given in Table IV. Survival was enhanced in the cool season in all villages.

TABLE IV. *The range of probability of survival of* Aedes polynesiensis *females through two gonotrophic cycles, each lasting four days, in the four study villages during the warm season (December 1977–May 1978) and the cool season (June–November 1978)*

	Range of probability of survival through two gonotrophic cycles		
	A. polynesiensis		*A. samoanus*
Season	Indoors	Outdoors	Indoors
Vailu'utai			
Warm	0·835–0·793	0·818–0·800	0·812–0·737
Cool	0·828–0·768	0·813–0·790	0·833–0·768
Luatuanu'u			
Warm	0·814–0·744	0·830–0·798	0·785–0·751
Cool	0·835–0·837	0·879–0·773	0·787–0·742
Vaipapa			
Warm	0·845–0·779	0·838–0·791	
Cool	0·878–0·762	0·868–0·816	
Lalomauga			
Warm	0·777–0·754	0·776–0·764	0·797–0·772
Cool	0·850–0·803	0·839–0·805	0·840–0·779

Discussion

Of the standard procedures for sampling populations of adult mosquitoes, the one suitable for *A. polynesiensis* and *A. samoanus* in Samoa is the human bait catch. In preliminary studies, indoor resting catches had given negative results even in the case of the nocturnal and endophagic *A. samoanus*. The catches of ten minutes' duration in 24 sites spread over a village provided a more representative sample of the vector populations and therefore were more acceptable for the study of their seasonal abundance than the 12-h catches made at a fixed site. Using 10-min catches, Jachowski (1954) found there was no seasonal variation in the density of *A. polynesiensis* in American Samoa. Suzuki & Sone (1974) in Samoa showed that the density of *A. polynesiensis* was positively correlated with rainfall. The present results broadly agree with those of Suzuki & Sone. In *A. samoanus*, there was no apparent relationship between density and rainfall.

The present findings on the diurnal activity cycle of *A. polynesiensis* agree closely with those of other workers (Jachowski, 1954; Ramalingam, 1968; Suzuki & Sone, 1974). The peak at 23.00 h of *A. samoanus* was also reported by Ramalingam (1968) in American Samoa. The technique adopted by Suzuki & Sone (1974) of catching for only 30 min in each hour in 12-h catches would not have given accurate hourly biting rates.

Ramalingam (1968) reported nocturnal activity by *A. polynesiensis* in American Samoa without giving details. Suzuki & Sone (1974) observed a density of 5·0/man-hour at midnight and 3·0 at noon in the same house. The present studies showed very low activity of *A. polynesiensis* between 19.00 and 06.00 h.

Hitchcock (1970) used the Polovodova method of age grading to find the age of infected females of *A. scutellaris* (Walker). The age of infective females of *A. polynesiensis* caught during the present studies has been described elsewhere (Samarawickrema *et al.*, 1987). Further, the age-composition data show there was better survival of the vectors during the cool than the warm season and that there was an early biting peak among older females of *A. samoanus*. These observations are of epidemiological interest and useful in planning control operations.

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