THE ECOLOGY OF ANOPHELINE MOSQUITOS IN NORTHWEST COASTAL MALAYSIA: LARVAL HABITATS AND ADULT SEASONAL ABUNDANCE

Zairi Jaal[1] and WW Macdonald[2]

[1]School of Biological Sciences, Universiti Sains Malaysia, Penang, Malaysia; [2]School of Tropical Medicine Liverpool, UK

Abstract. Collections of anopheline mosquitos were made twice monthly for 13 months from a cow-baited trap in two villages, Kampung Permatang Rawa and Sungai Udang Kecil, on mainland coastal Penang, Malaysia. Each collection period was six hours from sunset. Unquantified larval collections were made regularly in each area. Although the villages were only about 50km apart, and each had extensive, irrigated rice-fields in its vicinity, the species abundance and the seasonal fluctuations diffiered significantly. In Kampung Permatang Rawa *Anopheles sinensis* and *An. peditaeniatus* were dominant in prevalence, whereas in Sungai Udang Kecil *An. indefinitus* and *An. lesteri paraliae* were most common and *An. peditaeniatus* was relatively rare. The rice growing schedules in the two areas differed, but there was a moderate correlation between the abundance of several species and the rice-growing pattern. There was no correlation at either site with rainfall.

INTRODUCTION

In an earlier paper Jaal and Macdonald (1992) recorded the distribution of anopheline mosquitos at a series of collection sites along the coast of northwest Malaysia. Two of the nine sites, Kampung Permatang Rawa and Sungai Udang Kecil, were selected for a longer series of observations which occupied 13 months from April 1988. The objectives were to follow the changes in seasonal abundance of the anopheline populations and to relate any fluctuations to the availability of larval habitats and to climatic and environmental changes. Separate studies were made of the host preferences and the biting-cycles of the mosquitos, and these are reported separately (Jaal and Macdonald, 1993).

The two villages are situated nearly 50 km apart on the mainland of the State of Penang towards the southern end of the main rice-growing region of Malaysia. There are no pronounced wet and dry seasons in this region, only periods of greater or lesser rainfall. Generally March to May and September to December have the highest rainfall, and February and June are relatively dry, but there is considerable variation from year to year and from district to district. The mean monthly temperature is relatively constant at about 27°C.

Rice-growing practices greatly influence mosquito populations. In this region irrigation water is made available to the farmers in each district according to a predetermined and fixed pattern. This pattern usually allows two crops to be grown during the year, but individual farmers may elect to leave some of their fields fallow throughout one season.

MATERIALS AND METHODS

Study sites

The two sites have been briefly described before (Jaal and Macdonald, 1992). Kampung Permatang Rawa lies in the north of Penang State near the border with Kedah. Sungai Udang Kecil lies in the south on the border with Perak. In both areas there are extensive rice-fields inland of the villages, and bunds and tide-gates protect the cultivated land from inundation by sea-water.

The drains and ditches around the houses are often partially covered with *Eichhornia,* the water hyacinth, and when the rice-fields are flooded, such floating plants as *Hydrilla, Lemna, Salvinia, Azolla* and *Wolffia* are common in the fields.

In Kampung Permatang Rawa there are two seasons of rice cultivation. The second planting of

1987 began in September, when water was released into the fields, and the crop was harvested in February 1988. In March the next planting was started, and the harvest was in August. The second planting of the year was due in September, but many of the fields adjoining the village were left fallow, and no rice was planted until March 1989. However, fields situated 0.5 - 1.0 km away were cultivated on schedule.

In Sungai Udang Kecil the pattern was different. Owing to an inadequate water supply, there are generally only three crops of rice in a two-year period. In 1987 rice was planted in October and harvested in March 1988. The next planting was in May with harvesting in October. The fields were then not flooded until January 1989 and the crop was harvested by mid-June. However, within the district, different areas are irrigated in a staggered arrangement so that different stages of rice can be seen concurrently within a distance of a few kilometres.

Larval sampling

Larvae, and occasionally pupae, were collected using a standard 450ml plastic dipper with an extendable handle. Early instar larvae were grown in the laboratory and identified at the 3rd or 4th instar. Final instar larvae were allowed to pupate and the subsequent adults were identified. Fifteen collection visits were made to Kampung Permatang Rawa and 23 to Sungai Udang Kecil, but the larval collections were not quantified in any way.

Adult collections

Adult collections were made twice monthly at each village using a cow-baited net trap (Jaal and Macdonald, 1992). The trap was in operation for six hours from sunset, and at the end of each hour resting mosquitos were collected for 15 minutes. Collections made throughout the night had shown that more than 75% of the anophelines came to bite during the first six hours. Most of the collection was identified in the field, the remainder being brought back to the laboratory.

The two collections made each month were pooled, and the number (n) of each species was transformed to log (n + 1). The monthly value of each species was then plotted as a percentage of the summed log (n + 1) throughout the 13 - month collection period.

RESULTS

Since the larval habitats in and around each village seemed comparable, no distinctions are drawn between the collections made in the two areas. Table 1 summarizes the findings. Since the patterns of adult abundance differed markedly between the two collection sites, and since there was no apparent correlation between these pat-

Table 1

The larval habitats of anopheline species in Kampung Permatang Rawa and Sungai Udang Kecil.

Species	Larval habitats					
	Rice-fields	Irrigation canals	Grassy pools	Muddy pools	Ditches	Ponds
An. campestris	–	×	–	–	–	×
An.l. paraliae	–	×	×	–	×	×
An. peditaeniatus	×	–	–	–	–	–
An. sinensis	×	×	×	–	×	–
An. indefinitus	×	×	×	×	–	–
An. subpictus	–	×	–	×	–	×
An. vagus	–	×	×	×	–	–

terns and rainfall, adult fluctuations will be discussed in relation to the rice-growing schedules.

Anopheles campestris

An. campestris was not a common species at either village. Larvae are associated with clear, still water with light to moderate shade. It is not a noted rice-field breeder, but Thevasagayam *et al* (1979) recorded larvae from rice-fields on Penang Island as common. Larvae have been reported at the edges of the fields where the water is moderately deep and shaded. In Kampung Permatang Rawa collections were made in an irrigation canal and a pond. Although adult numbers were low, those in Kampung Permatang Rawa showed clear increases in months 3 and 4 of the first rice season and months 4 and 5 of the second (Fig 1), periods when the water level is relatively stable. In Sungai Udang Kecil the two comparable increases were during months 2 - 4 and 1 - 2 respectively (Fig 2), but only 60 mosquitos were collected over the 13-month period.

Anopheles lesteri paraliae

An. l.paraliae larvae were most common in ditches running alongside houses in Sungai Udang Kecil and in irrigation canals bordering the rice-fields. The habitats were usually shaded by trees or coconut and nipah palms. Floating and emergent vegetation was common. Adults were 10 times more common in Sungai Udang Kecil than in Kampung Permatang Rawa. In the latter village adult numbers peaked during

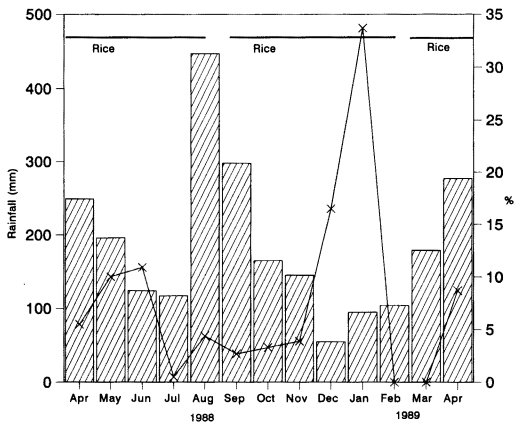

Fig 1—The seasonal fluctuations of *An. campestris* (n = 193) at Kampung Permatang Rawa in relation to rice-growing and rainfall (histogram)

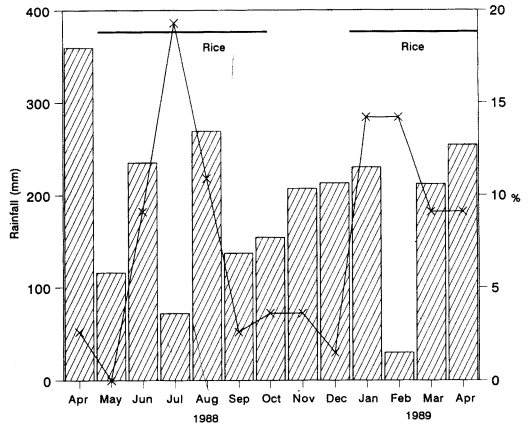

Fig 2—The seasonal fluctuations of *An. campestris* (n = 60) at Sungai Udang Kecil in relation to rice-growing and rainfall (histogram).

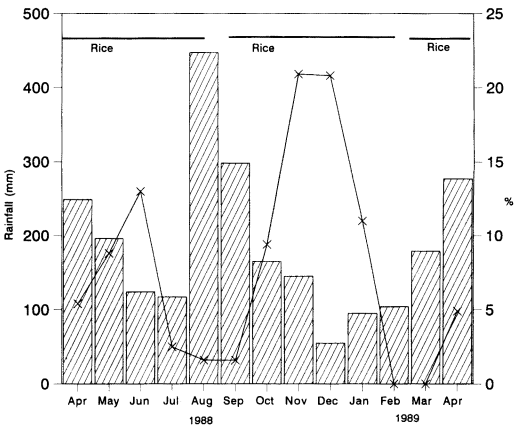

Fig 3—The seasonal fluctuations of *An.l.paraliae* (n = 263) at Kampung Permatang Rawa in relation to rice-growing and rainfall (histogram).

months 3 and 4 of both rice seasons (Fig 3) and in Sungai Udang Kecil there were peaks in month 3 and month 4 respectively of the two seasons (Fig 4).

Anopheles nigerrimus

No larvae of *An. nigerrimus* were collected, but Reid (1968) recorded the habitats as ponds and marshy areas well covered with floating plants. The habitats described by Harrison and Scanlon (1975) in Thailand are not unlike those previously described for *An.l.paraliae*. In India Russell and Ramanatha Rao (1940) and Ramachandra Rao (1984) recorded *An. nigerrimus* as a common rice-

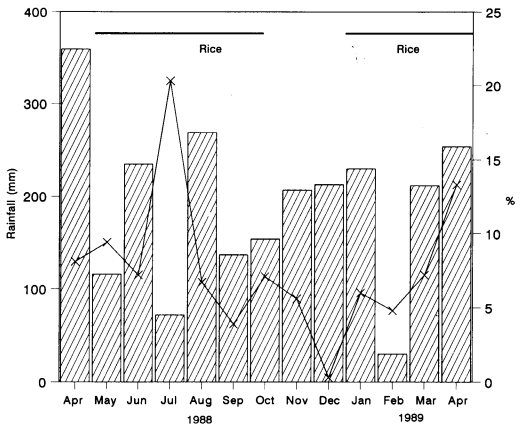

Fig 4—The seasonal fluctuations of *An.l.paraliae* (n = 2649) at Sungai Udang Kecil in relation to rice-growing and rainfall (histogram).

field species, especially when the rice was in the later stages of growth, but although larvae have been collected from rice-fields in Malaysia and Thailand, they were usually only from sites where the water was relatively deep and cool and under shade.

Adults were moderately common in both villages. In Kampung Permatang Rawa there were peaks in month 4 and months 3 and 4 of the two rice reasons (Fig 5), and in Sungai Udang Kecil the peaks were during months 2 and 3 in each season (Fig 6). In addition, however, in the latter village there was a third, intermediate peak after the end of the first season when the surrounding fields were dry. We have no explanation of this

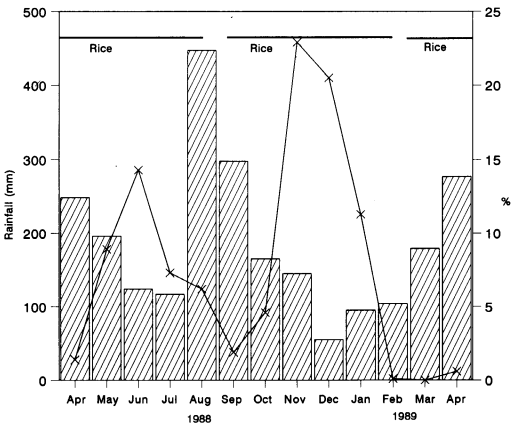

Fig 5—The seasonal fluctuations of *An. nigerrimus* (n = 982) at Kampung Permatang Rawa in relation to rice-growing and rainfall (histogram).

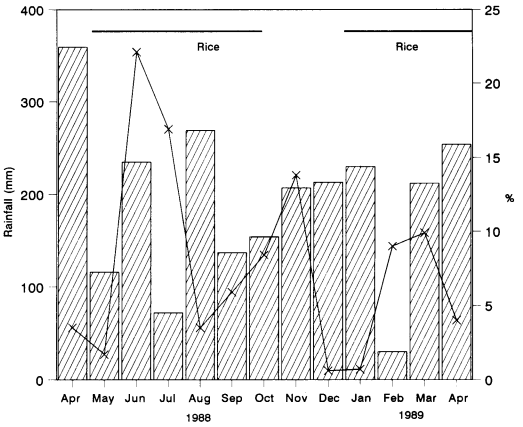

Fig 6—The seasonal fluctuations of *An. nigerrimus* (n = 739) at Sungai Udang Kecil in relation to rice-growing and rainfall (histogram).

peak, but it is noteworthy that about the same time there was a suggestion of an increases in *An. l.paraliae* (Fig 4) and a quite pronounced increase in *An. sinensis* (Fig 9). It may be that the mosquitos were immigrants from outlying fields which were still under cultivation, but there is no evidence to support a conclusion.

Anopheles peditaeniatus

Although recorded from a variety of habitats, *An. peditaeniatus* is a recognized rice-field species. Nevertheless, it was most uncommon in Sungai Udang Kecil, where only 32 adults were collected throughout the study. In Kampung Permatang Rawa, on the other hand, adults were common, and during the early months of the rice season, when the water level was high, larvae were col-

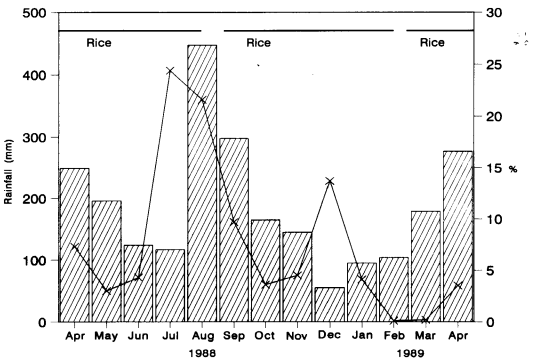

Fig 7—The seasonal fluctuations of *An. peditaeniatus* (n = 2068) at Kampung Permatang Rawa in relation to rice-growing and rainfall (histogram).

lected around the edges of the fields and close to the base of individual plants. The adult numbers did not peak until months 5 and 6 of the first season and month 4 of the second (Fig 7).

Anopheles sinensis

An. sinensis is a common and widely- distributed rice-field species, breeding also in exposed irrigation canals, grassy pools and ditches. In Kampung Permatang Rawa adults were very common with peaks of abundance in month 4 and 5 of each season (Fig 8). The pattern was not dissimilar to that of *An. peditaeniatus*. In Sungai Udang Kecil, on the other hand, there was a conflicting pattern, with clear peaks in month 2 of each season and a between-seasons peak (Fig 9) similar to that of *An. nigerrimus*.

Anopheles indefinitus

An. indefinitus larvae were collected from rice-fields but they were taken more commonly from freshwater grassy pools and irrigation canals. Some collections were made from a large muddy depression in Kampung Permatang Rawa 30m from the sea and from small muddy pools in Sungai Udang Kecil. In the latter sites the water was brackish and the larvae were associated with the closely-related *An. subpictus* and, less commonly, with *An. vagus*.

In Kampung Permatang Rawa *An. indefinitus* showed two peaks of abundance, a small one at the end of the first rice season and a more pronounced increase towards the end of the second (Fig 10). In Sungai Udang Kecil, where much larger numbers were collected, the first peak was during months 3 and 4 and the second during months 2 - 4 (Fig 11). In both villages there were similarities with the fluctuations of *An. subpictus*, but a much more quantitative study of larval habitats and adult production from those habitats is required to explain the seasonal changes.

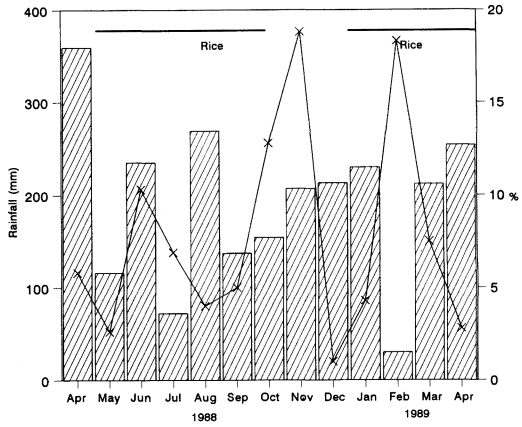

Fig 9—The seasonal fluctuations of *An. sinensis* (n = 1207) at Sungai Udang Kecil in relation to rice-growing and rainfall (histogram).

Anopheles subpictus

Most larval collections of *An. subpictus* came from muddy pools containing brackish water and lesser numbers were taken from the grassy edges

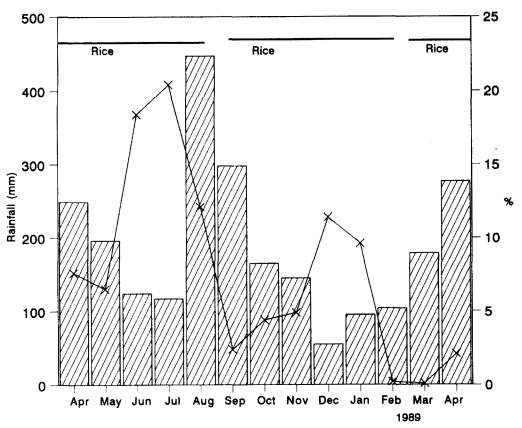

Fig 8—The seasonal fluctuations of *An. sinensis* (n = 4006) at Kampung Permatang Rawa in relation to rice-growing and rainfall (histogram).

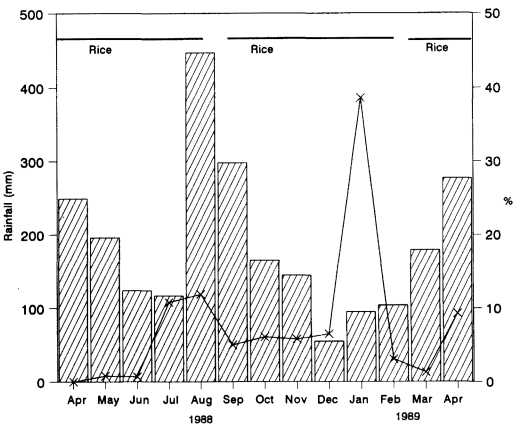

Fig 10—The seasonal fluctuations of *An. indefinitus* (n = 453) at Kampung Permatang Rawa in relation to rice-growing and rainfall (histogram).

of a large freshwater pond and from a canal that ran alongside a bund. As noted above, the adult fluctuations (Figs 12, 13) resembled those of the closely-related *An. indefinitus,* and Sungai Udang Kecil again supported much the larger population. In India there is clear cytogenetic evidence of two forms of *An. subpictus* (Suguna, 1982), one restricted to coastal brackish pools, the other more widespread throughout India in freshwater habitats. In coastal villages of Tamil Nadu both may be collected. Russell and Ramanatha Rao (1940) recorded the freshwater form as being very common in pools of water in fallow rice-fields, becoming much less common when the rice was planted and as it grew in height and the water became less turbid. No studies have yet been made in Malaysia on the cytogenetics of *An. subpictus,* but there is no ecological evidence of two forms.

Anopheles vagus

An. vagus was commonly found in freshwater grassy pools, but collections were also made in a large muddy depression with brackish water in Kampung Permatang Rawa, from irrigation canals, and occasionally with *An. subpictus* from small, brackish, muddy pools. In India Ramachandra Rao (1984) noted that *An. vagus* was not uncommon in rice-fields when the fields were freshly flooded and the water was turbid. It became less common after the rice had been planted. Sen (1948) recorded very heavy breeding in both ploughed and unploughed fallow fields in Bengal.

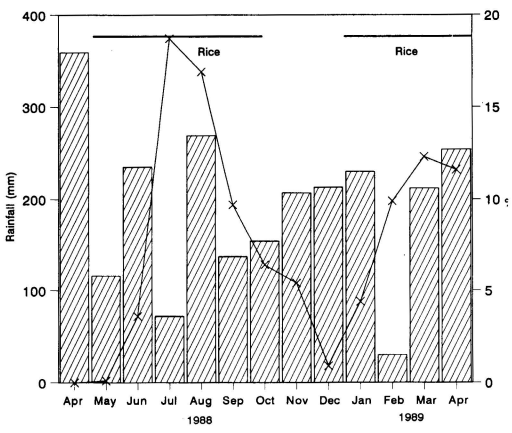

Fig 11—The seasonal fluctuations of *An. indefinitus* (n = 5877) at Sungai Udang Kecil in relation to rice-growing and rainfall (histogram).

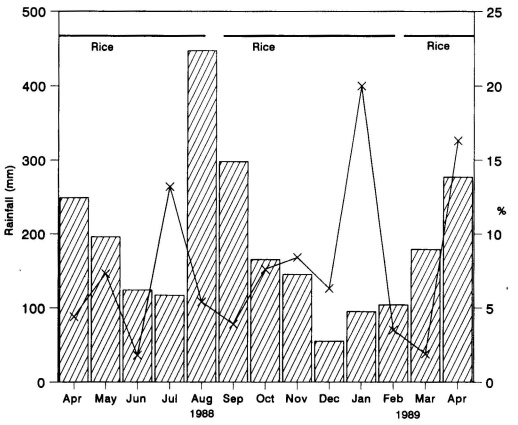

Fig 12—The seasonal fluctuations of *An. subpictus* (n = 518) at Kampung Permatang Rawa in relation to rice-growing and rainfall (histogram).

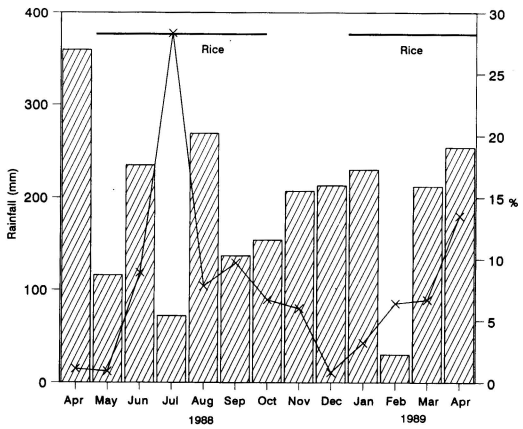

Fig 13—The seasonal fluctuations of *An. subpictus* (n = 1725) at Sungai Udang Kecil in relation to rice-growing and rainfall (histogram).

The patterns of adult abundance were quite different in the two villages. In Kampung Permatang Rawa, where good numbers were collected, there were two peaks, the first in the middle of the first rice-growing season, the other towards the end of the second (Fig 14). In Sungai Udang Kecil, where the catches were lower, *An. vagus* was collected in significant numbers only during the last three months of the study (Fig 15). There was no apparent relationship with rice growing.

DICUSSION

Although the two collecting sites were only about 50km apart and both had extensive rice-

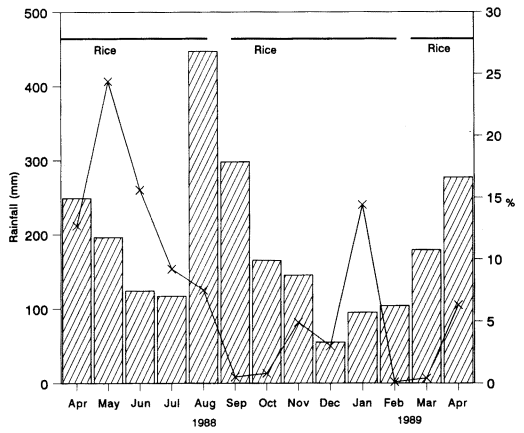

Fig 14— The seasonal fluctuations of *An. vagus* (n = 1662) at Kampung Permatang Rawa in relation to rice-growing and rainfall (histogram).

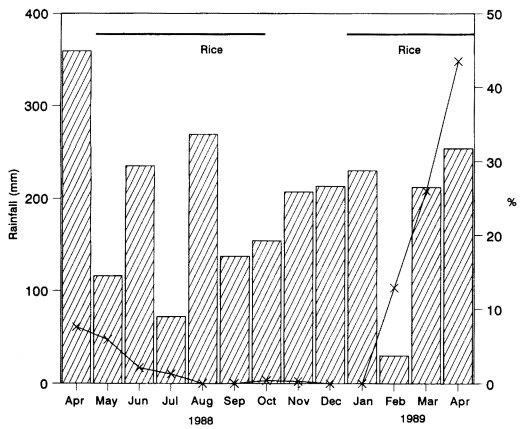

Fig 15—The seasonal fluctuations of *An. vagus* (n = 386) at Sungai Udang Kecil in relation to rice-growing and rainfall (histogram).

fields nearby, the relative numbers and the seasonal fluctuations of the mosquitos differed quite markedly. In Kampung Permatang Rawa the dominant species were *An. sinensis* and *An. peditaeniatus,* whereas in Sungai Udang Kecil they were *An. indefinitus* and *An.l.paraliae.* These differences are difficult to explain. There were perhaps more extensive areas under rice cultivation around Kampung Permatang Rawa, and at Sungai Udang Kecil there was a greater variety of vegetation and larval habitats. Nevertheless, the diffences between the collections were greater than expected. This was particulary so in the case of *An. peditaeniatus,* which is commonly associated with rice-fields, and which was very uncommon in Sungai Udang Kecil but abundant in Kampung Permatang Rawa.

It is clear that none of the species collected showed any correlation with rainfall, whereas most species showed a clear peak in abundance at one period of each rice-growing season. The peaks did not necessarily correlate precisely with the same month of each season, but by and large they were in good agreement. The interpretation of the data is made difficult at both sites owing to the rice-fields and irrigation canals not all being at the same stage at any one time. There can be a difference of several weeks in planting times among nearby fields.

The triple peaks in abundance of *An. nigerrimus* and *An. sinensis* at Sungai Udang Kecil contrast with the results from Kampung Permatang Rawa. At the time of the intermediate peak the nearby fields were fallow, but there were fields further distant in which rice was still growing. It may be that the mosquitos were immigrants from outlying areas, but the anomaly emphasizes the need for more detailed concurrent studies of larval populations. The differences between the adult fluctuations in the two villages show that the results of studies in one rice-growing area can not necessarily be applied to another.

ACNOWLEDGEMENTS

We are grateful to the technicians of the School of Biological Sciences, Universiti Sains Malaysia, who assisted with the mosquito collections. The rainfall data were kindly provided by the Malaysian Meteorological Services. The work received Support from the UNDP/World Bank/-WHO Special Programme for Research and Training in Tropical Diseases.

REFERENCES

Harrison BA, Scanlon JE. Medical entomology studies - II. The subgenus *Anopheles* in Thailand (Diptera: Culicidae). *Contrib Am Entomol Inst* 1975; 12 : 1 - 307.

Jaal Z, Macdonald WW. Anopheline mosquitos of northwest coastal Malaysia. *Southeast Asian J Trop Med Public Health* 1992; 23 : 479 - 85.

Jaal Z, Macdonald WW. The ecology of anopheline mosquitos in northwest coastal Malaysia: Host preferences and biting-cycles. *Southeast Asian J Trop Med Public Health* 1993; 24 : 530-5.

Ramachandra Rao T. The anophelines of India. New Delhi: Indian Council of Medical Research. 1984: 518 pp.

Reid JA. Anopheline mosquitos of Malaya and North Borneo. *Stud Inst Med Res Malaysia* 1968; 31 : 520 pp.

Russell PF, Ramanatha Rao H. The *Anopheles* of rice-fields in south-eastern Madras. *J Mal Inst India* 1940; 3 : 427 - 46.

Sen P. *Anopheles* breeding in the rice-fields of Lower Bengal: its relation with the cultural practices and with the growth of rice plants. *Indian J Malariol* 1948; 2 : 221 - 37.

Suguna SG. Cytological and morphological evidence for sibling species in *Anopheles subpictus* Grassi. *J Commun Dis* 1982; 14 : 1 - 8.

Thevasagayam ES, Chooi CK, Yap S. Studies on the biology of *Anopheles campestris* Reid (Diptera: Culicidae) and its response to residual spraying with DDT, carried out in experimental huts in Penang, Malaysia, *Med J Malaya* 1979; 34 : 117 - 30.