RELATIONSHIP BETWEEN RAINFALL AND *AEDES* LARVAL POPULATION AT TWO INSULAR SITES IN PULAU KETAM, SELANGOR, MALAYSIA

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Abstract. Two insular settlements (Kampung Pulau Ketam and Kampung Sungai Lima) were selected to study the population dynamics of *Aedes aegypti* and *Aedes albopictus* mosquitoes, vectors of dengue and chikungunya infections. Ovitrap surveillance was conducted between October 2007 and October 2008. There was an inverse negative association between ovitrap index and rainfall at the time of collection, probably because rainfall increased the number of available oviposition sites. Rainfall and ovitrap index were positively associates the 25th day after rainfall occurred. A minor, second peak was observed from the 38th to the 42nd day. The first peak was consistent with the minimum 18-day period between the hatching of eggs to the first oviposition. The second minor peak could be due to the second gonotrophic cycle of the female mosquitoes. Rainfall is an important environmental factor associated with *Aedes* breeding at the study sites.

Keywords: *Aedes aegypti, Ae. albopictus*, rainfall, population dynamic, Malaysia

INTRODUCTION

Aedes mosquitoes are the vectors for dengue and chikungunya infections and are endemic in Malaysia. Both diseases are transmitted by *Aedes aegypti* and *Aedes albopictus* (Nazni *et al,* 2008). In many *Aedes* mosquito-endemic regions, the mosquito populations exhibit a strong seasonal pattern associated with temperature and rainfall. Heavy rainfall is associated with mass egg hatching and an increase in the number of mosquitoes (Ndiaye *et al,* 2006). Rainfall has an impact on two factors important for arbovirus transmission: vector density and adult mosquito longevity (Diallo *et al,* 2003). While vector population densities are already high at the beginning of the rainy season, virus amplification occurs primarily at the end of the rainy season (Diallo *et al*, 2003). However, one retrospective study found no clear relationship between dengue infection emergence and rainfall in Senegal (Diallo *et al*, 2003).

Aedes endemic regions frequently experience a peak of the number of dengue infections during some months; these

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peaks coincide with the rainy season in Thailand and Vietnam (Bartley *et al*, 2002). Loh and Song (2001) in Singapore reported a significant positive relationship between dengue infection cluster size and the number of habitats positive for *Ae. aegypti*, as well as rainfall and the number of habitats positive for *Ae. albopictus*.

We studied the effect of rainfall on the breeding of *Aedes* spp at 2 insular sites on the island of Pulau Ketam, Malaysia.

MATERIALS AND METHODS

Study sites

Two townships in Pulau Ketam were selected for ovitrap surveillance: Kampung Pulau Ketam and Kampung Sungai Lima. Kampung Pulau Ketam has a population of 9,150 and Kampung Sungai Lima has a population of 1,540. Both townships are fishing villages. Most of the buildings are one or two storey terraced houses built with wood and cement. The buildings are situated near the sea and have poor drainage and scattered vegetation (plants in pots). These two townships are separated from each other by 2 km of mangrove forests and may be considered as insular sites.

Ovitrap surveillance

The ovitrap surveillance was conducted in accordance with the guidelines of the Ministry of Health, Malaysia (Tee *et al*, 1997). Three hundred milliliter black plastic containers (base diameter 6.5 cm, opening diameter 7.8 cm and height 9.0 cm) were used as ovitraps. An oviposition paddle (10 cm x 2.5 cm x 0.3 cm) was placed in each ovitrap container with a rough surface upwards; clean water was added to each container to a level of 5.5 cm.

Eighty ovitraps were placed indoors (inside houses) and outdoors (outside houses) (Lee, 1991) in locations randomly selected; their locations were plotted using a Global Positioning System (GPS). The traps were labeled and placed in potential breeding sites that would not be flooded or directly exposed to sunlight; near adult resting sites, such as dark corners, along walls, in vegetation or near ground level with minimum human or animal disturbances. After 7 days, the ovitraps were retrieved and the contents placed in plastic containers (16 cm x 11 cm x 7 cm). Tetramine® powder (fish food) was provided as larval food. The hatched larvae were counted and identified at the third or fourth instar using a compound microscope.

The rainfall and temperature data were obtained from the Malaysian Meteorological Department for the study areas. An independent *t*-test was used to evaluate the correlation between the distributions of *Ae. aegypti* and *Ae. albopictus* larvae and trap site. A p-value ≤ 0.05 was considered statistically significant. SPSS version 10 (SPSS, Chicaco, IL) was used for statistical analysis.

RESULTS

The rainfall data were obtained from nearest weather station to Pulau Ketam: Port Klang, 10 km away. Data from Port Klang shows two wet seasons in 2008: March to April and September to December (Fig 1).

Fig 2 shows the relationship between rainfall and the *Aedes* population in Kampung Pulau Ketam. The rainfall affected the *Aedes* population inversely; *ie*, the increase in rainfall was associated with a reduction in the *Ae. aegypti* and *Ae. albopictus* populations.

A negative association between

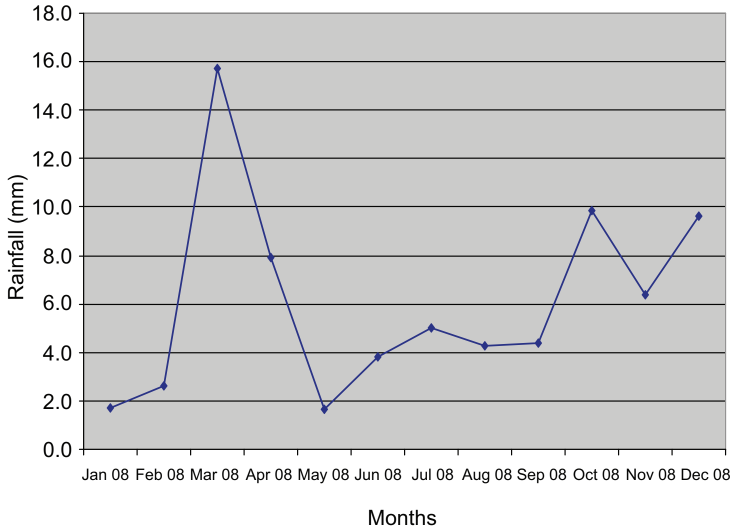

Fig 1–Mean monthly rainfall at Port Klang in 2008.

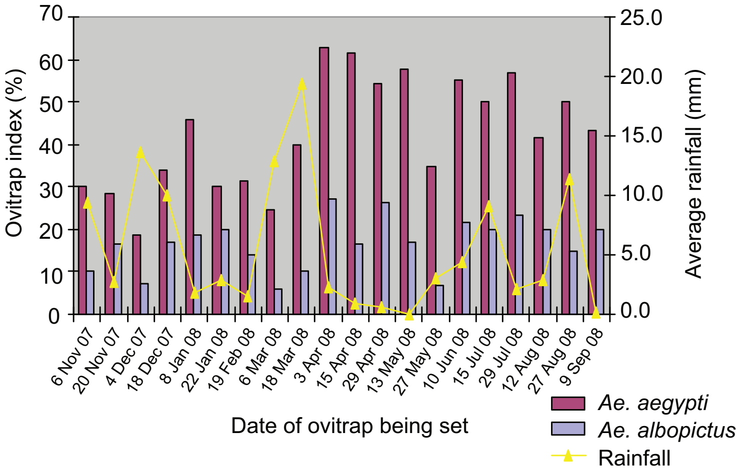

Fig 2–Ovitrap indices for *Ae. aegypti* and *Ae. albopictus* and average rainfall in Kampung Pulau Ketam.

rainfall and ovitrap index occurred in Kampung Pulau Ketam and a positive association occurred 25 days later for both *Ae. aegypti* and *Ae. albopictus*. Peaks occurred 38 and 41 days after the rains for *Ae. aegypti* and *Ae. albopictus* mosquitoes, respectively (Figs 3, 4). All correlations were significant ($p<0.05$) except the second peak with *Ae. albopictus* (Figs 5-7).

A direct inverse relationship between rainfall and ovitrap index also occurred immediately in Kampung Pulau Ketam for the outdoor environment. The positive association occurred 25 days later for both the indoor and outdoor ovitrap indices for *Ae. aegypti*. The indoor *Ae. albopictus* ovitrap index peaked 16 days later but the outdoor ovitrap index peaked 25 days later. Second peaks occurred among *Ae. aegypti* mosquitoes 35 and 38 days later, indoors and outdoors, respectively. The indoor *Ae. albopictus* mosquitoes did not have a second peak but the indoor *Ae. albopictus* ovitrap index peaked 39 days later (Figs 8, 9).

Tables 1 and 2 show the outdoor ovitrap indices were more significantly associaiton with rainfall for both *Aedes* species in Kampung Pulau Ketam. Rainfall had a significant association with the number of *Ae. albopictus* mosquitoes captured outdoors.

Fig 10 shows the relationship between rainfall and the *Aedes* population in Kampung Sungai Lima.

Similar to Kampung Pulau Ketam, there was a negative association between rainfall and the ovitrap index for *Ae. aegypti* in Kampung Sungai Lima. A positive association occurred after a 27 day lag

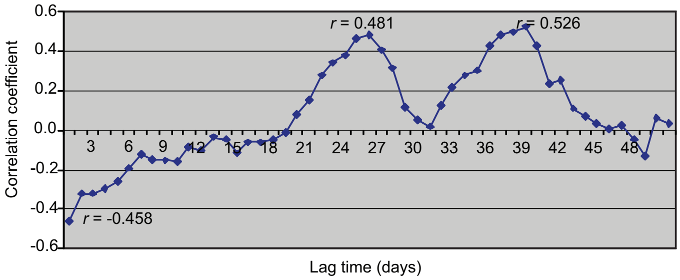

Fig 3–Association between *Ae. aegypti* ovitrap index and rainfall in Kampung Pulau Ketam.

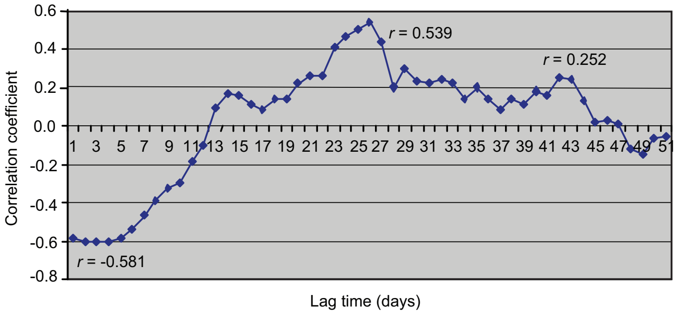

Fig 4–Association between *Ae. albopictus* ovitrap index and rainfall in Kampung Pulau Ketam.

time; a second positive association occurred after a 42 day lag time (Fig 11). However, only the first positive association was significant ($p<0.05$) in Kampung Sungai Lima (Figs 12-14).

There was a negative association between rainfall and ovitrap index for *Ae. aegypti* in Kampung Sungai Lima for both indoors and outdoors. Positive associations occurred after lag times of 27 and 28 days, indoors and outdoors, respectively.

A second positive association occurred after a lag time of 40 days for indoors and 44 days for outdoors (Fig 15).

Table 3 shows the outdoor ovitrap indices were more significantly correlated with rainfall

Table 1
Indoor and outdoor correlation coefficients for rainfall and ovitrap indices among *Ae. aegypti* in Kampung Pulau Ketam.

	Indoors		Outdoors	
	Correlation coefficient	Significance	Correlation coefficient	Significance
Current	-0.123	$p>0.05$	-0.545	$p<0.01$
First Peak	0.389	$p>0.05$	0.447	$p<0.05$
Second Peak	0.542	$p<0.01$	0.411	$p>0.05$

Table 2
Indoor and outdoor correlation coefficients for rainfall and ovitrap indices among *Ae. albopictus* in Kampung Pulau Ketam.

	Indoors		Outdoors	
	Correlation coefficient	Significance	Correlation coefficient	Significance
Current	-0.241	$p>0.05$	-0.617[a]	$p<0.05$
First Peak	0.265	$p>0.05$	0.723	$p<0.01$
Second Peak	-		0.433	$p<0.05$

[a]A lag time of 3 days

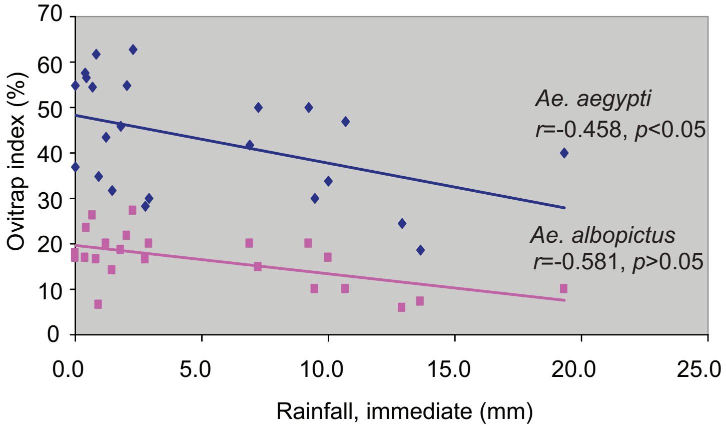

Fig 5–Ovitrap index per immediate rainfall for *Aedes* mosquitoes in Kampung Pulau Ketam.

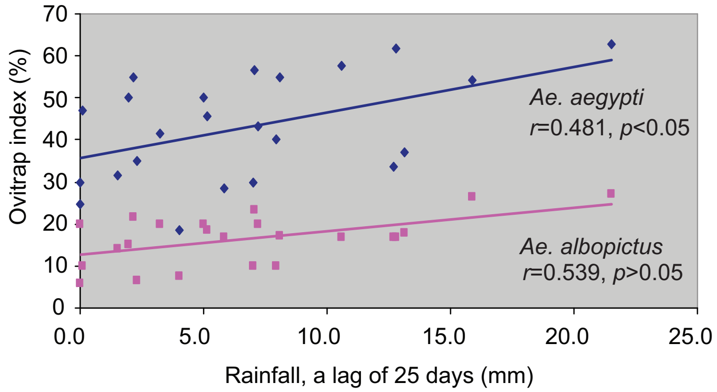

Fig 6–Ovitrap index versus rainfall; a lag of 25 days (first peak) among *Aedes* mosquitoes in Kampung Pulau Ketam.

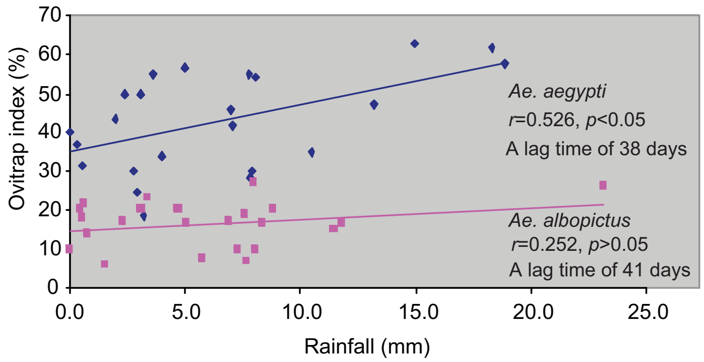

Fig 7–Ovitrap index versus rainfall; lag of 38 and 41 days (second peak) among *Ae. aegypti* and *Ae. albopictus* mosquitoes, respectively in Kampung Pulau Ketam.

than the indoor ovitrap indices for *Ae. aegypti* in Kampung Sungai Lima.

DISCUSSION

A negative association between the number of *Aedes* mosquitoes and rainfall was observed in Pulau Ketam. Adnan *et al* (2009) also reported a negative association between ovitrap index and high rainfall on the campus of Universiti Putra Malaysia (UPM), Selangor. The Breteau index (number of positive containers per 100 houses) reached its lowest value at the peak of the rainy season in a study from Jinjang, Kuala Lumpur (Lee and Cheong, 1987). A study of *Ae. aegypti* egg numbers in Salta, Argentina found they remained low during the dry season, increased at the beginning of the rainy season and decreased at the end of the rainy season (Micieli and Campos, 2003). The larvae were most abundant during the wet season, with the largest number of positive containers, the highest larval index and largest number of high density sites (Stickman and Kittayapong, 2002). Heavy rain and strong winds may disturb the flight activity of *Aedes* resulting in difficulties in finding hosts and suitable breeding sites (Rozilawati *et al*, 2007). Another reason for the negative impact of heavy

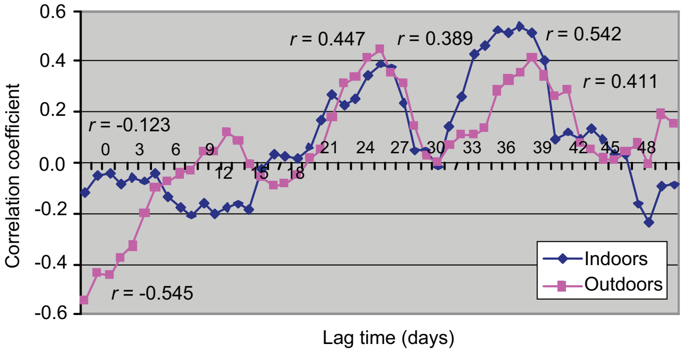

Fig 8–Correlation between *Ae. aegypti* ovitrap index (indoor and outdoor) and rainfall in Kampung Pulau Ketam.

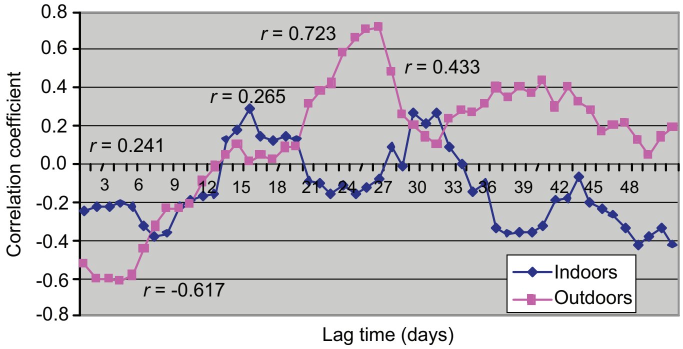

Fig 9–Correlation between *Ae. albopictus* ovitrap index (indoor and outdoor) and rainfall in Kampung Pulau Ketam.

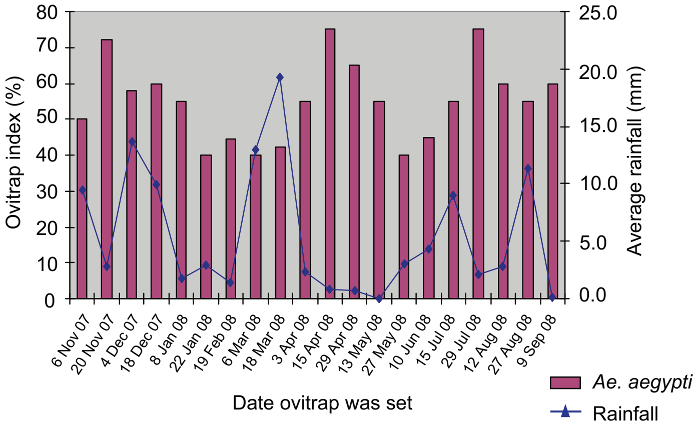

Fig 10–Ovitrap index for *Ae. aegypti* and rainfall in Kampung Sungai Lima.

rain on the *Aedes* ovitrap index is the larvae were flushed out of the ovitrap and other potential containers during heavy downpours (Foo *et al*, 1985; Lee and Cheong, 1987). Thus, the negative association between outdoor ovitrap index and rainfall was more pronounced than indoors since the rainfall exerted a greater influence on outdoor *Aedes* larvae than indoor *Aedes* larvae. A study from Kolej Mohamed Rasid, Malaysia also showed similar results (Adnan *et al*, 2009).

A higher ovitrap index was found during the dry season in Chiang Mai, Thailand (Mogi *et al*, 1988), similar to our observations. The higher index may be due to attraction to the ovitrap caused by the the scarcity of other suitable breeding sites (Mogi *et al*, 1988). A study in Tubiacanga, Rio de Janeiro, Brazil also found the container index, Breteau index, pupae per hectare and pupae per person were higher during the dry season (Maciel-de-Freitas *et al*, 2006).

In our study, a large amount of rainfall was followed 25-27 days later by a peak in the ovitrap index. A one month lag time between rainfall and peak in the container index (number of positive containers per house) was also seen in Singapore (Rao *et al*, 1973). An 18 day lag time was seen under laboratory condi-

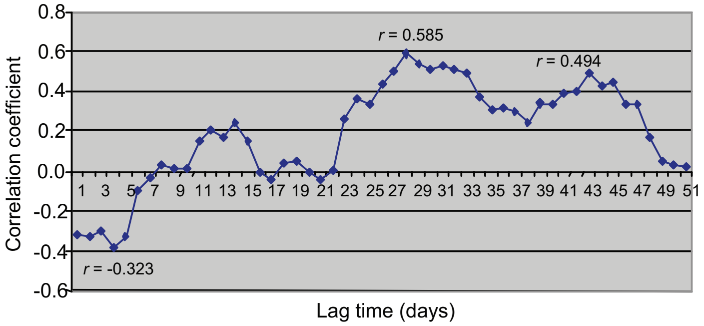

Fig 11–Correlation between *Ae. aegypti* ovitrap index lag time and rainfall in Kampung Sungai Lima.

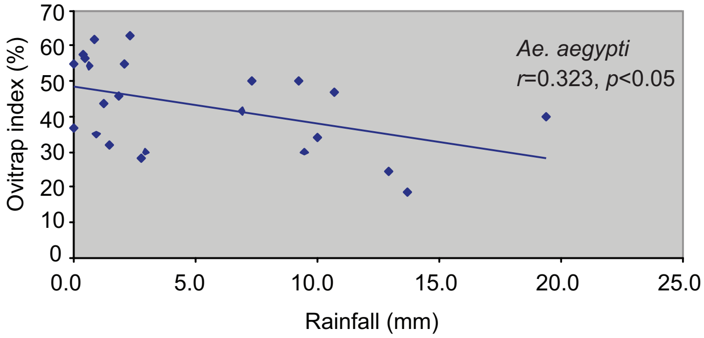

Fig 12–Ovitrap index by rainfall for *Ae. aegypti* in Kampung Sungai Lima.

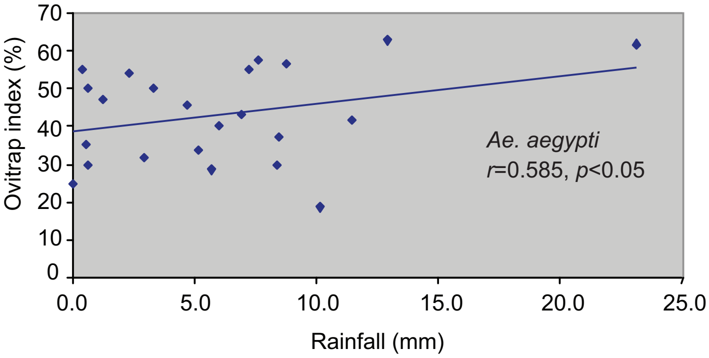

Fig 13–Ovitrap index versus rainfall with 27 day lag time (first peak) for *Ae. aegypti* in Kampung Sungai Lima.

tions, which may be explained by the time period between hatching of eggs and first oviposition (Nazni *et al*, 2008). A development time of 24 days was found among *Ae. aegypti* in the field in our study (Wijeyaratne *et al*, 1974). A study conducted in Taman Permai Indah, Penang, Malaysia also showed a significant positive association between ovitrap index for *Ae. albopictus* and a lag time after rainfall of two months; while the mean number of eggs was also significantly associated with a one month lag time after rainfall (Rozilawati *et al*, 2007). The findings show there is a correlation between rainfall and *Aedes* population numbers after a lag time.

Schaeffer *et al* (2008) found an *Ae. africanus* population increased during the rainy season; however, *Ae. furcifer* population initially increased at the beginning of the rainy season, but then declined. *Ae. furcifer* needs a dry season to mature: eggs laid during the rainy season become mature during the next dry season until new rainfall (Schaeffer *et al*, 2008). In Manaus City, Brazil, *Ae. aegypti* reproduction was greater during the rainy season due to less use of water storage vessels, allowing for *Aedes* development (Pinheiro and Tadei, 2002).

The second peak in the *Aedes* population in our study occurred 37 to 41 days after

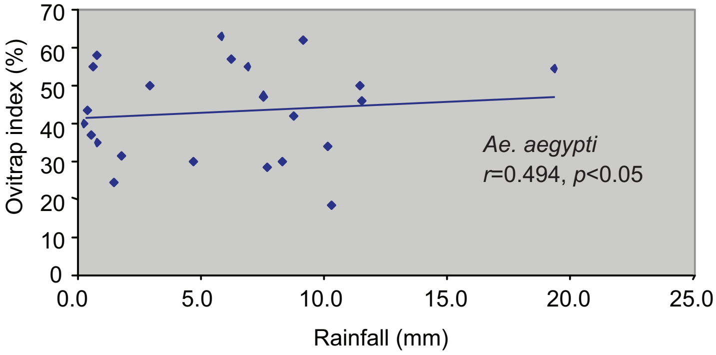

Fig 14–Ovitrap index versus rainfall with a 42 day lag time (second peak) for *Ae. aegypti* in Kampung Sungai Lima.

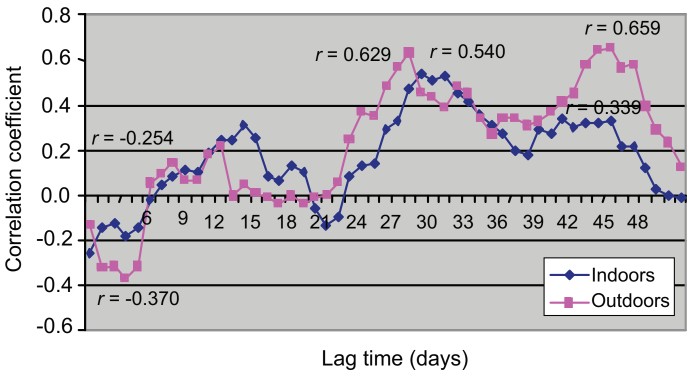

Fig 15–Correlation between *Ae. aegypti* ovitrap index (indoors and outdoors) and rainfall in Kampung Sungai Lima.

the rains. This can be explained by a second gonotrophic cycle, since the interval between the first oviposition and second oviposition in *Ae. albopictus* is approximately 17 days in the lab (Neto and Navarro-Silva, 2004).

Rao *et al* (1973) found the average monthly container indices outdoors were related to rainfall. In the present study, we also found the outdoor ovitrap indices had a greater correlation with rainfall than indoor ovitrap indices. Consequently, *Ae. albopictus* may be more dependent on rainfall than *Ae. aegypti.* Schultz (1993) reported a similar observation in the Philippines.

Information regarding climate variations is useful for dengue outbreak prediction and disease prevention (Rawlins *et al*, 2007). Rainfall as an early indicator of vector reproduction has obvious advantages over late indicators, such as ovitrap indices, larval density, *Aedes* house indices and Breteau indices (Foo *et al*, 1985).

Table 3
Indoor and outdoor correlation coefficients for rainfall and ovitrap index among *Ae. aegypti* in Kampung Sungai Lima.

	Indoors		Outdoors	
	Correlation coefficient	Significance	Correlation coefficient	Significance
Current	-0.254	$p>0.05$	-0.370[a]	$p>0.05$
First peak	0.540	$p<0.05$	0.629	$p<0.05$
Second peak	0.339	$p>0.05$	0.659	$p<0.05$

[a]A lag time of 3 days

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