REVIEW

MALARIA AND *ANOPHELES* MOSQUITOS IN MALAYSIA

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Abstract. Until today, malaria is still one of the most important diseases in Malaysia. This is because Malaysia is located within the equatorial zone with high temperatures and humidities, usually important for the transmission of malaria. The number of malaria cases were estimated to be around 300,000 before the launching of the Malaria Eradication Program (MEP). The program was successful in reducing the numbers progressively during the 1967-1982 period. During the period 1980-1991, the highest number of malaria cases recorded for the country was 65,283 in 1989 (16,902 in Peninsular Malaysia, 47,545 in Sabah and 836 in Sarawak) whilst the lowest was 22,218 (10,069 in Peninsular Malaysia, 11,290 in Sabah and 859 in Sarawak) in 1983. In Malaysia, there are 434 species of mosquitos, representing 20 genera. Of these, 75 species are *Anopheles* that comprise of 2 subgenus, *ie Anopheles* and *Cellia*. Of the 75 species, only 9 have been reported as vectors: *An. maculatus, An balabacensis, An. dirus, An. letifer An. campestris, An. sundaicus, An. donaldi, An. leucophyrus* and *An. flavirostris*. The behavior, seasonal abundance, biting activities and breeding sites of these species are discussed.

INTRODUCTION

Until today, malaria is still one of the most important tropical diseases in the world. It is a disease caused by protozoa and transmitted by mosquitos. Human malaria results in a fever often associated with anemia, splenogomaly, and tissue pigmentation (Sandosham and Thomas, 1982).

In Peninsular Malaysia, although a total of 68 species of *Anopheles* have been recorded, only 9 of them have been shown to be capable of being vectors of the disease: *An. balabacensis, An. maculatus, An. campestris, An. sundaicus, An. letifer, An donaldi, An. dirus, An. leucosphyrus*, and *An. flavirostris* (Vector-borne Disease Control Program, 1988), while in neighboring countries some other species are involved. *Anopheles dirus* and *An. minimus* are the main vectors of malaria in Thailand (Patipongse, 1986). In Indonesia, *An. aconitus* is an important vector in Java (Sudomo *et al*, 1985), *An. koliensis* in remote areas of Irian Jaya (Michael *et al*, 1993) and *An. balabacensis* in Kalimantan (Kirnowardoyo, 1985). *Anopheles maculatus, An. subpictus subpictus, An. sinensis* and *An. aconitus* are the main vectors in Vietnam, whilst *An. vagus* is restrictive only to North Vietnam (Tran-Thi-Minh-Phoung *et al*, 1972). These vectors are often found in different ecological zones. For example, *An. maculatus* breeds prolifically in hilly areas which are exposed to sunlight, especially in streams with clear waters, whilst *An. letifer* are often found in abundance in swampy and marshy woodlands (Sandosham, 1962; Vythilingam *et al*, 1992).

There are four species of human malaria. *Plašmodium falciparum* (Welsh, 1897), causes "tertian-malignant" type of malaria, is responsible for more than 95% of the total malaria cases in the world, and is the most important malaria species in Malaysia. *Plasmodium vivax* (Grassi and Feletti, 1890) is responsible for the "benign tertian" malaria type and is the second most important species in Malaysia. *Plasmodium malariae* (Laveran, 1881) is rarely reported in Malaysia, whilst *P. ovale* (Stephens, 1922) is only found in tropical Africa.

Until today, malaria is still one of the most important vector-borne diseases in Malaysia. This is because Malaysia is located within the equatorial zone with high temperatures and humidities, usually important for the transmission of malaria (Rahman *et al*, 1992). In Peninsular Malaysia, the State that has recorded the highest number of malaria cases since 1985 is Pahang, followed by Kelantan, Trengganu, Perak and Johor (Mak *et al*, 1992). Most of these cases were traced to more remote areas with limited infrastructure facilities and also to those areas heavily involved with the opening of new lands either for agriculture or the

construction of major new roads such as the East-West and North-South Highways, where large areas of forest were cleared. These activities provide new sites suitable for the breeding of the vector mosquitos (Sandosham and Thomas, 1982). Malaria cases have also been reported from the Orang Asli, plantation workers and army personnel (Mak *et al*, 1992).

There are no reliable records of malaria cases in Malaysia pre-1960. The number of cases were estimated to be around 300,000 before the launching of the Malaria Eradication Program (MEP). The program was successful in reducing the numbers progresively during the 1967-1982 period (Yap, 1984). In 1967 the number of cases were reported to be around 401,500, of which 300,000 were from Peninsular Malaysia, 100,000 from Sabah, and 1,500 from Sarawak (Mak *et al*, 1992). Although the original objective of the MEP was to eradicate malaria by the year 1982, this objective had to be modified to a more realistic approach towards controlling of the disease instead, when the MEP was replaced by the Malaria Control Program (MCP). This approach was taken with the realization of the impossibility of eradicating the disease especially with the continuous opening up of new land schemes adopted by the government either for agriculture or highways, contruction of dams for generating electricity, the nomadic way of life chosen by the Orang Asli, movement of army personnel in and out of jungles, and population movements across the Malaysia-Thailand, Malaysia-Myanmar, Malaysia-Kalimantan borders and also because of the steady increase of chloroquine resistance as shown in some *P. falciparum* cases. However, in 1983, the MCP was replaced by the Vector-borne Disease Control Program (VDCP) to reduce morbidity and mortality caused by malaria such that it no longer is a public health problem in Malaysia and to ensure that cases should not arise in areas with no previous history of the disease. The VDCP was also formulated to include the control of other vector-borne diseases like filariasis, dengue, and Japanese encephalitis. In 1985, the VDCP was further expanded to include other diseases like scrub typhus, murine typhus, plague and yellow fever.

During the period 1980-1991, the highest number of malaria cases recorded for the country were 65,283 in 1989 (16,902 in Peninsular Malaysia, 47,545 in Sabah and 836 in Sarawak) whilst the lowest were 22,218 (10,069 in Peninsular Malaysia, 11,290 in Sabah and 859 in Sarawak) in 1983 (Mak *et al*, 1992). Deaths due to malaria during the said period were 106 (the highest) in 1985 and 43 (the lowest) during 1990. The annual parasite incidence (API) ranged between 1.5-4.3 per 1,000 population and deaths due to malaria were between 0.9-2.7 from 1,000 confirmed malaria cases during the period (Mak *et al*, 1992).

The reduction of malaria cases is carried out by controlling the vector population through the spraying of the chemical, 1,1-bis (4 chlorophenyl)-2,2,2-trichloroethane (DDT) at concentrations of $2g/m^2$ on walls of houses, whilst the malaria parasite in patients is treated with chloroquine and fansidar. Since 1982, the parasite malaria has shown some resistance to chloroquine (Ponampalam, 1982) whilst the mosquito vector has shown some behavioral changes, including resistance to DDT. Some alternative control methods were tried by various bodies to reduce the vector population numbers; amongst others, these included the use of biological agents, insect growth regulators (IGR), insecticides and many more (Yap, 1985; Yap and Sulaiman, 1976), but their effectiveness were doubtful. It has been suggested that various aspects of the ecology and biology of the mosquito *Anopheles*, which includes distribution, biting rates, resting places, blood sucking behavior and breeding sites, need to be fully understood to effectively carry out these alternative control methods (Sandosham, 1984; Rejmankova *et al*, 1991).

GENERAL BIOLOGY OF *ANOPHELES* MOSQUITO

Anopheles mosquitos are active only at night; it is a nocturnal species. For most species, most of their critical activities in the life cycle (which includes blood-sucking, mating, and egg-laying) takes place at dusk or at night, while for other species, at dawn. The species do not normally rest indoors during the daytime, but prefer to rest in dark and damp places, outdoors. It normally is attracted towards its bait through body odor or carbondioxide emitted from the prey (Arbain, 1990).

In Malaysia, there are 434 species of mosquitos representing 20 genera. Out of this number, a total of 75 species of *Anopheles* comprise 2 subgenus, *ie* *Anopheles* and *Cellia*, which in turn contain 32 and

43 species, respectively (Abu Hassan and Che Salmah, 1990). Of the 75 species, only 9 have been reported to be vectors of malaria, *ie An. maculatus, An. balabacensis, An. dirus, An. letifer, An. campestris, An. sundaicus, An. donaldi, An. leucosphyrus* and *An. flavirostris* (Vector-borne Disease Control Program, 1988; Tham, 1989; Harinasuta *et al*, 1992). From a study carried out by Rahman *et al* (1992) in Hulu Perak District, 16 species of *Anopheles* were recorded, and *An. maculatus* were incriminated as the sole vector, with *An. aconitus* and *An. phillipinensis* as secondary vectors. Although *Anopheles* mosquitos are often associated with the more remote areas of the country with abundant ricefields, open streams and ponds, the adult mosquitos are capable of flying a reasonable distance from their original breeding sites. For example, *An. maculatus* can fly a distance of 1.2 km (Sandosham and Thomas, 1982), *An. sinensis*, 2 km or more (Self and De Datta, 1987).

Anopheles mosquitos are zoophylic, but significant numbers have been shown to bite humans, indoors (Wharton, 1951, 1953; Reid, 1968). However in the absence of animals, the numbers biting humans can be high (Davidson and Gonapathipillai, 1956; Reid, 1968). During daytime, they do not normally rest indoors, but more often outdoors, especially on shady trees (Wharton, 1950; Reid, 1968).

Morphological studies on *An. maculatus* have shown the presence of significant intraspecific variations in the species (Reid *et al*, 1966; Reid, 1968). But there is no clear evidence to suggest that it is a species complex. However, studies carried out by Green *et al* (1968) and Rattanarithikul and Green (1986) in Thailand have shown that *An. maculatus* is a complex comprised of 6 species; specimens collected from different localities in Peninsular Malaysia have been identified as *An. maculatus* species E (Leong *et al*, 1988).

Anopheles balabacensis is a main vector in Sabah and Sarawak (Hii, 1982) and is an anthrophophylic species. McArthur (1947, 1951) estimated that in Sabah 90% of this species feeds on humans, whilst Eyles *et al* (1964) showed that in Cambodia the ratio between human to cattle feeding was 5:1. The larva of this species breeds in temporary ponds or pools (Rajapaksa, 1971).

Anopheles dirus is an anthrophophylic species (Scanlon and Sandhinand, 1965), but do not normally cause many problems in malaria (Vector-borne Disease Control Program, 1988) in contrast to some other countries.

Anopheles letifer is found in coastal areas, more so in brackish forest fringes whereby the larvae are often found in waters which are cold, calm and acidic (Reid and Hodgkin, 1950). In Peninsular Malaysia it is an important vector not only for human malaria, but also for animal malaria and filariasis (Reid, 1968). In Sarawak, its status as a vector is doubted, although some individuals were found to be infected with sporozoites. Comparative studies have shown that *An. letifer* prefer cattle, but they also feed on humans (Reid, 1961). Moorhouse and Wharton (1965) showed that this species bite humans outdoors and are much attracted to chickens.

Much attention has been given to *An. campestris* as a malaria vector because of its close association with two other vector species, *viz. An. letifer* and *An. sundaicus* (Hodgkin, 1956; Sandosham, 1962). However, Reid (1962) reiterated that this species is an important malaria vector in coastal areas. Its larva breeds in paddy fields and in brackish waters (Chooi, 1985; Chow, 1970). It is both an anthrophophylic and endophagic species (Reid, 1961).

Anopheles donaldi is a secondary vector in Sarawak (Chooi, 1985), and its status as a vector in Peninsular Malaysia is not confirmed, although it is a minor vector for filariasis. The adults are more attracted to cattle than humans, but significant numbers can be found indoors (McArthur, 1949). In Peninsular Malaysia, the larvae are often found in forest fringes in hilly areas, whilst in East Malaysia, it breeds in paddy fields, and open marshlands (Reid, 1962; 1968).

Anopheles leucosphyrus is a vector in interior Sarawak, although in Peninsular Malaysia, it is vector for simian malaria (Reid, 1968). It is an highly anthrophophylic species (Chow, 1970). Although this species bites humans indoors, the adults rests oudoors during daytime (Colles, 1956). It is present in hilly areas and its larvae breeds in ponds or pools in swampy areas (Chow, 1970).

Anopheles flavirostris was originally identified by Reid (1968) from samples collected from Kudat and Semporna in Sabah. However, its role as a vector for malaria and filariasis was confirmed in 1984 (Hii *et al*, 1985). The adults are largely zoophylic, suck human blood indoors at night but rest outdoors during the day (Chow, 1970).

NON-VECTOR *ANOPHELES*

Although *An. aconitus* is not a main vector for malaria in Malaysia, it is a potential secondary vector for the disease (Rahman *et al*, 1992). It is a zoophylic species and prefer to bite outdoors than indoors (Wharton, 1953; Reid, 1968). This species rests on outdoor plants during the day (Reid, 1968). It bites throughout the whole night with a bimodal biting curve (Rahman *et al*, 1995). Nevertheless, this species is an important vector in Central Java, Indonesia (Sudomo *et al*, 1985).

Anopheles kochi is a common species in Malaysia, and the adults often rest on outdoor plants. It prefers cattle to human blood (Wharton, 1953; Reid, 1961).

Anopheles sinensis is a zoophylic species (Reid, 1961; Harrison and Scanlon, 1975). It likes to bite humans indoors, but is not a vector for any disease in Peninsular Malaysia (Reid, 1968; Chiang *et al*, 1968). However, it is an important malaria vector in Korea (Kanda *et al*, 1975; Kim, 1974), China (Ho *et al*, 1962) and Japan (Otsuru and Ohmari, 1960). In Malaysia, its larvae are found in paddy fileds, ponds and temporary water pools exposed to sunlight (Jaal and Macdonald 1993).

Anopheles peditaeniatus is a species often found in paddy fields, whilst its larvae breeds in swamps (Reid, 1953). It is a zoophylic species and are often found in and around cattle sheds (Reid, 1961). Although this species has been shown to be a good vector for *Brugia malayi* in experiments, this has yet to be shown in wild populations (Reid, 1962; Wharton *et al*, 1963).

Anopheles nigerrimus is less zoophylic when compared to *An. sinensis* and it is sometimes a vector for malaria and filariasis (Sandosham and Thomas, 1982; Bahang *et al*, 1984). Its larvae are found in deep wells and in swampy areas with plenty of aquatic plants where the water is considerably colder than those waters frequently inhabited by *An. sinensis* larvae (Reid, 1968; Sandosham and Thomas, 1982). *Anopheles barbirostris* is a zoophylic species and is not a malaria vector, except in Sulawesi (Reid, 1968). *Anopheles vagus* is not considered to be a disease vector in Malaysia (Jaal and Macdonald 1993), although in India the wild species can be infected with sporozoites (Russel and Ramachandra Rao, 1940; Strickland *et al*, 1933), and is a secondary vector for filariasis (Lee *et al*, 1983). Nevertheless, it is a malaria vector in North Vietnam (Tran-Thi-Minh-Phoung *et al*, 1972).

LARVAL HABITAT

Until today, total control of *Anopheles* mosquitos in Malaysia has still not been fully achieved. The distribution of *Anopheles* spp differs according to the type of ecological zones and vegetations (Sandosham and Thomas, 1982). These varying habitats support the breeding of different species of *Anopheles*. *Anopheles* larvae are adaptable to various habitats, except for water polluted with waste or chemicals.

Anopheles maculatus breeds in slow-moving waters exposed to sunlight, especially in areas where trees are felled (Reid, 1968: Roa, 1984; Rahman *et al*, 1992). Christophers (1933) reported the breeding of the larvae in streams with vegetation.

In Malaysia and Indonesia *An. aconitus* breeds in valleys and lowlands, and the optimal temperature for its breeding is 25°-29°C (Reid, 1968). The larvae of *An. aconitus* needs aquatic plants, slow moving waters, an altitude of around 2,800 ft and shade for optimal breeding (Christrophers, 1933).

Larvae of *An. kochi* can be found in open waters, especially in paddy fields (Roa, 1984), in fish ponds with aquatic plants (Bonne and Wepster, 1953) and also in bamboo stumps (Christophers, 1933).

The breeding of *An. phillipensis* is often associated with aquatic plants like *Lemna* and *Eichornia* (Roa, 1984), although generally it is quite comfortable in flowing streams and canals of paddy fields with clear water (Harrison *et al*, 1991; Rattanarithikul *et al*, 1994).

Larvae of *An. barbirostris* breeds in a variety of habitats, both exposed and shaded waters, but usually deep water with aquatic plants as in paddy fields are preferred (Reid, 1986; Rattanarithikul *et al*, 1994), although sometimes they breed in brackish waters (Reid, 1968; Covell, 1927). The larvae are usually more abundant during the rainy season (Christophers, 1933). *Anopheles vagus* larvae prefers muddy water together with *An. subpictus* (Roa, 1984).

BITING CYCLES AND SEASONAL ABUNDANCE

The biting cycle determines the time suitable for the transmission of any disease. Generally *Anopheles* have largely been shown to be nocturnal (Otsuru and Ohmari, 1960; Moorhouse and Wharton, 1965; Thevasagayam *et al*, 1970; Chiang *et al*, 1968; Jaal, 1990). In Malaysia *An. maculatus* bites throughout the night but shows two biting peaks during the earlier part of the night (Loong *et al*, 1988; Rahman *et al*, 1995), and has similarly been shown in studies carried out in the Phillipines (Schultz, 1992). However, in Thailand, *An. maculatus* shows a biting peak between 19.00 to 21.00 hours (Wilkinson *et al*, 1970; Rattinarithikul *et al*, 1996).

Anopheles aconitus is active throughout the night with two small peaks between 18.00-23.00 hours (Rahman *et al*, 1995), although in Indonesia its biting activity is around 18.00-24.00 hours (Kirnowardono, 1985). *Anopheles kochi* and *An. vagus* have similar biting cycles, *ie* a peak activity immediately after dusk (Rahman *et al*, 1995). In Phillipines, Schultz (1992) also reported similar behavior for *An. kochi*.

Anopheles peditaeniatus showed a bimodal biting cycle after dusk (Jaal and Mcdonald, 1993; Abu Hassan, 1994). *Anopheles sinensis* is active throughout the night, more so after dusk and it generally shows a unimodal pattern of biting activity (Chiang *et al*, 1986).

Seasonal abundance is useful when there is a need to know the density of the species and its potential in transmitting any particular disease. In Hulu Perak area, *An. maculatus* is usually present in large numbers in June during the dry season (Rahman *et al*, 1992), concurred by some studies carried out in Thailand (Rattanarithikul *et al*, 1966). The same behavior has similarly been shown in *An. aconitus* (Rahman *et al*, 1993). However, for other species like *An. sinensis*, its seasonal abundance depends on paddy planting activities tied up with the wet season (Chiang *et al*, 2986; Mogi and Miyagi, 1990; Abu Hassan, 1944).

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