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Vectors of *Wuchereria bancrofti* and *Brugia malayi* in the South and Southeast Asian Regions: Their Distribution, Biology and Control*

by

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SUMMARY The countries included in this review are: Pakistan, India, Sri Lanka, Bangladesh, Burma, Thailand, Laos, Khmer, Vietnam, Malaysia, Singapore, Brunei and Indonesia. The first section includes countrywise information on the species and strains of filarial parasites and their vectors. In the second section, information is given on the distribution, relation to filariasis, biology and control of each of the important vector species in the area. A map of the area shows the distribution of human filariasis and four tables provide information on the vectors.

INTRODUCTION

Filariasis is very widespread throughout South and Southeast Asia and is one of the more important communicable diseases in the area. It has been estimated that in India alone, a population of 122 million live in endemic areas and are exposed to active transmission. The terms 'South' and 'Southeast' Asia are ambiguous as they have been variously defined by different authors and organizations. As a matter of convenience, South and Southeast Asia in this paper include: Pakistan, India, Sri Lanka, Bangladesh, Burma, Thailand, Laos, Khmer, Vietnam, Malaysia, Singapore, Brunei and Indonesia. The Philippines, Taiwan, Korea and Japan are excluded from this review.

In this area, two species of human filarial parasites are present, *Wuchereria bancrofti* and *Brugia malayi*. The distribution of these species is illustrated in Fig. 1. A new microfilaria, somewhat resembling *Brugia*, has been reported from man, in Timor Island. Until the adults are obtained, its exact taxonomic status will be doubtful and it will continue to be referred to as the 'Timor microfilaria'. *Wuchereria bancrofti* has a wide though spotty distribution throughout Southeast Asia. It is 'nocturnally periodic' throughout Southeast Asia, except for a focus of infection in Southern Thailand, where the periodicity turned out to be 'nocturnally subperiodic'. In West Malaysia, two distinct strains of *W. bancrofti* are recognised. One occurs in the immigrant races living in cities and mainly transmitted by *Culex pipiens fatigans*, whereas the other occurs in the indigenous people living in the rural areas and transmitted by species of anophelines. The former is referred to as the 'Urban Strain' and the latter as the 'Rural Strain'. *Brugia malayi* occurs only in the Oriental Region

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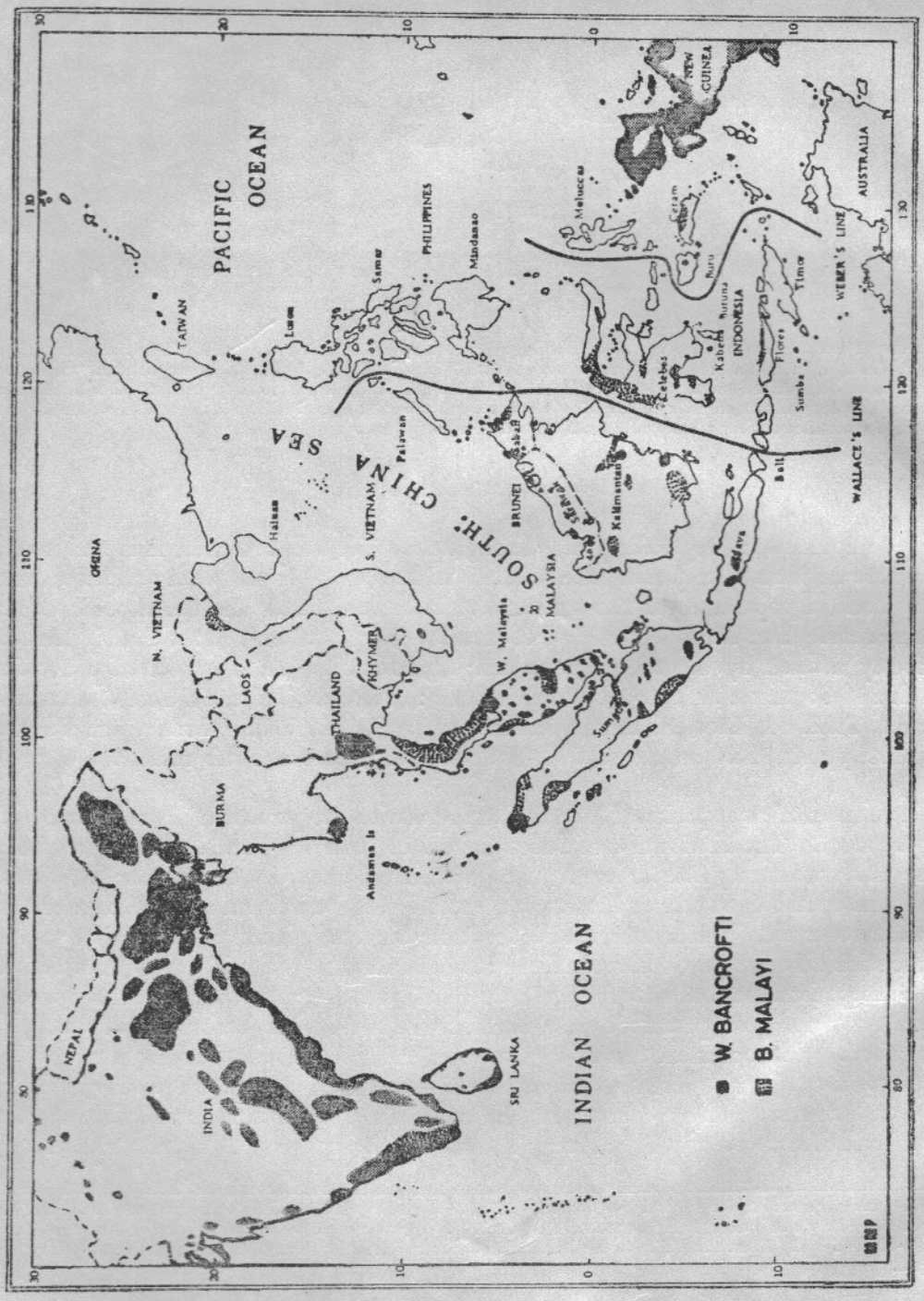
PACIFIC OCEAN
SOUTH CHINA SEA
INDIAN OCEAN
CHINA
TAIWAN
PHILIPPINES
Luzon
Samar
Mindanao
Palawan
Sabah
BRUNEI
Kalimantan
Celebes
Moluccas
NEW GUINEA
Buru
Seram
Kabena
Buruna
INDONESIA
Flores
Timor
Sumba
Bali
WEBER'S LINE
AUSTRALIA
WALLACE'S LINE
Sumatra
W. Malaysia
MALAYSIA
S. VIETNAM
N. VIETNAM
LAOS
KHYMER
THAILAND
BURMA
Andaman Is
SRI LANKA
INDIA
NEPAL
W. BANCROFTI
B. MALAYI

FIG. 1

and is represented by two forms, the 'nocturnal periodic' and the 'unnocturnal subperiodic'. The nocturnal periodic form has a wide distribution and occurs in India, Thailand, Malaya, Indonesia, Japan and Korea. The subperiodic form was first reported from the east coast of W. Malaysia and is now known to occur in Thailand, Philippines and Indonesia. The periodic form is typically found in open swamp terrain and has no animal reservoirs. The vectors are *Anopheles* and *Mansonia* mosquitoes. The subperiodic form is found in swamp forests and is a zoonosis. The vectors are species of forest *Mansonia*. The vectors of the 'Timor microfilaria' are as yet unknown. *Brugia pahangi* is a parasite of animals that can be experimentally transmitted to man. The microfilaria and developing stages in the mosquito of *B. pahangi* cannot easily be separated from those of *B. malayi*.

Only mosquitoes are capable of transmitting filariasis caused by *Wuchereria bancrofti* and *Brugia malayi*. Burton (1962) reported developing and infective larvae of *W. bancrofti* and *B. malayi* in bedbugs (*Cimex hemipterus* and *Cimex lectularius*) in Kerala State, India. Workers in India (Singh, Pattanayak, Mammen, Vijayan, Bhatnagar, Sharma and Mondal, 1962), Malaya (Wharton and Omar, 1962) and Africa (Nelson, 1963) were unable to confirm his findings. The criteria for incriminating a filarial vector is to find the infective larvae in field-caught mosquitoes, dissected soon after capture. Care should be taken to correctly identify the infective stages of filarial larvae in the mosquito. A key for their identification is provided by Nelson (1959). Experimental infection in the laboratory with the same species of mosquito should collaborate the field findings, with a large percentage of mosquitoes becoming infective. For a mosquito to be an efficient vector it should be anthropophylic, endophylic or be in close association with man and it should occur in fairly large numbers.* 'The term 'infected' is used for mosquitoes with the developing larvae in them, whereas 'infective' is used for mosquitoes containing third instar or infective larvae.

During the last few years, there have been a number of changes in the names of countries and islands in the Southeast Asian region. For the convenience of readers, some of these changes are mentioned here : Ceylon is now known as Sri Lanka ; East Pakistan as Bangladesh ; Cambodia as Khmer; Malaya is now referred to as West Malaysia or more recently as Peninsular Malaysia. East Malaysia consists of the two states of Sabah and Sarawak, situated in the north-western part of Borneo. The eastern portion of Borneo, called Kalimantan, is part of Indonesia ; Celebes in now Sulawesi and Indonesian New Guinea is West Irian.

Previous review papers on the vectors of *Wuchereria* and *Brugia*, their biology and control, pertaining to this region and the South Pacific have been compiled by Iyengar (1960) ; Raghavan (1961) ; Wharton (1965) ; Chow (1965) ; Mouchet (1967) and Ramalingam, Guptavanij and Harinasuta (1968).

This paper is divided into two sections, the first dealing with the vectors on a country-wise basis and the second section with individual vectors.

*The longevity of the vector is also important for successful transmission (Lawrance, B. R., 1963). This is particulary true for *Wuchereria* and *Brugia*, where the period of development in the vector may take nine days to two weeks or more.

I. COUNTRY-WISE SURVEY

India :

Elephantiasis has been known to occur in India from ancient times. Filariasis is still a disease of major public health importance in India. It is extensive along the East and West Coasts, in South India, Bengal and Assam. It was long supposed that filariasis did not extend to the northern states of India, including Rajastan, Punjab and Delhi. Recent surveys by teams from the National Institute for Communicable Diseases, Delhi, indicate that filariasis does exist in many of the larger towns and cities in the north and that, in fact, a low level of transmission is occurring. Filariasis appears to be spreading with urbanization (Krishnaswami, Nair, Singh, Bhatnagar, Mammen and Sharma, 1963). Both species of human filariasis occur in India.

Nocturnal periodic *W. bancrofti* is widespread in India, and occurs in almost every state. The most important vector throughout India is *Culex p. fatigans*. Species of *Anopheles* and *Culex* have been found with developing larvae (Iyengar 1938, Rao and Iyengar, 1932), but these may only have a minor role in transmission.

Only one form of *B. malayi*, the nocturnal periodic form, is present in India. It is very common in the state of Kerala, but also occurs in Andhra, Orissa, Madhya Pradesh and Assam states. *Mansonia annulifera* and *Mansonia uniformis* are the two most important vectors. Occasionally, *Mansonia indiana* is also involved in transmission.

Pakistan :

Pakistan, like the northern states of India, was long considered to be free of filarial infections. Recent findings of *W. bancrofti* in north Indian towns and cities, led Wolfe and Aslamkhan (1969) to conduct a limited survey in Karachi. No indigenous person was found with microfilariae and the few *Culex p. fatigans* dissected were negative. In order to rule out the presence of filariasis in Karachi and other towns in Pakistan, more extensive surveys will have to be made.

Bangladesh :

Early reports indicated the presence of both *W. bancrofti* and *B. malayi* in former East Bangal and Sylhet. Very little was known of the actual distribution of the filarial parasites throughout the country. Wolfe and Aslamkhan (1971) made a fairly wide survey through what was then known as East Pakistan and reported that *W. bancrofti* occurred in all the districts. *Brugia malayi* was found in only two areas : Chittagong and Chittagong Hill tracts. The most important vector of *W. bancrofti* is *Culex p. fatigans* in Dinajpur District and probably throughout Bangladesh (Wolfe and Aslamkhan, 1972). The vectors of *B. malayi* are not known but may be species of *Mansonia*, as these are plentiful in Chittagong District.

Sri Lanka :

Extensive filariasis surveys carried out before the Second World War by Dassanayake (1938) and by other workers, showed the presence of both *Brugia malayi* and *Wuchereria bancrofti*. The former species was then widespread and predominant. The vectors of *B. malayi* were mainly *Mansonia annulifera*, *M. uniformis* and *M. indiana* (Carter, 1948), although other mosquitoes may also have been involved, to a slight extent, in the transmission An anti-filarial campaign against *B. malayi* was started in 1947, aimed against both the parasite and the vector. This campaign was very successful, so that *B. malayi* infection is practically non-existent in Ceylon today (Dissanaike, 1968).

Bancroftian filariasis has become a problem after the Second World War. One of the reasons ascribed to this increase is the construction of about 30,000 bucket latrines, each provided with a cement-lined catch-pit, which facilitates the breeding of *Culex p. fatigans*—the main vector of *W. bancrofti* in Ceylon.

Burma :

Wuchereria bancrofti is the only species of filaria known from Burma. It occurs in Rangoon and in some of the other coastal towns. (Hayashi, 1965). Urban filariasis has been on the increase in Rangoon, following the Second World War, due to the break-down of the sewage system and the subsequent increase of favourable breeding habitats for *Culex p. fatigans*. The principal vector of *W. bancrofti* in Rangoon is *Culex p. fatigans* (de Meillon, Grab and Sebastian, 1967*a*).

Thailand :

In Thailand, filariasis occurs only in the southern half and was little known until after the advent of the Second World War. Surveys conducted by Iyengar in 1951 (1953) indicated the presence of *Brugia malayi* in four provinces in the southern part. It was concluded at that time that *B. malayi* was the only species occurring in Thailand. Recent studies by the Faculty of Tropical Medicine, Bangkok, showed that both the periodic and subperiodic strains of *B. malayi* are present in the southern peninsula of Thailand. The vectors of the periodic strain are *Mansonia uniformis*, *Mansonia indiana*, *Mansonia bonneae* and *Mansonia annulata*. The main vector of the subperiodic form is *Mansonia bonneae*, with *Mansonia uniformis* also playing a part.

Two foci of infection with *Wuchereria bancrofti* have recently been discovered. One area is close to the Thailand-Malaysia border and is typically nocturnally periodic. The vectors are not yet known, but may be species of *Anopheles*. The second focus of infection is along the banks of the river Kwai Noi. *Wuchereria bancrofti* in this area has a nocturnal subperiodic periodicity. Vectors are members of the *Aedes* (*F.*) '*niveus*' group.

Laos, Khmer & Vietnam :

Both *B. malayi* and *W. bancrofti* are known to occur in North Vietnam. The distribution of filariasis in South Vietnam is not known. Both species of filariasis undoubtedly occur in South Vietnam as large numbers of refugees have brought the infection with them from the north (Giaquinto, 1966). The vectors are unknown. Scott (1967) lists 12 species of Vietnamese mosquitoes as efficient transmitters of Malayan filariasis and 13 species as transmitting *Wuchereria bancrofti*. However, he fails to give details as to whether these mosquitoes have been incriminated by natural or experimental infections as vectors in Vietnam.

No information is available on the prevalence and distribution of filariasis in Laos and Khmer.

Malaysia :

West Malaysia : Both *W. bancrofti* and *B. malayi* occur in West Malaysia. Early studies in the beginning of this century in Malaya demonstrated the presence of *W. bancrofti* in Kuala Lumpur and Penang and it was thought that this species was introduced into the country by Indian and Chinese immigrants. It was about 40 years later that workers (Polunin 1951, Wharton, 1960) found that *W. bancrofti* was in fact endemic in the country and that it had a wider distribution than was first suspected, occurring fairly widespread in Malays and in the 'Orang Asli' (aborigines) living in the rural areas. The vector of the urban strain of *W. bancrofti* is *Culex p. fatigans*, but this species is refractory to the rural strain (Wharton, 1960). The vectors of the rural strain of *W. bancrofti* are in fact species of anophelines e.g. *Anopheles* (*A.*) *whartoni*, *Anopheles* (*A.*) *letifer* and *Anopheles* (*C.*) *maculatus*.

Brugia malayi is the predominant species in *W. Malaysia* and is widely distributed in scattered patches throughout the country. *Brugia malayi* occurs in two forms, the nocturnal periodic form and the nocturnal subperiodic form. The periodic form occurs mainly in the north-west coast, characterised by open swamps and paddy fields. There are no animal reservoirs. The vectors are *Anopheles campestris*, *Anopheles* (*A.*) *donaldi*, *Mansonia uniformis*, *M. annulifera* and *M. dives*. The subperiodic form occurs in swamp forests. It is common on the east coast of West Malaysia. The subperiodic form has many animals which act as reservoirs of infection. The vectors are mainly *Mansonia dives* and *Mansonia bonneae* and to a lesser extent *Mansonia uniformis* and *M. annulata*.

East Malaysia : East Malaysia consists of the two states of Sabah and Sarawak on the island of Borneo. In Sabah, Barclay (1969) reported the presence of the rural form of the nocturnally periodic *W. bancrofti* and the subperiodic form *B. malayi*. The vectors of *B. malayi* are *Mansonia dives/bonneae*, the vectors of bancroftian filariasis are as yet unknown (Barclay, 1969).

In Sarawak, Zulueta (1957) reported the presence of the rural form of *W. bancrofti* in just one focus of infection e.g. Leppu Leju in the Fourth Division of Sarawak. *Anopheles leucosphyrus* and *Anopheles barbirostris* were both found to be positive in Leppu Leju, and are probably the vectors of *W. bancrofti*. *Brugia malayi* has a much wider distribution, especially in the First, Second and Third Divisions of Sarawak. Zulueta (1957) is of the opinion that it is the subperiodic form, since microfilariae were present in thick films that had been collected during the day. Species of *Mansonia* may be vectors of *B. malayi* in Sarawak.

Brunei :

Brunei, an independent state, is situated between Sabah and Sarawak on the island of Borneo. *Brugia malayi*—probably subperiodic—has been reported by Zulueta (1957) to be present. The vectors are not known.

Singapore :

Wuchereria bancrofti is the only species of filarial parasite occurring in Singapore. The vector is *Culex pipiens fatigans* (Danaraj, Schacher and Colless, 1958). In a recent paper, Colbourne and Ng (1972) have shown that active transmission by *Culex p. fatigans* is still occurring in Singapore and poses a small but definite risk to public health.

Indonesia :

Both *Wuchereria bancrofti* and *Brugia malayi* are present and widespread throughout the islands of Indonesia. A third and as yet undescribed species, the 'Timor microfilaria' has been reported from Timor Island and from the islands immediately surrounding it. In a recent review, Lie (1970) summarised our present knowledge on the distribution and vectors of human filariasis in Indonesia. However, since no countrywide survey has been made, the data is necessarily patchy and incomplete.

Nocturnally periodic *W. bancrofti* has been reported to occur in localised areas in Sumatra, Java (around Jakarta), Kalimantan, Sulawesi, Flores, Sumba and in Buru. In West Irian, *W. bancrofti* has a widespread distribution and occurs on low-lying flat areas of the mainland and on the offshore islands. In Java, *W. bancrofti* occurs in Jakarta and the principal vector is *Culex p. fatigans* (Chow, Lie, Winoto, Rusad and Soegiarto, 1959) Prawirohardjo (1939) has experimentally shown that a number of anopheline species are capable of transmitting *W. bancrofti*, but these mosquitoes do not appear to be epidemiologically important in Jakarta. *Culex p. fatigans* is not important in the transmission of *W. bancrofti* in West Irian. In northern West Irian anopheline mosquitoes are the main vectors of *W. bancrofti*. *Anopheles farauti* is the chief vector along the coastal tracts while *Anopheles koliensis* and *Anopheles punctulatus* are responsible for the transmission in the interior. All three species belong to the '*punctulatus*' group. In the upper reaches of the Digoel river *Anopheles bancrofti* is the main vector. On the island of Pam, *Anopheles farauti* and *Aedes kochi* are considered as the principal vectors. In southern West Irian, the culicines are important vectors in the transmission of filariasis, the main vectors being *Mansonia uniformis, Mansonia papuensis, Culex*

annulirostris and *Culex bitaeniorhynchus*. Toffaleti and King (1947) reported *Armigeres obturbans* (= *milnensis*) as being infected in nature. Out of 268 dissections of wild caught *Armigeres milnensis*, six were found to have developing stages in the thoracic muscles. These, however, could well be a species of animal filaria. No published data is available on the vectors of *W. bancrofti* in the rural areas of Sumatra, Kalimantan, Celebes, Flores, Sumba and Timor, but according to Oemijati and Partono (personal communications) species of *Anopheles*, including *Anopheles barbirostris* may be responsible for transmission.

Brugia malayi is widespread on the western portion of Indonesia and does not occur east of Seram. Both the nocturnal periodic and the nocturnal subperiodic forms of *B. malayi* occur in Indonesia, but the exact distribution of each form has yet to be determined. The subperiodic form is known to occur in Sumatra and Kalimantan, the periodic form in Sulawesi and Seram (Oemijati—personal communications). The vectors include species belonging to the genera *Mansonia*, *Anopheles* and *Coquillettidia*. The main vectors of *B. malayi* in Sumatra, Java and Kalimantan are species of *Mansonia*, whereas in Sulawesi the principal vector is *Anopheles barbirostris*. The various species incriminated as vectors are : *Mansonia dives*, *M. annulata*, *M. annulifera*, *M. indiana*, *M. uniformis*, *Anopheles barbirostris* *A. nigerrimus* and *Coquillettidia ochracea*.

TABLE I

Country-wise Distribution of the Vectors of *Wuchereria bancrofti* (Natural Infections)

COUNTRY	MOSQUITO SPECIES	REFERENCE
India — Kerela	*Culex pipiens fatigans*	Iyengar, 1938
Kerala	" " "	Pal *et al.*, 1960
Mangalore	" " "	Krishnaswamy, 1955
Laccadive Isls.	" " "	Subramaniam, 1958
Saurastra	" " "	Raghavan, 1961
Delhi, U.P., Punjab & Rajastan	" " "	Krishnaswamy *et al.* 1963
Bangladesh	" " "	Wolfe & Aslamkhan, 1972
Sri Lanka	" " "	Abdulcader, 1965
Burma — Rangoon	" " "	de Meillon *et al.*, 1967*a*
Thailand	*Aedes* (*F.*) *'niveus'* group	
Malaysia—West	*Anopheles* (*A.*) *letifer*	Wharton *et al.*, 1963
"	*Anopheles* (*C.*) *maculatus*	" "
"	" " "	Cheong *et al.*, 1965
"	*Anopheles* (*A.*) *whartoni*	Wharton, 1960
"	*Culex pipiens fatigans*	" "
East	*Anopheles* (*C.*) *leucosphyrus*	Zulueta, 1957
"	*Anopheles* (*A.*) *barbirostris*	" "
Singapore	*Culex pipiens fatigans*	Danaraj *et al.*, 1958
"	" " "	Colbourne & Ng, 1972
Indonesia—Jakarta	" " "	Chow *et al.*, 1959
"	" " "	Lie *et al.*, 1958
West Irian	*Anopheles* (*C.*) *farauti*	Toffaleti & King, 1947
"	" " "	Rook, de, 1957*b*
"	" " *punctulatus*	" 1959
"	" " *koliensis*	Toffaleti & King, 1947
"	" " *bancrofti*	" " "
"	*Culex* (*C.*) *annulirestris*	Elsbach, 1937
"	*Culex* (*C.*) *bitaeniorhynchus*	Rook, de, 1957*b*
"	*Mansonia* (*M.*) *uniformis*	" 1959
"	*Aedes* (*F.*) *kochi*	" 1959
		"

TABLE II

Country-wise Distribution of the Vectors of *Brugia malayi* (Natural Infections)

COUNTRY	MOSQUITO SPECIES	REFERENCE
NOCTURNAL PERIODIC		
India Kerala	*Mansonia (M.) annulifera*	Iyengar, 1938
,,	,, ,, ,,	Pal *et al.*, 1960
,,	,, ,, *uniformis*	Iyengar, 1938
,,	,, ,, ,,	Pal *et al.*, 1960
,,	,, ,, *indiana*	Iyengar, 1938
Thailand Surat-Thani	,, ,, *uniformis*	Harinasuta *et al.*, 1970*b*
Chumpern	,, ,, ,,	Harinasuta *et al.*, 1970*a*
,,	,, ,, *indiana*	Harinasuta *et al.*, 1970*a*
,,	,, ,, *bonneae*	,, ,, ,,
,,	,, ,, *annulata*	,, ,, ,,
Malaysia West	*Anopheles (A.) donaldi*	Wharton *et al.*, 1963
,,	,, ,, *campestris*	Reid et al., 1962
,,	*Mansonia (M.) annulifera*	,, ,, ,,
,,	,, ,, *uniformis*	Hodgkin 1938-40
,,	,, ,, ,,	Reid *et al.*, 1962
,,	,, ,, *dives*	Wharton *et al.*, 1963
NOCTURNAL SUBPERIODIC		
Thailand Chumpern	*Mansonia (M.) bonneae*	Guptavanij *et al.*, 1971
,,	,, ,, *uniformis*	,, ,, ,,
Malaysia West	,, ,, *bonneae*	Wharton, 1962
,,	,, ,, ,,	Ramachandran *et al.*, 1970
,,	,, ,, *dives*	Wharton, 1962
,,	,, ,, ,,	Ramachandran *et al.*, 1970
,,	,, ,, *annulata*	Wharton, 1962
,,	,, ,, *uniformis*	,, ,,
,,	,, ,, ,,	Ramachandran *et al.*, 1970
East	,, ,, *bonneas/dives*	Barclay, 1969
PERIODICITY—UNKNOWN		
Indonesia Sumatra	*Mansonia (M.) longipalpis**	Brug & Rock, de, 1930
,,	,, ,, *annulata*	Brug & Rock, de, 1930
,,	,, ,, ,,	Rees *et al.*, 1958
Java	,, ,, *indiana*	Lie & Winoto, 1960
Kalimantan	,, ,, *longipalpis**	Klokke, 1961
,,	,, ,, *annulata*	,, ,,
,,	,, ,, *annulifera*	Kariadi, 1938
,,	,, ,, *uniformis*	,, ,,
,,	*Coquillettidia ochracea*	Klokke, 1961
,,	*Anopheles (A.) barbirostris*	Kariadi, 1938
,,	(=*donaldi*)	
,,	*Anopheles (A.) venhuisi*	,, ,,
	(=*nigerrimus*)	
Sulawesi	*Mansonia (M.) longipalpis**	Jurgens, 1932
,,	*Anopheles (A.) barbirostris*	,, ,,
,,	,, ,, ,,	Brug, 1937
,,	,, ,, ,,	Partono *et al.*, 1972

**longipalpis - bonneae/dives*

II. VECTOR INFORMATION

A. *Wuchereria bancrofti* :

It can be seen from Tables I and III that members of the *Culex* (*C.*) *pipiens* complex are very important vectors of *W. bancrofti*. This is particularly true in the urban areas. In rural areas, mosquitoes belonging to the genera *Anopheles*, *Aedes* and even *Mansonia* may act as vectors. There are eight species of *Anopheles* that transmit the rural form of *W. bancrofti*, three species of *Aedes* belonging to the subgenus *Finlaya* and only one species of *Mansonia*. The *Mansonia* are usually refractory to the development of *W. bancrofti*, the only exception in this region being *M. uniformis* which actively transmits *W. bancrofti* in the Berau District of New Guinea (de Rook, 1957*b*).

1. *Culex* (*C.*) *pipiens fatigans* Wiedemann, 1828 :

The nomenclature of *Culex pipiens fatigans* (= *pipiens quinque-fasciatus* Say, 1823) is still highly controversial. In this paper, I am using the name '*pipiens fatigans*' for this mosquito simply because it is known only by this name throughout Southeast Asia and in the Indian sub-continent. *Culex p. fatigans* is a member of the *pipiens* complex, the other members of which are *Culex pipiens pallens*, a temperate form and an important vector of *W. bancrofti* in Japan ; *Culex pipiens pipiens* a variable form found in temperate regions ; *Culex pipiens molestus* an autogenous and temperate mosquito regarded by Barr (1967) as a mere variant of *C. pipiens pipiens* ; and *Culex pipiens australicus* an endemic form in Australia. The subspecies can be differentiated from each other by the phallosome of the male genitalia. The complex is predominantly Ethiopian. *Culex p. fatigans* probably came originally from Africa, but it is now very widespread throughout the warm tropical regions of the world. It owes its distribution to the fact that it is a good traveller and has accompanied man on his travels from the early days of the sailing ships.

Culex p. fatigans is a predominantly urban mosquito. The rapid urbanization in developing countries accompanied by the lack of sanitary facilities has resulted in the high density and spread of this mosquito. This has often resulted in the transmission of filariasis, as seen in Rangoon (Mcillon *et al.*, 1967), Ceylon (Abdulcader, 1965), Hyderabad and Bangalore (Singh, 1967). Krishnaswami *et al.*, (1963) have shown focal transmission of *W. bancrofti* by *C. p. fatigans* occurred in several cities in northern India which were previously thought to be free of filariasis. They ascribed this to rapid urbanization.

RELATION TO FILARIASIS : *Culex pipiens fatigans* is the most important vector of nocturnally periodic *W. bancrofti* in many parts of the world. This is true in the urban areas in Southeast Asia, as seen in Table I. A high percentage of *C. p. fatigans* became positive for infective larvae when experimentally fed on a *W. bancrofti* carrier. This susceptibility to the parasite shown by *C. p. fatigans*, in combination with its high densities, its domestic habit and high anthropophylic index, makes *C. p. fatigans* an efficient vector in the transmission of urban (periodic) *W. bancrofti*.

Wharton (1960) showed by experimental infections that *C. p. fatigans* is a poor host for rural strains of *W. bancrofti*. The infection rate with the rural strain is very low, as is the average number of infective larvae per infected mosquito. Wharton concluded that *C. p. fatigans* was 20 times more efficient for the urban strain than for the rural strain of *W. bancrofti*.

Culex p. fatigans is a very poor vector of the subperiodic *W. bancrofti* in the South Pacific e.g. 0.91% in Fiji (Symes, 1960); none infected in Samoa and Tonga (Ramalingam, 1968). *Culex p. fatigans* is normally refractory to *Brugia* species but Desowitz and Chellappah (1962) found that in older females the parasites were able to complete their development. Infection rates of 8.5 to 25.4% were obtained.

BIOLOGY: This species is widespread, common, and a great pest mosquito, so that numerous studies have been made on it. Of special significance is the work carried on by the World Health Organization Filariasis Research Unit at Rangoon.

Immature Stages: Culex p. fatigans breeds primarily in stagnant waters with heavy organic contamination. Its favourite breeding sites are drains, catch-pits, septic tanks, cesspools, husk pits, etc., the optimum breeding condition being when there is a contamination at a rate of 1,000 ppm. of organic solids (Singh, 1967). This mosquito will breed secondarily in comparatively clean waters such as in drums, cement tanks and other artificial containers. Abdulcader (1967) has reported *C. p. fatigans* breeding in brackish water as well, where the concentration of chlorides was 620 ppm.

In Rangoon, Burma, it was found that the ovipositing females visit and oviposit at the breeding sites at two peaks, the first just after sunset which falls gradually and the second about sunrise with a dramatic rise and fall. Wind and rain will affect ovipositing (de Meillon, Sebastian and Khan, 1967*b*).

The time taken from the period of egg laying to hatching was about 27.11 hours. The mean duration of larval life for the male was 118.4 hours and for the female 135.3 hours (de Meillon *et al.*, 1967*c*).

The Adult: Culex p. fatigans is a domestic mosquito and is very commonly found resting within houses. In urban areas, *C. p. fatigans* usually forms a high percentage of the mosquitoes resting indoors e.g. 84.6% of the total mosquito collections indoors in Ceylon (Abdulcader, 1967).

Chow and Thevasagayam (1957) in Ceylon found 23% of *C. p. fatigans* resting indoors on walls, 8% beneath the roof, 60% on clothing and other hanging objects and 9% on furniture. The indoor resting places are interesting in that it indicates the percentage resting on sprayable surfaces—which in Ceylon would form 31%. In Ernakulam, S. India, Pal, Nair, Ramalingam, Patil and Ram (1960) found 47.5% resting on walls and undersides of roof and 52.6% on hanging objects and furniture in houses that had never been sprayed. After spraying the houses, the percentages of mosquitoes resting on the walls and undersides of roof fell to 35.9% and those resting on hanging objects and furniture increased to 63.1%.

In Rangoon, *C. p. fatigans* was collected outdoors from underground drains, on vegetation, in tins, boxes, treeholes, etc. and in unoccupied shelters (de Meillon, Paing, Sebastian and Khan, 1967*d*).

The seasonal prevalence of *C. p. fatigans* is influenced by the climatic conditions in the country. In Ceylon, *C. p. fatigans* was reduced during the rainy season due to flooding (Singh, 1967). In Ernakulam, India, although *C. p. fatigans* was prevalent throughout the year, its density was high from January to March and comparatively low during the rainy season, e.g. April to October (Pal *et al.*, 1960). This was also true in Rangoon where the highest density was during the dry season and the lowest density during the rainy season (de Meillon *et al.*, 1967*a*).

Culex p. fatigans is a strong flier. In mark and release experiments in British Guiana, Burton (1964) collected females 900 yards or approximately one-half mile from the release point, three weeks later. Additional dispersal could be possible with strong wind. In a densely populated area in Rangoon, *Culex pipiens fatigans* tagged with ^{32}P were found to disperse more than half a mile from the point of release (Lindquist, Ikeshoji, Grab, de Meillon and Khan, 1967).

Females of *C. fatigans* feed readily either outdoors, or indoors. Biting begins after sunset and continues through the night with a peak between 1.00 a.m. and 3.00 a.m. Females will readily feed on sugar solutions even after taking a blood meal. This generally delays ovipositing. *C. p. fatigans* is a highly anthropophylic mosquito with an index of 75% to 85%. This mosquito will also feed on cattle and on birds. The number of eggs obtained after an avian blood feed is much more than after a human blood meal.

CONTROL : The control of this mosquito has presented public health workers with an ever increasing challenge. Some of the problems are :

1. The numerous and variable breeding places ranging from the highly polluted cesspits to clean water in containers. Some of the breeding places are not easily accessible, e.g. underground drains, septic tanks.

2. The high organic pollution in the breeding places is not favourable for eitherl insecticide application or biological control.

3. Resistance to the chlorinated hydrocarbons is both widespread and high in density. Resistance to organophosphorus compounds (OP) is spreading e.g. Malathion and Diazinon in Douala, Southern Cameron and Freetown, S. Africa and to Fenthion in Kuala Lumpur, Malaysia (Thomas, 1970). The resistance to OP compounds reverts when selection pressure is removed (Brown, 1967).

The construction of modern control sewage and drainage systems in urban areas offers long-term protection against the breeding of *C. p. fatigans*. Biological control agents ranging from fungi to fishes are being investigated and some of these show promise (Laird, 1965).

Control by genetic manipulation, especially using cytoplasmic incompatibility between populations has produced encouraging results (Laven, 1967). Chromosomal translocations have also attracted considerable attention in recent years. In 1969 the World Health Organization/Indian Council for Medical Research established a Research Unit on the Genetic

Control of Mosquitoes in Delhi. This Unit is establishing the feasibility of using genetic control techniques including sterilization by radiation or chemicals, release of males that are cytoplasmically incompatible or have adverse translocation, in order to control or eradicate *Culex p. fatigans.*

2. *Anopheles* (*Cellia*) *maculatus* Theobald, 1901 :

This mosquito has a wide distribution in the Oriental Region, from W. Pakistan through the foothills of the Himalayas in India, to Burma, Thailand, S. China and the former Indo-China to Taiwan ; also through Malaysia, Indonesia and the Philippines.

RELATION TO FILARIASIS : *Anopheles maculatus* has been incriminated as a vector of rural bancroftian filariasis in Selangor State, W. Malaysia (Wharton, Laing and Cheong, 1963) and on Pulau Aur, an island off the east coast of W. Malaysia (Cheong and Omar, 1965). Experimental infections with this mosquito also prove that it is an efficient vector for the rural strain of *W. bancrofti.* (Wharton *et al.*, 1963, Cheong, Omar and Chee, 1968). *Anopheles maculatus* is a poor vector of *B. malayi.* This was demonstrated by Cheong *et al.*, (1968) who obtained 5.5% infective out of 430 *A. maculatus* that fed on a *B. malayi* carrier. It is a very important vector of malaria in W. Malaysia.

BIOLOGY : This species is common in hilly areas exposed to the sun. The larvae breed in seepage waters and in small streams that are exposed to sunlight and will not tolerate deep shade or stagnant and polluted waters. In W. Malaysia, *A. maculatus* prefers to feed outdoors but enters houses at night to feed on man. They bite man even with cattle in the vicinity (Wharton, 1951). In Borneo and elsewhere in its range, *A. maculatus* appears to be more zoophylic. It feeds throughout the night with a peak between 9.00 p.m. and midnight. They do not rest in houses during the day but are found in low vegetation in dense shade. *Anopheles maculatus* has a flight range of a mile and a half. It is prevalent in W. Malaysia throughout the year with a peak in density during April and May and a lesser one in September-October.

CONTROL : In densely populated areas, control of the immature stages by the construction of drains (open and sub-soil) are both effective and long-lasting. It is still susceptible to DDT, BHC and Dieldrin.

3. *Anopheles* (*Anopheles*) *letifer* Sandosham, 1944 :

Anopheles (*A.*) *letifer* is a member of the *Anopheles umbrosus* group, which consists of a dozen species that are restricted in their distribution to Southeast Asia. *Anopheles letifer* is found in the coastal plains of Thailand, W. Malaysia, Sumatra and Borneo.

RELATION TO FILARIASIS : *Anopheles letifer* is an important vector of the rural form of *W. bancrofti* in West Malaysia. Wharton *et al.*, (1963) incriminated this mosquito as a vector in nature. Out of 2,867 females dissected from Bukit Mandul, Selangor State, Malaysia, eight were found positive for all stages and five for infective larvae. Experimentally also

this mosquito is a good vector for the rural strain of *W. bancrofti*. Wharton *et al.*, (1963) obtained 50 mosquitoes with infective larvae out of 61 females that were fed (82%) and Cheong *et al.*, (1968) obtained 44.7 % with infective larvae out of 331 fed females. *Anopheles letifer* is a poor vector of *B. malayi* as only 5% of 242 females became infective (Cheong *et al.*, 1968).

BIOLOGY : A species of the lowlands and coastal plains, *A. letifer* readily bites man and will enter houses at night to feed. It is also strongly attracted to chickens and ducks. They do not rest within houses during the day but will rest beneath houses and on upright shaded stems in vegetation. Breeds in stagnant pools and drains, mostly in the shade, in somewhat arid wastes. The seasonal density shows little variation.

CONTROL : It is still susceptible to the chlorinated hydrocarbon insecticides, although there was a tendency towards the development of vigour tolerance at the end of two cycles of spraying of DDT in W. Malaysia.

4. *Anopheles* (*Anopheles*) *whartoni* Reid, 1963 :

This mosquito belongs to the *Anopheles umbrosus* group and resembles *A. letifer*. It is known only from W. Malaysia, from the States of Pahang and Kelantan, where it occurs in the coastal plains.

RELATION TO FILARIASIS : Wharton (1960) found this mosquito to be infected in nature with the rural form of *W. bancrofti*.

Wharton (1960) incriminated this species (then thought to be *A. letifer*) as the vector of the rural strain of *W. bancrofti* in nature and experimentally.

BIOLOGY : Resembles *A. letifer* in its habits.

CONTROL : Susceptibility to insecticides not known.

5. *Anopheles* (*Cellia*) *farauti* Lawran, 1902.

6. *Anopheles* (*Cellia*) *punctulatus* Donitz, 1901.

7. *Anopheles* (*Cellia*) *koliensis* Owen, 1945.

These three closely related species make up the '*punctulatus*' group. The most widespread of these three species, *A. farauti*, occurs in the Moluccas, New Guinea, North Australia, Santa Cruz group and the New Hebrides. *Anopheles punctulatus* and *A. koliensis* occur in New Guinea, Solomons and the Bismarck Archipelago.

RELATION TO FILARIASIS : *Anopheles farauti* is the main vector of *W. bancrofti* in the coastal tracts of northern West Irian (New Guinea) and on the island of Pam. Toffaleti and King (1947) and de Rook (1957*a*; 1959); have shown it to be an extremely efficient vector in nature. It is also responsible for transmitting periodic bancroftian filariasis in Guadalcanal. It is the most important vector of malaria throughout its range. *Anopheles koliensis* and, to a lesser extent, *A. punctulatus* are responsible for transmission of periodic *W. bancrofti* in the interior of northern West Irian (Toffaleti and King, 1947; van Dijk 1959). *Anopheles punctulatus* and *A. koliensis* are also vectors of malaria in New Guinea and Guadalcanal.

BIOLOGY : All three species breed in water well-exposed to sunlight. *Anopheles farauti* breeds in brackish water to fresh water in ponds and swamps. *Anopheles punctulatus* breeds in drains and ditches beside the road ; while *A. koliensis* breeds in temporary pools and grassland. The three species will readily enter houses to feed on man. Feeding takes place throughout the night with a peak before midnight for *A. farauti* and after midnight for *A. punctulatus* and *A. koliensis*. They generally do not rest indoors during the day and are found resting outdoors among vegetation, in caves and ground holes, among firewood and stone fences.

CONTROL : All three species are as yet susceptible to the chlorinated hydrocarbon insecticides. In the Solomons, *A. koliensis* and *A. punctulatus* almost disappeared after two cycles of DDT spraying (Chow, 1965).

8. *Anopheles* (*Anopheles*) *bancrofti* GILES, 1902 :

This species occurs in northern Australia, New Guinea and the Bismarck Archipelago.

RELATION TO FILARIASIS : *Anopheles bancrofti* is the main vector of periodic *W. bancrofti* in the upper reaches of the Digoel River in New Guinea (Elsbach 1937; Iyengar, 1959).

9. *Aedes* (*Finlaya*) '*niveus*' :

Members of the *Aedes niveus* subgroup occur in the Oriental region from India to Japan. Most of the members occur in the Indo-Malayan area. It is difficult to differentiate the females of this complex, but the males may be readily distinguished by their genitalia.

RELATION TO FILARIASIS : Members of the complex have been incriminated as the only vectors of subperiodic *W. bancrofti* in West Thailand, by Harinasuta *et al.*, (1967). Dissections of over 2,700 females gave an infective rate of 0.22% with third-stage larvae.

BIOLOGY : Very little is known on the biology of these species. The immature stages of the *A. niveus* subgroup have been collected from tree holes and bamboo stumps. The females will bite during the day in shade, although they feed mostly at sunset and, to a lesser extent, at sunrise. In Malaya, these mosquitoes are mostly canopy feeders (Wharton, 1962).

TABLE III

Natural and Experimental infections of *Wuchereria bancrofti* in Mosquitoes in South and Southeast Asia

MOSQUITO SPECIES	COUNTRY	INFECTIONS RATE (%)		REFERENCE
		NATURAL	EXPERIMENTAL	
Culex pipiens fatigans	INDIA : Kerala	13.9 A		Iyengar, 1938
	,,	5.1 (3, 309) A		Pal *et al.*, 1960
	Mangalore	1.3 I		Krishnaswami, 1955
	Laccadive Isl.	12.5 A		Subramaniam *et al.*, 1958
	Punjab, Delhi U.P., Rajastan	0.13 (10, 221) I		Krishnaswami *et al.*, 1963
	BANGLADESH :	1.1 (3, 548) I		Wolfe & Aslamkhan, 1972
	SRI LANKA :	2.9 (115, 529) A		Abdulcader, 1965
	BURMA : Rangoon	0.36 (21, 921) I		de Meillon *et al.*, 1967*a*
	SINGAPORE :	0.9 (1, 152) I		Danaraj *et al.*, 1958
		0.1 (2, 895) I		Colbourne & Ng, 1972
	MALAYSIA : West		3-7	Wharton, 1960
	INDONESIA : Java	0.3 (24, 271) I		Chow, 1959
	,,	1.0 (25, 394) I		Lie et al., 1958
	,,	6 A		Flu, 1929
	,,		61 (102)	Prawirochardjo, 1939
	,,		59 (22)	Brug, 1920
	Kabaena		33 (175)	Brug, 1938
	West Irian		15 (13)	Brug & de Rook, 1933
	Papua-New Guinea		25.5 (27)	McMillan, 1960
Anopheles (A.) letifer	MALAYSIA : West	0.19 (2, 867) I	82(61)	Wharton *et al.*, 1963
	,, ,,		44.7	Cheong *et al.*, 1968
Anopheles (C.) maculatus	,, ,,	0.06 (3,449) I	75 (8)	Wharton *et al.*, 1963
	,, ,,	2.2 I	62.6	Cheong & Omar, 1965
Anopheles (A.) whartoni	,, ,,	0.2	38 (16)	Wharton, 1960
Anopheles (C.) leucosphyrus	,, Sarawak	0.8 (5,492) A		Zulueta, de, 1957
Anopheles (A.) barbirostris	,, ,,	1.5 (263) A		Zulueta, de, 1957
	INDONESIA : Java		66 (6)	Prawirohardjo, 1939
	Sulawesi		29 (144)	Brug, 1938
Anopheles (C.) farauti	West Irian	46.2 (13)		Toffaleti & King, 1947
	,,	6.61	92 (50)	Rook, de, 1957*a*
	,,	1.5 (199) I		,, 1959
Anopheles (C.) punctulatus	,,	8.3 (36)		Toffaleti & King, 1947
Anopheles (C.) koliensis	,,	7.1 (154)		,, ,, ,,
	,,		53 (36)	van Dijk, 1959
	,,		95 (22)	,, ,,
Anopheles (A.) bancrofti	,,	10.9 (655)	49 (284)	Elsbach, 1937
Anopheles (C.) annularis	Java		66 (6)	Prawirohardjo,1939
Anopheles (C.) sundiacus	,,		50 (18)	,, ,,
Anopheles (C.) subpictus	,,		72 (54)	,, ,,
Anopheles (C.) vagus	,,		55 (9)	,, ,,
Anopheles (C.) tessellatus	,,		100 (3)	,, ,,
Anopheles (C.) aconitus	Sulawesi		68 (31)	Brug, 1938
Mansonia (M.) uniformis	Irian	1.3 (227) I	94.2 (97)	Rook, de, 1959
	,,		91 (56)	van Dijk, 1959
Mansonia (M.) papuensis	,,		83 (43)	,, ,,
Aedes (F.) kochi	,,	1.6 (190) I	70 (111)	Rook, de, 1957*a*
Culex (C.) bitaeniorhynchus	,,	2.6 (142) I	87 (54)	,, 1959
Culex (C.) annulirostris	,,	1.6 (184) I	89 (157)	,, 1957*b*
	Sulawesi		66 (3)	Brug, 1938
Culex (C.) 'vishnui' group	,,		45 (197)	,, ,,
Culex (C.) whitmorei	,,		100 (3)	,, ,,
Culex (C.) fuscocephalus	,,		75 (12)	,, ,,
Armigeres (A.) obturbans (= *milnensis*)	,,	2.2 (268)		Toffaleti & King, 1947

Figures in brackets represent total mosquitoes dissected. A = all stages of larvae; I — infective larvae

TABLE IV

Natural and Experimental Infections of *Brugia malayi* in Mosquitoes in South and Southeast Asia

Mosquito Species	Country		Infections Rate (%)		Reference
			Natural	Experimental	
Nocturnal Periodic					
Mansonia (M.) annulifera	India :	Kerala	19.2 A		Iyengar, 1938
		,,	27.8 (1, 158) A		Pal *et al.*, 1960
		Madras		59.2	Raghavan & Krishnan, 1949
	Sri Lanka :	E. Province	4.7 (577) A		Carter 1948
	Thailand :	South	17.3 (52) A		Iyengar, 1953
	Malaysia :	Peninsula		68 (76)	Reid *et al.*, 1962
Mansonia (M.) uniformis	India :	Kerala	6.5 A		Iyengar, 1938
		,,	5.9 (856) A		Parl *et al.*, 1960
	Sri Lanka :	N.W. Province	1.4 (4, 361) A		Carter, 1948
	Thailand :	South	11.4 (44) A		Iyengar, 1953
		Chumporn	0.22 (10, 159) I		Harinasuta *et al.*, 1970*a*
		Surat Thani	0.3 (338) I		,, ,, 1970*b*
	Malaysia :	Peninsula	0.1 I	98 (400	Hodgkin, 1930-40
		,,	0.02 (4, 316) I	100 (22)	Reid *et al.*, 1962
Mansonia (M.) indiana	India :	Kerala	3.3 A		Iyengar, 1938
	Sri Lanka :	N.W. Province	3.1 (65) A		Carter, 1948
	Thailand :	South	8.8 (317) A		Iyengar, 1953
		Chumporn	0.28 (8, 823) I		Harinasuta *et al.*, 1970*a*
Mansonia (M.) annulata		,,	0.04 (2, 790) I		,, ,, ,,
Mansonia (M.) bonneae		,,	0.16 (2, 790) I		,, ,, ,,
	Malaysia :	Peninsula		0.0	Wharton, 1962
Mansonia (M.) dives		,,		2 to 36	,, ,,
Anopheles (A.) donaldi		,,	1.4 (146) I		Wharton *et al.*, 1963
Anopheles (A.) campestris		,,	0.5 (3, 573) I	88 (24)	Reid *et al.*, 1962
Anopheles (A.) barbirostris	Thailand :	South	11.7 (358) A		Iyengar, 1953
Anopheles (A.) nigerrimus	Sri Lanka :	N.W. Province	1.9 (421) A		Carter, 1948
	Sri Lanka			60 (25)	Niles, 1961
Nocturnal Subperiodic					
Mansonia (M.) bonneae	Thailand :	Chumporn	0.21 (5, 036) I		Guptavanij *et al.*, 1971
	Malaysia :	Peninsula	7.1		Wharton, 1962
		,,	1.0 (893) I		Ramachandran *et al.*, 1970
Mansonia (M.) dives	Malaysia :	,,	0.6		Wharton, 1962
		,,	0.3 (919) I		Ramachandran *et al.*, 1970
Mansonia (M.) divesibonneae		,,	0.4		Wharton, 1962
		Sabah	0.2 (1, 465) I		Barclay, 1969
Mansonia (M.) annulata		Peninsula	0.3 I	94-100	Wharton, 1962
		,,		95 (138)	Hodgkin, 1938-40
Mansonia (M.) uniformis		,,	0.1 I	58-100	Wharton, 1962
		,,	0.3 (14) I		Ramachandran *et al.*, 1970
		,,		98 (300)	Hodgkin, 1938-40
	Thailand :	Chumporn	0.04 (7, 045) I		Guptavanij *et al.*, 1971

B. Brugia malayi

Mosquitoes belonging to the subgenus *Mansonia* (*Mansonioides*) are the most important vectors of *B. malayi*. A few species of *Anopheles* will also transmit this filaria. The vectors of *B. malayi* are shown in Tables II and IV.

Mansonia (*Mansonioides*)

The only subgenus of *Mansonia* occurring in Southeast Asia is the *Mansonioides*. The *Coquillettidia*, until recently included as a subgenus of *Mansonia*, is now considered as a distinct genus. The *Mansonioides* is predominantly Oriental although its range extends from New Guinea and Japan in the east to Africa in the west. Six species of *Mansonioides* occur in Southeast Asia and all of them are vectors of *Brugia malayi*. Although species of *Anopheles* may transmit the periodic strain of *B. malayi*, the *Mansonia* are the main vectors of Malayan filariasis. They are generally refractory in infections of *W. bancrofti* except for *M. uniformis* which transmits the nocturnally periodic *W. bancrofti* in the Berau region of New Guinea (de Rook, 1957*b*).

The eggs are laid in clusters on the under-surface of floating leaves or on the stems of emergent aquatic plants. The larvae and pupae obtain their supply of oxygen by attaching their siphon to the roots of aquatic plants. It was earlier believed that the water cabbage *Pistia stratiotes* was the main plant for attachment and that it was in fact essential for development (Iyengar, 1938). It is now known that they will attach to a large number of other aquatic plants and trees (Burton, 1959-60; Wharton, 1962). The adults are fierce biters and feed on man indoors and out-of-doors. They are generally nocturnal in habit but may bite under dense shade during the day. The length of their life cycle, approximately a month, is relatively long.

CONTROL OF MANSONIA SPECIES : The use of oils is not effective against the immature stages of *Mansonia*. However, effective control of the immature stages of *M. annulifera*, *M. indiana* and *M. uniformis* may be obtained by physically or chemically destroying the host plant. Chow (1953) in Ceylon destroyed *Pistia strariotes* by using the sodium salt of methyl-chlorophenoxyacetic acid and *Salvinia* with pentachlorophenol (Chow, Thevasagayam and Wambeek, 1955), and obtained good results. These chemicals are ineffective against the swamp-forest mosquitoes.

The adults of *Mansonia* are still susceptible to insecticides. The use of chlorinated hydrocarbons as residual insecticide sprays against adults have been effective in several countries against *M. uniformis* and *M. annulifera* : e.g. DDT in Ceylon (Antonipulle *et al.*, 1958) ; Dieldrin in India ; DDT in Thailand (Harinasuta, Charoenlarp, Guptavanij, Sucharit, Deesin, Surathin and Vutikes, 1970*b*). Wharton (1958) used dieldrin against *M. bonneae/dives* without reduction of the number of mosquito attacks or the infection rate.

10. *Mansonia* (*Mansonioides*) *annulifera* (Theobald, 1901) :

Occurring widely throughout the Oriental region from India, Ceylon to Indo-China and south through Malaysia, Indonesia to New Guinea and the Philippines.

RELATION TO FILARIASIS : This mosquito is the dominant vector of periodic *B. malayi* in India and Ceylon (Iyengar, 1938 ; Pal *et al.*, 1960) and to some extent, of periodic *B. malayi* in Thailand (Iyengar, 1953) and in Kalimantan, Indonesia (Kariadi, 1938). It is a poor vector of the subperiodic strain of *B. malayi*.

BIOLOGY : *Mansonia annulifera* is a very domestic mosquito. It breeds profusely in small ponds covered over with the water cabbage *Pistia stratiotes*. These small ponds are present in the yard of almost every house in the South Indian state of Kerala. The larvae and pupae of *M. annulifera* will also attach to *Eichhornia* and other aquatic plants.

Mansonia annulifera will readily bite man indoors and outdoors and has an anthropophylic index of 43.7. They enter houses after sunset and will feed throughout the night with a peak after midnight. Many females will rest indoors during the day. In collections made indoors in Kerala State, over a period of 18 months, 95% were observed to rest on walls below height of five feet. Outdoors they were collected from vegetation, resting on stones, etc. (Pal *et al.*, 1960). Iyengar (1938) considered that they have a fairly short flight range. They were prevalent throughout the year in Ernakulam, S. India, with a high peak during the post-monsoon months e.g. September to November.

11. *Mansonioides* (*Mansonioides*) *uniformis* (Theobald, 1901) :

This mosquito occurs extensively over the Oriental region and also extends to the Ethiopian and Australasian regions.

RELATION TO FILARIASIS : A very important vector of *B. malayi*. It plays an important part in the transmission of periodic *B. malayi* in India (Iyengar, 1938 ; Pal *et al.*, 1968), in Thailand (Harinasuta *et al.*, 1970*a*) and in W. Malaysia (Hodgkin 1938—40 ; Reid et al., 1962). It also transmits the subperiodic strain of *B. malayi* in S. Thailand (Guptavanij, Harinasuta, Sucharit and Vutikes, 1971) and in Malaysia (Wharton, 1962 ; Ramachandran *et al.*, 1970). In Indonesia it transmits *B. malayi* (periodically uncertain) in Kalimantan, Borneo (Kariadi, 1938). It is the only *Mansonia* that transmits *W. bancrofti* in the Berau region of West Irian (de Rook, 1969).

BIOLOGY : Breeds in open swamps and in ponds and pools. The immature stages attach to *Eichhornia*, *Pistia* and a host of other aquatic plants (Burton, 1960). *Mansonia uniformis* prefers to feed on cattle and has a very low anthropophylic index, being 2.8% in India (Pal *et al.*, 1960) and 2.0% in W. Malaysia (Wharton, 1962). It is an exophylic species but will enter houses to feed on man. Feeding starts at dusk and proceeds through the night with the peak after midnight. They do not rest in houses during the day. Out-of-doors, they are found resting on the underside of leaves. Wharton (1962) believes that this species had a dispersal of at least two miles.

12. *Mansonia* (*Mansoniodes*) *indiana* Edwards, 1930 :

Occurs in Sri Lanka, India, through Burma, Thailand, Vietnam, W. Malaysia, Java and Sumatra in Indonesia and in New Guinea.

RELATION TO FILARIASIS : *Mansonia indiana* is a minor vector of periodic *B. malayi* in India (Iyengar 1938), S. Thailand (Harinasuta *et al.*, 1970*a*) and was involved in the transmission of *B. malayi* in Sri Lanka. In Java, Indonesia, it was incriminated as the vector of subperiodic *B. malayi* in a focus of infection, just west of Jakarta (Lie *et al.*, 1960). Hoedojo and Oemijati (1972) have recently reported the reduction of filariasis in this area. They attribute this mainly to the environmental changes around the village, brought about by the drainage of the swamp and the provision of an irrigation canal, the marsh being replaced by paddy fields.

BIOLOGY : *Mansonia indiana* is known to attach to the roots of of the water hyacinth *Eichhornia crassipes*. They occur in open swamps. The adults can be collected in cattle sheds. Apparently they do not occur in high densities and are therefore only of minor importance as vectors.

13. *Mansonia* (*Mansonioides*) *bonneae* Edwards, 1930 :

14. *Mansonia* (*Mansonioides*) *dives* (Schiner, 1868);

These two species resemble each other closely. *Mansonia dives* has been known in the past as *M. longipalpis*. In the past, many records referring to *M. longipalpis* may in fact refer to either *M. dives* or *M. bonneae* or to both. Of the two species *M. dives* has a wider distribution and is found in India, Thailand, W. Malaysia, Singapore, Indonesia, Philippines, New Guinea, Australia and the Bismarck Archipelago. *Mansonia bonneae* is found in Thailand, W. Malaysia, Borneo, Celebes and the Philippines. Both species occur in lowland ungle swamps.

RELATION TO FILARIASIS : Both mosquitoes, *M. bonneae* and *M. dives* are important vectors of the subperiodic *B. malayi* in W. Malaysia (Wharton, 1962 ; Ramachandran, Cheong, Sivanandam, Hassan and Mahadevan, 1970) and in Sabah (Barclay 1969). *Mansonia bonneae* transmits the subperiodic *B. malayi* in Thailand (Guptavanij *et at.*, 1971). *Mansonia dives* is also capable of transmitting the periodic strain of *B. malayi* in W. Malaysia (Wharton *et al.*, 1963). Experimentally also *M. dives* is much more efficient than *M. bonneae* in transmitting the periodic strain of *B. malayi* and of *B. pahangi*. *Mansonia bonneae* is capable of transmitting *Dirofilaria* infection in dogs and monkeys in nature.

BIOLOGY : Both species breed in swamp forests and are abundant in the east coast of Peninsular Malaysia. The immature stages are able to attach to roots and pneumatophores of tree and other plants. It is extremely difficult to collect the immature stages in nature or to breed these species in the laboratory.

These two species feed readily on man and on many other animals and birds. Precipitin tests on adults caught near houses in Malaya showed that 16% had fed on man. They bite at ground level and at the canopy. They occur throughout the year.

15. *Mansonia* (*Mansonioides*) *annulata* Leicester, 1908 :

Mansonia annulata is known to occur in Thailand, W. Malaysia, Sumatra and Borneo of Indonesia and in the Philippines. It occurs in swamps at the very verge of the forest.

RELATION TO FILARIASIS : This mosquito transmits the subperiodic form of *B. malayi* in Sumatra (Brug and de Rook, 1930; Rees *et al.*, 1958) in Kalimantan (Klokke, 1961) and in West Malaysia (Wharton 1962). Hodgkin (1938-40) and Wharton (1962) also showed that experimentally it is an efficient vector of the subperiodic *B. malayi* as 94% to 100% of the mosquitoes became infective. In an area in S. Thailand where the periodic *B. malayi* is present, Harinasuta *et al.*, (1970*a*) obtained a single *M. annulata* with infective larvae out of 2,790 dissected (0.036%).

BIOLOGY : *Mansonia annulata* breeds in swamps only, at the fringe of jungles, and have not been collected in open swamps or in swamp forests. The immature stages have been found attached to the roots of two species of trees and two species of grasses. It will feed on man, cattle, goats, dogs and birds. They feed during the day in small numbers, the peak being after sunset. They do not rest indoors during the day. *Mansonia annulata* does not show any seasonal fluctuations in Malaysia.

16. *Anopheles* (*Anopheles*) *barbirostris* Van Der Wulp, 1884 :

Anopheles barbirostris, the most common member of the '*barbirostris*' group, is easily confused with two other members of this group, e.g. *A. campestris* and *A. donaldi*, and can only be identified with certainty by examination of the immature stages. It has a widespread distribution and occurs in India, Ceylon, Burma, Thailand, Khmer, Southern China, W. Malaysia and from Sumatra to the Celebes, but not in Borneo.

Although *A. barbirostris* has a wide distribution in Southeast Asia, it has only been established as a vector of *B. malayi* in the Celebes, in Indonesia, where Jurgens (1932) reported it as an important vector in nature. In experimental infection as well, it appears to be an extremely efficient vector of *B. malayi* (Jurgens, 1932; Brug, 1937).

BIOLOGY : *Anopheles barbirostris* breeds in swamps and deep ponds with vegetation and some shade. It will also breed in paddy fields (Reid, 1968). This mosquito is zoophylic throughout its range except in the Celebes, where it enters houses and bites man readily.

CONTROL : Still susceptible to DDT, BHC and dieldrin.

17. *Anopheles* (*Anopheles*) *campestris* Reid, 1962 :

This mosquito, a member of the '*barbirostris*' group, was formerly referred to as the 'dark-winged' form of *A. barbirostris*. It occurs on the alluvial plains and deltas of W. Malaysia and Thailand (Reid, 1968).

RELATION TO FILARIASIS : Reid *et al.*, (1962) showed that it is an efficient vector of the periodic form of *B. malayi* in Malaysia, where it also transmits malaria.

BIOLOGY : *Anopheles campestris* breeds in deep pools, wells and swamps, with vegetation and at least some shade. It can tolerate low concentrations of sea water as well. The adults are anthropophylic and will readily enter houses to bite. Some of them will rest in houses during the day. The majority rest on grass and bushes under shade.

CONTROL : This mosquito is still susceptible to DDT, BHC and dieldrin. Due to its habit of resting indoors, *A. campestris* disappeared after just one cycle of spraying in Malaysia (Moorhouse and Chooi, 1964).

18. *Anopheles* (*Anopheles*) *donaldi* Reid, 1962 :

This mosquito is also a member of the '*barbirostris*' group. It occurs in W. Malaysia, Borneo, Thailand and may also be present in Sumatra and Java. In Borneo it appears to be the dominant member of the '*barbirostris*' group.

RELATION TO FILARIASIS : Wharton found this species to transmit periodic *Brugia malayi* in Ulu Lui, Selangor State, and W. Malaysia. Out of 146 wild-caught *A. donaldi* dissected, two were positive for infective larvae. It is a minor vector of malaria in W. Malaysia and Borneo.

BIOLOGY : The breeding places of *A. donaldi* are similar to those of *A. barbirostris* i.e. deeper ponds, pools and marshes, with Vegetation and at least some shade. In Borneo they appear to prefer feeding on cattle, but despite this, may enter houses at night to feed on man. They do not rest in houses during the day.

C. *Laboratory vectors :*

From the foregoing account it is clear that the vectors of filariasis are numerous and that they differ with the species, strain and geographical distribution of the parasite. *Wuchereria bancrofti* affords a good example of this : The diurnal subperiodic form in the South Pacific is mostly transmitted by members of the '*scutellaris*' group of *Aedes* (*Stegomyia*) and *C. fatigans* is refractory to this infection ; the nocturnal subperiodic form in Southern Thailand is transmitted by members of the '*niveus*' group of *Aedes* (*Finlaya*) ; the urban strain of nocturnally periodic *W. bancrofti* is widely transmitted by *C. p. fatigans*, while the rural strain is transmitted by species of *Anopheles*. A vector that is capable of transmitting more than one species and several strains of filarial parasites, and that can be easily maintained in the laboratory, would obviously be advantagous in the experimental study of filariasis. *Aedes* (*Finlaya*) *togoi* is such a vector.

1. *Aedes* (*Finlaya*) *togoi* (Theobald, 1907) :

This mosquito is primarily found in temperate climates, from Siberia through Japan, Ryukyu-Retto, Korea, China, Taiwan and Marcus Island. Recently it has been reported to occur in Vietnam, Thailand and Malaysia (Ramalingam, 1969).

RELATION TO FILARIASIS : *Aedes togoi* is a vector of nocturnal periodic *B. malayi* in nature in Japan (Sasa, Hayashi, Kano and Stato, 1952; Seo, Rim, Lim, Kang and Park, 1968). In Japan it is experimentally capable of transmitting periodic *W. bancrofti*. Ramachandran, Wharton, Dunn and Kershaw (1963) showed that *Ae. togoi* was an extremely good experimental vector of the periodic and subperiodic strain of *B. malayi* ; of the rural strain of *W. bancrofti* ; of *B. pahangi* ; of *Dirofilaria immitis*, of a species of *Breinlia* and finally of a species of *Setaria*. It is also capable of transmitting *B. patei*.

BIOLOGY : In nature, *Ae. togoi* breeds in brackish water, in rock and tidal pools by the sea, often exposed to direct sunlight. In Japan they also breed inland in artificial containers with rain water. They feed throughout the day, with peaks after sunset and sunrise. They enter houses to feed, but prefer cattle to man.

Aedes togoi adapts easily to laboratory conditions. They will lay their eggs on moist filter paper and the larvae will breed in de-chlorinated tap water. The females will feed readily on guinea-pigs or on cats, and will mate in cages.

2. *Armigeres* (*Armigeres*) *subalbatus* (Coquillett, 1898) :

This species is present throughout the Oriental region, from Japan to India.

RELATION TO FILARIASIS : Wharton (1962) found *Armigeres subalbatus* to be an excellent vector of *Brugia pahangi*, and in a series of experiments he obtained 90% to 100% infective larvae when the carrier had a minimum of one microfilaria per c.mm. of blood. The infective larvae were formed relatively early, i.e. on the 7th or 8th day after the blood meal. With the periodic and subperiodic strain of *B. malayi*, *Armigeres subalbatus* is a poor vector with an infective rate of 0% to 20%. Since it is not possible to differentiate the microfilariae of *B. malayi* from that of *B. pahangi*, *Armigeres subalbatus* could be infected and used for differential diagnosis of these two species.

BIOLOGY : This species breeds in waters with very high organic pollution. In the field it breeds in rotting coconuts, bamboo stumps, tree holes and in septic tanks. It feeds at dusk and soon after sunset. It can easily be colonised in the laboratory. It is a big and hardy mosquito.

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