Arboviruses and their Vectors in the Pacific - Status Report

Laurent Guillaumot*

**Entomology Unit, New Caledonia Pasteur Institute, E-mail: lguillaumot@pasteur.nc*

Abstract

Three arboviruses have already caused epidemics in various Pacific Island countries and territories, and currently represent a direct threat to public health. The diseases concerned are all mosquito-borne and should be kept under careful surveillance.

Dengue fever, which is a worldwide major public health problem, is mainly transmitted in the Pacific by the Aedes aegypti *vector but also by other mosquitoes of this genus with varying ranges.*

Epidemic polyarthritis due to the Ross River virus is endemic in Australia. At least one major epidemic has occurred in the Pacific where various vector mosquito species occur.

Japanese encephalitis is a zoonosis that can be transmitted to humans by mosquitoes of the genus Culex. Its area of distribution in Asia is expanding and the possibility of fresh incursions into the region should be borne in mind.

This paper reviews the situation regarding these diseases in the Pacific and provides information on the way they are transmitted as well as on the biology of the mosquito vectors. (PHD, 2005 Vol 12 No 2 Pages 45 - 52)

Introduction

A vector is an organism that, through its lifestyle, picks up a pathogen from an infected vertebrate and then, after a phase of biological evolution that is almost always obligatory, actively passes on this pathogen to a healthy vertebrate. Within this definition, the subject is almost always a blood-feeding arthropod.

Vector-borne diseases are those which, with very few exceptions, are always transmitted in the wild in this way. The pathogens concerned can be viruses (e.g. yellow fever, encephalitis, dengue fever), bacteria (e.g. typhus, plague), protozoans (e.g. malaria, trypanosomiasis) or helminths (e.g. filariasis).

The viruses transmitted by vectors are called "arboviruses" (**a**rthropod-borne **v**irus), a term which refers to a common mode of transmission but which has no bearing on taxonomy as arboviruses can belong to very different families. Three of them represent a direct threat to public health in Pacific Island countries and territories, all of which are transmitted by mosquitoes.

Alongside the major public health problem of dengue fever, outbreaks of epidemic polyarthritis due to the Ross River virus have already occurred in some island countries. More marginally, the same can be said of Japanese encephalitis, a disease that requires our attention not only because of its severity but also because of its currently expanding area of distribution.

This paper contains information on the status of these diseases in the Pacific and on the way they are transmitted, as well as on the biology of the vector mosquitoes.

Dengue Fever

Disease

This arbovirus is presently one of the major public health problems in the world with estimates standing at some 50 million cases of infection annually.

It is caused by viruses of the genus *Flavivirus*, and four different serotypes (DEN 1 to DEN 4) are known. In its usual form, the disease is characterised by the rapid onset of intense fever accompanied by headaches, joint pains and asthenia, often associated with a skin rash. The disease usually clears up without treatment and without consequences after some five to six days but in a certain number of cases and for reasons that are not yet fully understood, it can develop into a severe form, i.e. dengue haemorrhagic fever or dengue shock syndrome, which are often fatal if hospital intensive care facilities are not available. Apart from these extreme cases, one of the problems of this disease is the explosive character of outbreaks: the few initial cases quickly grow into hundreds and thousands, with a

considerable impact on the economic and social fabric of the countries affected.

There are also asymptomatic forms of the infection, which could account for up to 50% of cases. Cured subjects possess lasting immunity to the serotype concerned.

Dengue fever's current area of distribution covers a major proportion of the tropical and subtropical world.

The first dengue epidemics in the Pacific were reported in 1844 in Hawaii, 1852 in Tahiti and 1883 in Fiji and New Caledonia. Subsequently, transmission periods recurred at various intervals, with significant episodes such as the major pandemic from 1940 to 1945 (serotype unknown) contemporary with World War II. After a 25-year break, various waves of epidemics affected a varying number of Pacific Island countries and territories, e.g. Dengue 2 and 1 in the 1970s, Dengue 4 and 3 in the 1980s. Then, after another relative pause from 1990 to 1994, a further occurrence of Dengue 3 and 4, followed by Dengue 2 from 1997 to 1999 were observed.

Lastly, a Dengue 1 outbreak began in 2000 in Palau and continued in 2001 in French Polynesia before spreading to almost the whole of the Pacific, including Hawaii, which had been spared by dengue fever since 1944, and Easter Island, previously untouched by this disease (the vector was only introduced there in 2000).

Mode of transmission

Although it has been proved that monkeys can be infected by the dengue virus in the wild, it is believed that there is no sylvatic cycle outside Africa and that humans are the only reservoir of the virus.

However, the existence of vertical transmission and the ability of eggs laid by mosquitoes of the Aedes genus to resist desiccation would suggest that the mosquitoes themselves may play a role in the survival of the virus in periods between outbreaks.

Apart from this particular case, the transmission of a virus from an infected subject to a healthy one takes place as follows. The female mosquito takes in viral particles when it feeds on the blood of a viraemic subject. The virus is carried with the ingested blood to the insect's oesophagus and ends up in the stomach and penetrates the intestinal epithelium cells where, after a latency phase, it replicates intensively. Carried in the haemolymph (the insect's 'blood'), the virus invades the whole of the mosquito's organism and reaches the salivary glands where another replication phase takes place. During a subsequent bite, the female will inject into its victim some micro-drops of saliva as all haemophageous arthropods do and simultaneously inoculate a small amount of virus which, if the subject is not immune, will trigger the disease after a 3–8 day incubation period.

Ingestion of infected blood and the subsequent infectious bites are separated by a time period called extrinsic incubation (if the arthropod takes another blood meal in between, the bite will not be infectious). This period, which basically depends on the temperature and dose of virus ingested, may range from 8 to 14 days. A female that becomes infectious will remain so until the end of its life, which usually lasts about a month.

Vectors

The mosquitoes capable of transmitting the dengue viruses in the Pacific all belong to the genus *Aedes*, sub-genus *Stegomyia**. Apart from *Aedes aegypti*, they include various species of the Scutellaris group, including *Ae. albopictus*, *Ae polynesiensis* and at least nine (9) others with varying ranges.

Ingestion of infected blood and the subsequent infectious bites are separated by a time period called extrinsic incubation

Aedes (Stegomyia) aegypti* Linnaeus 1762, is a mosquito of African origin. Its quasi-domestic lifestyle has enabled it to passively colonise almost all the tropical and mild temperate countries of the world. It was eradicated in the mid-20th century from the Mediterranean rim and subsequently from a major part of the American continent under the impetus of programmes to control yellow fever, for which it is also the main vector. During the 20–30 years that followed the end of such programs, *Ae. aegypti* reappeared in much of the territory it had disappeared from. It was introduced to the Pacific in the late 19th and early 20th centuries and can now be found in most island groups.

It is the major dengue fever vector everywhere it occurs and its bio-ecology has been extensively studied.

The eggs are laid around the lips of containers, often artificial ones. These eggs are said to be durable, in other words they can resist desiccation, remain intact for a number of months and finally hatch normally once they come in contact with water. It is probably mainly in this desiccated form that the mosquito has accompanied humans during their migrations.

The larvae are vermiform and highly mobile. They possess a bullet-shaped abdominal "siphon", which is darker than the body and forms only a slight angle with it. Under powerful magnification, it is possible to

distinguish the presence of thick spines at the base of the lateral thoracic bristles.

The larvae are exclusively found around human dwellings, in small to medium-sized recipients, off the ground, that contain fresh water with little organic matter content. The distinction can be made between domestic breeding grounds, directly maintained by humans and active all year round (drinking water storage containers, flower pots, animal drinking bowls, etc), and peri-domestic breeding sites, associated with human activity, but only filled up with rain water (old tyres, recipients of all kinds left out exposed to the weather, bottoms of boats, clogged gutters, etc).

Less frequently, some natural breeding sites such as hollow trees, rockholes or plants with a leaf sheath (e.g.: Bromeliaceae) may harbour *Ae. aegypti* larvae. On the other hand, the larvae are never found in large bodies of water at ground level such as marshlands, ruts or flooded flatlands.

Adults are active in the daytime, particularly in the morning and late afternoon.

Ae. aegypti's anthropophily (preference for human beings as hosts) is very marked. Its spontaneous dispersal range is less than 100 m, at least so long as hosts and adequate egg-laying sites are available. The corollary of these two characteristics is that they are only found in the immediate vicinity of human habitats, on which they are completely dependent.

Less frequently, some natural breeding sites such as hollow trees, rockholes or plants with a leaf sheath (e.g.: Bromeliaceae) may harbour Ae. aegypti larvae.

Females readily enter dwellings to bite their victims (endophagy) and remain indoors to rest (endophily). The flight of *Ae. aegypti* is discreet and prudent with the female often flying off when disturbed during a blood meal. For this reason, it may bite several people one after the other and thus spread a disease more quickly among a human population.

The body is dark with white or silver patches. The legs are clearly striped in white at the joints, and the ends of the back legs (tarsi n°5) are completely white. *Ae. aegypti* is also recognisable from a conspicuous white marking in the form of a two-string lyre on the back of the thorax, visible under magnification.

Aedes (Stegomyia) albopictus* Skuse 1895, originates in the Far East. It is a member of the *Scutellaris* group, a closely related group of species, probably of common origin in the relatively recent past. Its area of distribution, until recently limited to Eastern Asia and some Indian Ocean and Pacific Islands, has expanded in a spectacular manner over the past 15 years. It is now firmly established in the United States, Latin America, Southern Europe (Albania, Italy) and Africa (Nigeria). In the Pacific, it is found in Papua New Guinea, Solomon Islands, Micronesia, Fiji and Hawaii, where it was the only dengue vector during the 2001–2002 outbreak.

The bio-ecology of *Ae. albopictus* is similar to that of *Ae. aegypti*.

The eggs are also durable but those of certain strains are more cold-resistant, which explains the broader distribution of the species in temperate countries.

The larvae are almost identical to those of *Ae. aegypti*, from which they can be distinguished only by trained observers assisted by powerful magnification.

Dependence on the human environment is less strict than *Ae. aegypti*'s. In addition to artificial egg-laying sites, *Ae. Albopictus* may use a wider variety of natural breeding grounds (rockholes, hollow trees, leaf stems, bamboo stumps, etc) and adult females are as likely to bite animals as humans, which explains why this species is often found in rural areas and even in forests. This also explains the fact that its vector ability is generally considered lower than that of *Ae. aegypti*, whereas its susceptibility to oral infection is higher. In the wild, a major proportion of the infectious blood meals are taken from animals, which are epidemiological dead-ends. Less endophagic than *Ae. aegypti* and seldom endophilic, *Ae. albopictus* has a wider flight range, which does not, however, seem to exceed 400 to 500 meters around the original breeding site. It is also a diurnal mosquito.

The adult is very similar to *Ae. aegypti* with some exceptions: the lyre-shaped marking on the back of the thorax is replaced by a single white stripe in *Ae. albopictus* and a conspicuous patch of white scales shaped like a boomerang can be seen on the sides of the thorax, under the wings.

Aedes (Stegomyia) polynesiensis* Marks 1951 also belongs to the scutellaris group. It is likely that following human migrations in the Pacific, this mosquito has undergone speciation associated with its ability to breed in land crab burrows. Other ecological niches, vacant in the island environment, are thought to have been recolonised subsequently. Its current area of distribution includes, to quote full current knowledge, Fiji, Samoa, Wallis and Futuna, Tuvalu, Tokelau, Cook Islands, French Polynesia and Pitcairn.

It is the major vector of lymphatic filariasis in the Pacific areas where it occurs but its ability to transmit dengue has also been proven. Research has shown that this mosquito can maintain epidemics by itself as was the case in the past in American Samoa, the Marquesas Islands and the Cook Islands before *Ae. aegypti* was introduced to these areas. In Wallis and Futuna, the transmission of dengue in 1975–1976 was associated with *Ae. polynesiensis*, the only potential vector recorded during this period, and similar observations were made during the 2002–2003 outbreak.

This species is particularly well-suited to the ecosystems found in the Pacific Islands. Its larvae can be found in the artificial recipients already mentioned in connection with *Ae. aegypti* and in a variety of natural breeding grounds, but also in the highly specific biotopes like fallen coconuts gnawed by rats and the burrows of the land crab *Cardisoma carnifex*.

These characteristics make it a mosquito that occurs in the human environment, in forests and on uninhabited islets. Swarms may be very large in some cases and biting rates of 600 or more per human and per hour are not unusual.

The larvae are impossible to distinguish from those of *Ae. albopictus* and other members of the *scutellaris* group without extensive experience. The same can be said of adult females, which are also characterised by a single white stripe on the thorax. In the same way as the two species previously referred to, they have diurnal activity but, like *Ae. albopictus*, they do not usually enter human dwellings. They take their blood meals from both humans and wild or domestic animals. Their dispersal around the original breeding site extends to several hundred metres but can exceed one km if there is a shortage of hosts and/or breeding sites.

Other species of the *scutellaris* group

Species of the *scutellaris* group are numerous in the Pacific where speciation has taken place because of the specific isolation conditions prevailing in islands. Distribution is often highly localised.

Some of them have been incriminated as dengue vectors either on a biological basis, i.e. experimental transmission or laboratory-induced infection, or on an epidemiological basis, i.e. occurrence of dengue epidemics with no significant presence of *Ae. aegypti* or other species with a recognised vector capacity, or both of the above simultaneously.

For this reason, the Western Pacific is probably the world's region with the highest number of different dengue fever vector species.

These mosquitoes have a morphology similar to that of *Ae. polynesiensis* and are extremely difficult to distinguish one from another.

They have in common the fact that they lay durable eggs in small clutches in containers generally above ground level, e.g. hollow trees or rocks, coconut shells, axils of plants with sheathed leaves and a very wide range of artificial recipients such as those used by *Ae. aegypti*.

Table 1: *Aedes (Stegomyia)* species of the *scutellaris* group that are dengue vectors in the Pacific

Species	Distribution	Arguments in favour of vector status.
***Aedes cooki* Belkin 1962**	Niue, Vava'u Group (Tonga)	Epidemiology, laboratory infections
***Aedes hebrideus* Edwards 1926**	Wuvulu Island (PNG), Rennell, Bellona and Santa Cruz Islands (Solomon Islands), wide distribution in Vanuatu	Epidemiology, laboratory infections
***Aedes hensilli* Farner 1945**	Palau, Yap, Chuuk	Epidemiology
***Aedes kesseli* Huang & Hitchcock 1980**	Niua Group (Tonga)	Epidemiology, laboratory infections
***Aedes marshallensis* (Stone & Bohart 1944**	Marshall Islands, Kiribati, Kosrae, Pohnpei	Laboratory infections
***Aedes pseudoscutellaris* Theobald 1910**	Fiji	Laboratory infections
***Aedes rotumae* Belkin 1962**	Rotuma Island (Fiji)	Epidemiology.
***Aedes scutellaris* Walker 1859**	Indo-Malay archipelago, north-eastern Australia. In the Pacific: Papua New Guinea, Palau and some islands of Micronesia	Epidemiology, experimental transmission
***Aedes tabu* (Ramalingam& Belkin) 1965**	Ha'apai Group and Tongatapu (Tonga)	Laboratory infections

The larvae of certain species colonise land crab burrows in large numbers and they are occasionally found in wells.

The adult mosquitoes all have diurnal activity. They virtually all only attack humans. Endophagic and endophilic behaviour varies from species to species.

A partial list of those mosquitoes is given in Table 1.

Epidemic Polyarthritis Due To The Ross River Virus

Disease

The Ross River virus, the agent of this disease, belongs to the genus *Alphavirus*. It was first isolated in 1959 in a batch of mosquitoes (*Aedes vigilax*) collected close to the river of the same name in Queensland, Australia.

The incubation period varies from 3 to 21 days but in most cases is between 7 and 14 days. The main symptom is the rapid sudden onset of arthralgia, usually in limb joints and extremities, accompanied by asthenia and muscle pains. Frequently observed is a maculopapular rash, which is normally not pruriginous. The patient's temperature is not often high.

Vector infection occurs in the same way as for dengue fever, i.e. during blood meals on viraemic vertebrates.

Evolution is always favourable but temporary after-effects are not uncommon. The rash goes away after one to two weeks. Joint pains may last from several days to several months or even years.

It is estimated that about 30% of infected subjects develop the disease while the others remain asymptomatic.

The area of distribution extends over the whole of Australia where thousands of cases are reported every year. Cases of transmission have also been recorded in New Guinea (Papua New Guinea and Irian Jaya), and a major outbreak affected several South Pacific countries from 1979 to 1980, including Fiji, Cook Islands, New Caledonia, Wallis and Futuna, Tonga and Samoa.

Mode of transmission

The Ross River virus mainly infects animals, with macropod marsupials serving as the main vertebrate host-reservoirs in those areas where the disease is endemic (Australia). However, domestic animals such as horses may play a role in the epidemiology of the virus, as may certain species of Chiroptera (*Pteropus spp*.). Lastly, some aspects of the 1979–80 Pacific outbreak strongly suggest that, under certain conditions, direct human–mosquito–human transmission may occur. It is possible that the survival of the virus between epidemics partly occurs due to the existence of vertical transmission, which has been demonstrated in some vector species.

Vector infection occurs in the same way as for dengue fever, i.e. during blood meals on viraemic vertebrates.

Vectors

The Ross River virus has been isolated from a large number of Culicidae. We will only refer here to those whose epidemiological role is significant and which represent a risk for the Pacific area.

Aedes (Ochlerotatus) vigilax* Skuse 1889 is a mosquito of the coastal zones which occurs all along the western Pacific seaboard from Thailand to Australia and from Malaysia to Fiji and New Caledonia.

The eggs, which are durable in the same way as those of *Ae. aegypti*, are laid separately directly on the ground or at the base of plant stems. Breeding sites are formed by pools and troughs to the landward side of the mangroves that fill with water either during the highest high tides or because of heavy rains.

The larvae can tolerate water with high salinity. They are very similar to that of *Ae. aegypti* but the two species never cohabit. Densities of several hundred specimens per square metre are not unusual.

The adults are active throughout the nycthemeron, with a peak of aggressiveness at sunset. Large clouds of these mosquitoes can often be found close to breeding sites.

This mosquito has excellent flying abilities and some specimens can be found as far as several kilometres away from their original breeding site.

The body is dark and the pointed abdomen is banded with pale stripes. No markings are visible on the back of the thorax and only a few yellowish patches appear on the flanks. The legs are striped and are black at the ends. The proboscis is yellow close to the head and black over the last third.

The female *Ae. vigilax* attacks both humans and a wide variety of animals, including birds.

***Culex (Culex) annulirostris** Skuse* 1889 occurs in the Philippines, Indonesia and Australia. It is found in New Guinea and throughout the Pacific Islands except New Zealand. It is the main vector of the Murray Valley virus in Australia but it is also extensively responsible for transmitting the Ross River virus.

Its eggs do not tolerate desiccation. They are laid directly on the surface of the water, in "rafts" of 50 to 200 eggs.

The larvae possess a long thin respiratory siphon. They may be found in almost all kinds of ground-lying water bodies: temporary or permanent, fresh or slightly brackish, clear or containing organic matter, exposed to the sunshine or in the shade. Less frequently, artificial recipients may also be used.

The adult female has a rounded abdomen and a white ring on the proboscis. The legs have clear markings at the joints. This is a generally nocturnal mosquito but the peak of activity would appear to vary from one location to another and attacks may occur in the daytime. The choice of hosts is very wide but livestock is usually preferred, followed by dogs, then humans and other mammals. *Cx. annulirostris* does not seem to be attracted to birds.

Aedes (Finlaya) notoscriptus* Skuse 1889 is an Australian species. Its area of distribution in the Pacific includes New Guinea, New Caledonia and New Zealand. This semi-domestic mosquito breeds in small natural recipients or artificial containers. It bites humans, birds and various wild or domestic animals at any time of the day or night. Its responsibility in the transmission of the Ross River virus is based on isolations performed from specimens collected in the wild.

The mortality rate reaches 30% of clinical cases and half of the survivors suffer from severe neuro-psychiatric consequences.

Other vector mosquitoes

During the 1979–80 outbreak in the Pacific Islands, the main species responsible for transmission was apparently *Ae. polynesiensis* where it occurred and when *Ae. vigilax* was absent. *Ae. aegypti* has never been found to be carrying the virus in the wild but experimental transmission has proved possible. *Ae. albopictus* was not present in great numbers in Fiji during the relevant outbreak. On the other hand, it is possible that it plays a role in the transmission of the virus in Papua New Guinea and Solomon Islands.

Japanese Encephalitis

Disease

Japanese encephalitis is the most important arboviral encephalitis in the world in terms of morbidity and mortality, with some 50,000 cases causing 15,000 deaths each year. The virus, of the genus *Flavivirus*, has been in circulation for a long time throughout southern and eastern Asia. It has recently appeared in Papua New Guinea and the Torres Strait Islands of Australia. Outbreaks have also occurred in Micronesia, i.e. on Guam in 1947 and on Saipan in 1990. After a 6–16 day incubation period after the bite by the vector mosquito, the infection develops into asymptomatic forms (estimated to prevail in approximately 98% of cases) or into a clinical profile ranging from a benign feverish syndrome to acute encephalitis. The latter condition may be characterised by headaches, vomiting, reduced awareness and convulsions. The mortality rate reaches 30% of clinical cases and half of the survivors suffer from severe neuro-psychiatric consequences.

Mode of transmission

Japanese encephalitis is a zoonosis affecting many domestic and wild animals. From the epidemiological standpoint, the most important species are pigs, that show a high and long-lasting viraemia, which is difficult to detect due to the lack of clinical signs, some birds (in particular the Ardeidae: herons, egrets, etc.) and Chiroptera. On the other hand, cattle, dogs, horses and humans have insufficient viraemia to infect vector mosquitoes and so do not play any role in the dissemination of this virus. The mode of infection for vectors is the same as for dengue fever.

Vectors

Although other species can transmit this virus in the laboratory (e.g. *Ae. albopictus*), it is believed that the vectors of the JE virus in the wild are usually mosquitoes of the genus *Culex*. We will only refer here to those species that occur in the Pacific.

Culex (Culex) tritaeniorhynchus Giles 1901 has a very broad geographical range in the whole eastern bio-geographical region and extends northeast to Japan, Korea, China and maritime Russian Siberia. It is present in the Pacific in the Mariana Islands. It is the principal vector of the JE virus in continental Asia.

Both its bio-ecology and morphology are very close to those of *Cx. annulirostris*. It is a nocturnal mosquito, which feeds preferentially on cattle, pigs and birds and occasionally on humans.

Culex (Culex) annulirostris Skuse 1889 is also considered to be a vector of the JE virus.

Culex (Culex) sitiens Wiedemann 1828, like *Ae. vigilax*, is a seaside-dwelling mosquito. It is found on the tropical shores of the Indian Ocean, the Pacific and adjacent seas. It does not occur east of Niue. It transmits the virus very efficiently in laboratory conditions and its abundance pleads in favour of an active role in the epidemiology of this disease. It is always found along the seashore, where its larvae colonise pools, puddles and drains

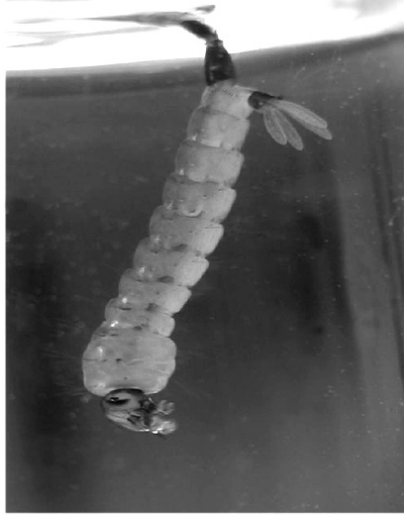
containing brackish or salt water. In the same way as *Ae. polynesiensis*, it is able to breed in land crab burrows.

The larvae are very similar to those of *Cx. Annulirostris*, with which it sometimes cohabits. The adult has the same general appearance but the colouring is darker and some details make it possible to distinguish it easily with powerful magnification. *Cx. sitiens* is a nocturnal mosquito. Its aggressiveness to humans seems to vary considerably from place to place.

---

* A recent taxonomic review (Reinert, 2004) proposed a thorough restructuring of the genus *Aedes*, elevating many sub-genera to genus level with consequent name changes affecting species of major medical importance. A lively debate ensued between taxonomists, medical entomologists and publishers of scientific journals and the consensus that emerged concluded that further investigation was necessary. Pending the results of such further research, the traditional names should continue to be used. This means that the genus *Ochlerotatus*, created by Reinhardt in 2000, reverts to being a sub-genus of the genus *Aedes*.

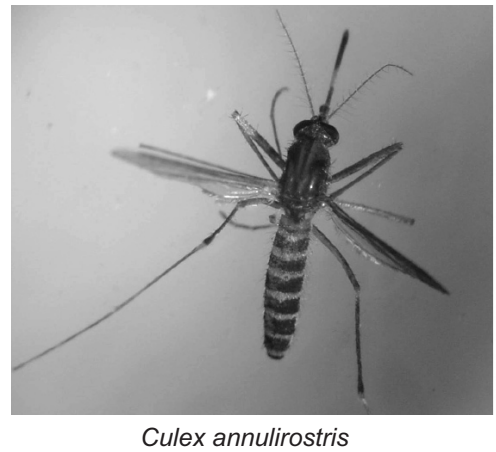
Aedes aegypti



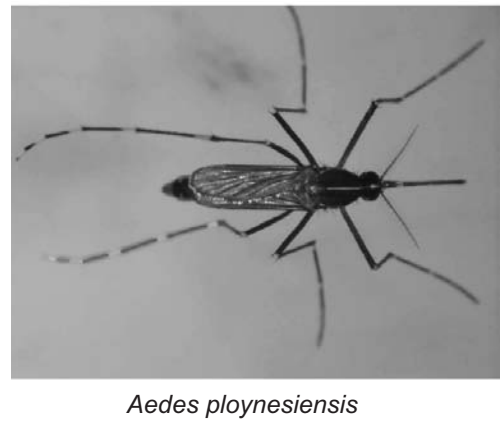
Aedes aegypti larvae

Culex sitiens

Aedes vigilax



Culex annulirostris



Aedes ploynesiensis

Bibliography

1. Belkin, J.N. The mosquitoes of the South Pacific. University of California Press, Berkeley & Los Angeles. 1962; 2 vols.

2. Calisher C.H. Persistant Emergence of Dengue. Emergent Infectious Diseases, 2005; 11(5): 738-739.

3. Effler P.V. Dengue fever, Hawaii, 2001-2002. Emerging Infectious Diseases, 2005; 11(5): 742-749.

4. Gubler D.J. Dengue and dengue hemorrhagic fever: its history and resurgence as a global public health problem. In : Gubler D.J ., Kuno G. , editors. Dengue and dengue hemorrhagic fever . New York CAB International, 1997; p.1-22.

5. Halstead S.B., Jacobson J. Japanese Encephalitis. Advances in Virus Research, 2003; 61: 103-138.

6. Harley D., Sleigh A., Ritchie S.A. Ross River Virus Transmission, Infection and Disease: a Cross-Disciplinary Review. Clinical Microbiology Reviews, 2001;14(4): 909-932.

7. Kiedrzynski T., Souares Y., Stewart T. Dengue in the Pacific : an updated story. Pacic Health Dialog, 1998;5(1): 129-136.

8. Lee D.J., Hicks M.M.,Griffiths M., Russell R.C., Marks E.N. Entomology monograph n° 2 : The Culicidae of the Australasian Region. Australian Government Publishing Service. Canberra, 1989;12 vols.

9. Lindsay M.D.A.Ross River and Barmah Forest viruses in Western Australia. Course notes, Mosquito Control Course, Mandurah, 16-20th September 2002, published by the Health Department of Western Australia, 2002.

10. Perret C, Abarca K, Ovalle J, et al. Dengue-1 virus isolation during first dengue fever outbreak on Easter Island, Chile. Emerg Infect Dis [serial online] 2003 Nov [date cited]. Available from: URL: http://www.cdc.gov/ncidod/EID/vol9no11/02-0788.htm

11. Riviere F. Thèse de doctorat. Écologie de Aedes (Stegomyia) polynesiensis, Marks, 1951, et transmission de la filariose de Bancroft en Polynésie, 1988.

12. Rodhain F, Perez C. Précis d'Entomologie Médicale et Vétérinaire. Maloine s.a. éditeur, 1985.

13. Rodhain F, Rosen L. Mosquito vectors and dengue virus-vector relationships. In : Gubler D.J., Kuno G., editors. Dengue and dengue hemorrhagic fever. New York CAB International, 1997; p. 45-60.

14. Rueda L.M. Pictorial keys for the identification of mosquitoes (Diptera : Culicidae) associated with Dengue Virus Transmission. Zootaxa 2004; 589,:1-60.

15. Savage H.M. et al. Epidemic of dengue-4 virus in Yap state, Federated States of Micronesia, and implication of Aedes Hensilli as an epidemic vector. American Journal of Tropical Medecine and Hygiene, 1998:58(4); 519-524.

16. Trpis M., Hausermann W. Dispersal and other population parameters of Aedes aegypti in an African village and their possible significance in epidemiology of vector-borne diseases. American Journal of Tropical Medecine and Hygiene, 1986; 35: 1263-1279.

To address poverty, economic growth is not an option: it is a necessity
(Mahibub ul Hag – 1994)