



## **DISASTERS AND MEDICALLY IMPORTANT INSECTS IN THE NORTHERN TERRITORY**

Peter Whelan  
Senior Medical Entomologist  
Medical Entomology Branch  
Department of Health and Families  
Darwin NT

and

Andrew Van Den Hurk  
Department of Microbiology and Parasitology  
School of Molecular and Microbial Sciences  
University of Queensland  
Brisbane Queensland

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For more information contact:

Department of Health and Families  
Medical Entomology  
PO Box 40596  
Casuarina NT 0811

## INTRODUCTION

Insects are the largest class in the animal kingdom. They belong to the Phylum Arthropoda, which also includes spiders, crustaceans, ticks, centipedes and millipedes. All members of the phylum are characterized by having a segmented body and segmented legs. Insects and some other arthropods are the vectors of some of the most destructive diseases in the world, some of which are listed in Table 1. The vectors of disease that are of relevance to Australia are mosquitoes, black-flies, ticks and mites. Of these, mosquitoes are considered to be the most important.

Vector	Disease	Pathogen
Mosquitoes ( <i>Anopheles</i> spp.)	Malaria	<i>Plasmodium</i> spp.
Mosquitoes ( <i>Aedes</i> spp.)	Dengue fever	Dengue virus
	Yellow fever	Yellow fever virus
Mosquitoes ( <i>Aedes</i> , <i>Ochlerotatus</i> and <i>Culex</i> spp.)	Encephalitis	Various viruses
	Ross River Virus Disease	Ross River virus
Sand-flies ( <i>Phlebotomus</i> )	Leishmaniasis	<i>Leishmania</i> spp.
Triatome bugs	Chagas' disease (American trypanosomiasis)	<i>Trypanosoma cruzi</i>
Tsetse flies ( <i>Glossina</i> )	African Trypanosomiasis	<i>Trypanosoma</i> spp.
Black flies ( <i>Simulium</i> )	Onchocerciasis	<i>Onchocerca</i>
Mosquitoes ( <i>Culex</i> , <i>Anopheles</i> , <i>Mansonia</i> and <i>Ochlerotatus</i> spp.)	Lymphatic filariasis	<i>Wuchereria</i> spp., <i>Brugia</i> spp.
Ticks	Tick typhus	<i>Rickettsia</i> spp.
	Lyme disease	<i>Borrelia burgdorferi</i>
Mites	Scrub typhus	<i>Orientia tsutsugamsushi</i>
House flies & Blow flies	Food poisoning	<i>Shigella</i> , <i>Salmonella</i> , <i>Escherichia coli</i>

**Table 1.** Arthropod vectors of human diseases (after Sutherst, 1993).

## MOSQUITO BORNE DISEASES OF AUSTRALIAN SIGNIFICANCE

### Malaria

Malaria is a debilitating disease caused by protozoa of the genus *Plasmodium*. There are 120 different species of *Plasmodium*, of which *P. vivax*, *P. falciparum*, *P. malariae* and *P. ovale* infect humans. Depending on the species of *Plasmodium*, symptoms of malaria include fever, chills, sweats and headache. In *P. falciparum* it progresses to blood coagulation, shock, renal and liver failure, coma and death. *Plasmodium* undergoes its sexual cycle in mosquitoes and asexual cycle in humans. Malaria in nature is only transmitted to humans through the bite of *Anopheles spp.* mosquitoes.

Endemic malaria last occurred in Australia in the Northern Territory in 1962. Australia has been certified free of endemic malaria since 1981. However, there is still potential for malaria transmission from people infected in malarious countries. Local transmission is only possible where known vectors occur, generally north of 19°S. In northern Australia, any of the three sibling species of *Anopheles farauti* are considered to be the primary potential malaria vector.

### Dengue fever

Dengue fever (DF), and dengue haemorrhagic fever (DHF) results from infection by any of the four serotypes of dengue virus. Patients suffering from classic dengue fever experience a sudden onset of fever, headache, retro-orbital pain, arthralgia, myalgia and minor haemorrhaging. Manifestations of DHF include severe haemorrhage from vascular permeability leading to shock through blood loss and encephalopathy with hepatitis. Dengue was common in northern Australia earlier in the twentieth century with epidemics occurring in Queensland, the Northern Territory and New South Wales. All available evidence suggests that dengue is not endemic in Australia, although outbreaks do occur in Queensland from virus introduced by viraemic travelers.

Dengue virus transmission occurs through the bite of infected *Aedes* mosquitoes, of which *Aedes aegypti* is the only vector in Australia. *Aedes aegypti* is not present in the NT but it and the other dengue vector, the Asian tiger mosquito *Aedes albopictus*, have been occasionally imported and eradicated. There is a continuous risk of these dengue vectors being introduced to the NT.

### Murray Valley encephalitis

Murray Valley Encephalitis (MVE) is caused by a flavivirus, first isolated from a fatal human case from the Murray valley of northern Victoria in 1951. Most human infections are subclinical, with a clinical to sub-clinical ratio varying from 1:500 to 1:5000. The presentation of MVE cases is variable but major symptoms include sudden onset with fever, nausea, headache, vomiting and non-specific dizziness, followed by symptoms of meningitis and brain dysfunction. Approximately one third of cases are fatal, with one third of survivors suffering neurological sequelae with physical and/or intellectual handicap. Since 1974, as many as 50 clinical cases of MVE have been recorded from northern Australia, with the majority from the north of Western Australia and the Northern Territory.

Humans are infected by mosquitoes, which acquire the virus from a vertebrate reservoir. Major vertebrate hosts of MVE are waterbirds (particularly night herons), although a range of avian (including ducks and parrots) and mammalian (such as kangaroos and rabbits) vertebrates have been implicated on serological grounds. Extensive field studies have confirmed that *Culex annulirostris* is the major vector of MVE in Australia, accounting for more than 90% of isolates.

### Japanese encephalitis

Japanese encephalitis (JE) is a mosquito-borne arboviral disease of major public health concern in Asia, responsible for 35,000 cases and 10,000 deaths annually. In 1995 an outbreak of JE resulted in three cases at Badu Island in the Torres Strait, indicating the first incursion of this disease into Australia. Infection with JE virus results in similar clinical symptoms as MVE, although the clinical to subclinical ratio ranges from 1:25 to 1:400. Fortunately, a JE vaccine exists, which gives up to 5 years protection.

During the Badu Island outbreak an extensive mosquito trapping program resulted in the isolation of JE virus from *Culex annulirostris*, implicating this species as the most likely Australian vector. Potential vectors also include *Culex palpalis* and the recently established *Cx. gelidus*. Wading birds and pigs are the principle vertebrate amplifying hosts, while humans are dead-end hosts. Active surveillance is currently being undertaken to determine when JE is introduced or becomes established on the Australian mainland. Risk areas in the NT are the ones closest to Papua New Guinea or Timor.

### **Ross River virus disease (formerly epidemic polyarthritis)**

Ross River (RR) virus, the aetiological agent of the disease, is the most common arboviral disease in Australia. RR virus has been reported from all Australian states including Tasmania, with several hundred to several thousand cases reported annually. In northern and central Queensland and the Top End of the NT, particularly in coastal regions, the virus is active throughout the year. In the Top End of the NT the principle transmission season is from December to March inclusive. Elsewhere in Australia, virus activity tends to be epidemic, following summer rain and/or tidal inundation of saltmarsh in coastal regions of Australia. The major clinical features of epidemic polyarthritis include various combinations of arthralgia and arthritis, usually involving joints of the extremities, myalgia, lethargy, a maculopapular rash, headache and (less often) fever. RR virus infection is often subclinical, particularly in adolescents, with as many as 80% of cases being asymptomatic.

RR virus is sustained in a mosquito-mammal cycle, with kangaroos, wallabies and flying foxes being the main vertebrate hosts. There are indications that humans may act as primary hosts in epidemic situations and serve to distribute the virus geographically. So far, at least 30 species of mosquitoes have been shown to carry RR virus in nature. The most important species associated with RR virus in the NT are: *Verrallina funerea*, *Oc. notoscriptus*, *Oc. vigilax*, *Cx. annulirostris* and *Oc. normanensis*. In the Top End of the NT *Oc. vigilax* and *Cx. annulirostris* are the major vectors, while in inland areas *Oc. normanensis* and *Cx. annulirostris* are the major vectors.

### **Barmah Forest virus disease**

Barmah Forest (BF) virus was originally isolated from *Cx. annulirostris* collected in the Barmah Forest on the Murray River in northern Victoria. BF virus and RR virus infection exhibit similar symptomatology. However, BF virus causes significantly more rash than RR virus, while arthralgia and arthritis are less common than with RR virus. Again, like RR virus, BF virus has a high ratio of subclinical to clinical infection.

Sporadic cases of BF infection have been reported Australia wide, with most of the cases in the NT occur in the Top End from December to March. The first major Australian outbreak of BF was recorded in the NT at Nhulunbuy in February 1992.

Very little is currently known about the ecology and epidemiology of BF virus. The vertebrate hosts of BF virus are yet to be elucidated, although

marsupials, cattle, horses and waterbirds have been implicated as a source of infection. The major mosquito vectors of BF virus are considered to be *Ochlerotatus vigilax* and *Cx. annulirostris*.

## **BIOLOGY OF IMPORTANT VECTOR AND PEST MOSQUITO SPECIES**

Apart from their ability to transmit disease, mosquitoes can be a considerable nuisance in some areas. Of the species that are important vectors of disease in the NT, mmmmm *Verrallina funerea*, *Oc. vigilax*, *Oc. normanensis* and *Cx. annulirostris* can proliferate after high tides, heavy rainfall or flooding associated with cyclones and floods. Others such as *Ae. aegypti* could become introduced to the NT or prolific following cyclones and widespread rain filling exposed receptacles such as drains and tyres.

### ***Aedes aegypti***

*Aedes aegypti* is a peridomestic mosquito that breeds in artificial water containers such as tyres, ice cream containers and pot plant bases, and occasionally in natural receptacles such as leaf axils of *Bromeliads* and palm fronds. *Aedes aegypti* is predominantly a day biter, being most active in the early morning (0600 hr-0800 hr) and late afternoon (1500 hr-1800 hr). *Aedes aegypti* has a preference for human blood and is found frequently biting and resting inside buildings.

### ***Verrallina funerea***

*Verrallina funerea* is a recently discovered RR virus vector, which can be major pest in areas close to *Melaleuca* swamps or mangroves. This species breeds in slightly brackish to fresh pools, usually well shaded, in swampy areas of *Melaleuca* and sedges adjoining tidal areas. *Verrallina funerea* is a common daytime biter, with activity also on dusk. It rarely bites outside of well-shaded areas during the day.

### ***Ochlerotatus notoscriptus***

*Ochlerotatus notoscriptus* is arguably the major domestic pest species in Australia. It breeds in artificial containers, such as tyres, pot plant drip trays, roof gutters and boats. Its habitat is similar to *Ae. aegypti*. *Ochlerotatus notoscriptus* readily bites indoors or outdoors throughout the day, with peak activity at dusk.

### **Ochlerotatus vigilax**

*Ochlerotatus vigilax* is the main coastal vector of RR virus in northern and north-western Australia. Most commonly found breeding in temporary, brackish water left in saltmarsh or mangrove pools or shallow depressions on tidal flats by higher than normal tides or rainfall. *Ochlerotatus vigilax* usually bites outdoors at sunrise and sunset but will bite throughout the day in shaded areas within 5-10km of coastal breeding sites. It is more common in the Top End from August to January, usually reaching a peak in the December to January period.

### **Ochlerotatus normanensis**

*Ochlerotatus normanensis* is usually associated with drier, sparsely populated areas (i.e. outback), where it can become an abundant pest nuisance at times. This northern species breeds in a variety of freshwater breeding sites, ranging from temporary ground pools and animal footprints to large temporary pools. *Ochlerotatus normanensis* will readily bite during the afternoon and night.

### **Anopheles farauti s.l.**

*Anopheles farauti* breeds in semi-permanent brackish or freshwater sites, such as swamps, lagoons or ponds, usually with emergent vegetation. *Anopheles farauti* is predominantly a night biter (1900 hr-0030 hr) with a peak for the first hour after sundown. It bites both inside and outside houses.

### **Culex annulirostris**

*Culex annulirostris* is the major vector of arboviral disease in Australia, particularly in inland areas, where proliferation of this species occurs after summer rain. Typical *Cx. annulirostris* breeding habitats include freshwater swamps, lagoons and transient grassy pools, as well as saltmarsh pools, irrigation channels, raw sewage effluent and artificial containers. *Culex annulirostris* is mainly a nocturnal biting species, with peak activity during the first hour after sundown (1700 hr-2000 hr) and a small peak before dawn (0530hr-0630 hr).

## **Culex gelidus**

*Culex gelidus* is a new introduction to Australia and is currently in Queensland and the Northern Territory. It is found in Indonesia, New Guinea and Timor and other areas of Asia where it is regarded as a vector of Japanese encephalitis. In the NT it is widely distributed from Darwin to Alice Springs, breeding in freshwater ground pools, marshes and containers, with productive sites in wastewater ponds with high organic levels. It is found mainly breeding during the wet season. If *Cx. gelidus* breeds in close association with pigs, it could play a major role in Japanese encephalitis transmission in Australia. It is reported to bite humans readily, particularly in the absence of other animals.

## **Culex palpalis**

*Culex palpalis* is a potential vector of MVE and other arboviruses. It breeds in situations similar to *Cx. annulirostris*, although generally it is found more often in clear freshwater swamps. It is widespread in the NT and is often found in high numbers in sub coastal swamps in the latter wet season and early dry season. It bites humans readily after sundown and can reach very high population levels.

## **OTHER INSECT SPECIES THAT BECOME ABUNDANT DURING CYCLONES AND FLOODS**

### **Houseflies and BlowFlies.**

Domestic flies can occur in pest numbers throughout the year in the Top End of the NT, with a tendency for higher populations in the wet season, when suitable breeding materials are kept moist and soil can be more suitable for maggot entry and survival. Populations of flies can be annoying but more importantly they play a role in disease transmission

Domestic flies carry disease-causing organisms in a number of ways. This includes:

- On their mouthparts.
- Through their vomit.
- On their body and legs

- On the sticky pads on their feet.
- Through their intestinal tract to faeces.

Diseases transmitted mechanically by domestic flies include typhoid, cholera, bacillary dysentery, infantile diarrhea, amoebic dysentery, giardiasis, pinworm, roundworm, whipworm hookworm and tapeworms. This includes transmission of organisms such as *Salmonella typhimurium* and *Shigella*, which causes food poisoning. Recently enterohaemorrhagic *Escherichia coli* have been shown to proliferate in houseflies and are excreted by the flies.

The house fly *Musca domestica* and the green/blue blow fly *Chrysomya megacephala* are the most common problem domestic flies in the Top End of the NT.

The housefly breeds in a wide range of garbage and is the most likely species to cause a nuisance and lead to food spoilage inside a house. It commonly breeds in wheelie bins in poorly packaged garbage. It also breeds in prolific numbers in horse dung and moist chicken manure.

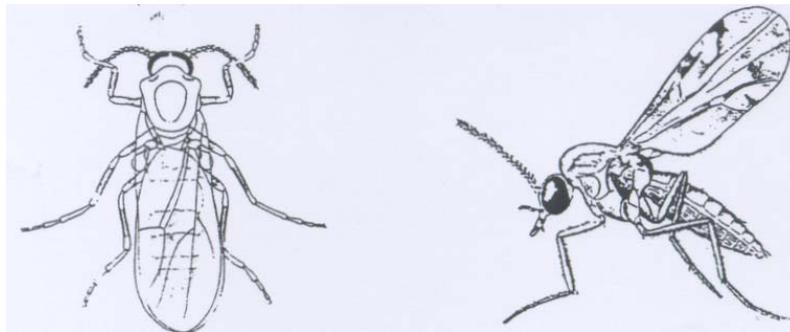
A female housefly can lay 4 to 6 batches of eggs of about 20 eggs each over a period of a few days. The eggs hatch in about 12 hours and the maggot stage takes about 5 days. The full-grown maggot migrates to a drier area or enters the soil to develop into a pupa. Pupae are often found in wheelie bins that have missed a collection. The pupa stage lasts about 4 days before the adult fly emerges. The development from egg to adult takes about 9 to 10 days in summer conditions. The adult flies feed on a great variety of materials such as faeces, meat, sugar, milk, or any other foodstuff. The fly vomits and deposits faeces on food and in this way can spread disease.

The blowfly tends to be less common inside houses but is more obvious because of its larger size and very active flight habits. It breeds mainly in meat products, other garbage with a high protein content, and dead animals. Common breeding places including wheelie bins with unpackaged garbage, waste pet food, discarded bones, and dead rats.

Blowflies can lay from 100 to 400 eggs in a single batch and the eggs hatch in about 8 hours. After hatching maggots can take as little as 3 days to mature and reach the wandering stage. Over 5000 mature maggots can be produced from 300 grams of food garbage in a single wheelie bin under Darwin conditions. Wandering maggots crawl out of garbage storage areas at night and then enter moist soil, where they pupate and can emerge as adults 5 to 7 days later. The adult flies are attracted by smell and feed on a variety of materials such as faeces, blood, sugar, milk, or any other foodstuff.

### Biting Midges (*Culicoides spp.*)

Biting midges (often erroneously called sandflies) are small (less than 2mm), relatively robust looking flies, that are annoying pests of man and domestic animals (Figure 1). They usually breed in wet soil in the zone between aquatic and terrestrial habitats, such as estuarine mud in mangroves (*Culicoides ornatus*), freshwater pond margins (*Culicoides marksii*) and wet soils with a high content of animal wastes (*Culicoides brevitarsis*).



**Figure 1.** Lateral and dorsal view of a female *Culicoides spp.*

The eggs are laid in batches (30-450 eggs depending on the species) and hatch within a few days. The larva, which emerges from the egg, feeds on a wide range of organisms, which they encounter in their movement through the substrate. There are four larval instars, which last anywhere from 2-3 weeks to 2-3 months (depending on the species). The larva then pupates and after several days, the adult emerges.

The adult *Culicoides* only disperse a short distance from their breeding sites (usually less than 1.0 km but up to 3.0 km for *C. ornatus*). *Culicoides* generally feeds at dusk (1800 hr-2000 hr) and dawn (0600 hr-0800 hr), although biting can be experienced throughout the day near breeding sites. The bites from *Culicoides* cause itching and, in sensitive individuals, welts and lesions that may persist for several days. These are sometimes complicated by secondary infections resulting from scratching.

## THE NATURE OF DISASTERS OF RELEVANCE TO MEDICALLY IMPORTANT INSECTS

It should be noted that disease outbreaks following a disaster are rare, as many of the diseases, such as malaria and dengue do not occur in Australia unless imported by travelers. Other diseases such as MVE and JE only have

a small and often isolated foci of activity. It is possible that transmission of RR virus and BF virus could increase, although appropriate self protection and control measures should limit this threat. Houseflies and blowflies can cause diseases which can be life threatening for old people and young children. In Australia biting midges are not vectors of any human disease, although they can cause considerable irritation through their bites.

There are several disaster scenarios that can directly result in an increase in the potential for vector and pest insects to become a menace to the human population. In situations that involve widespread flooding, *Aedes* or *Ochlerotatus spp.* eggs usually hatch first, as they have drought resistant eggs in ground depressions or receptacles such as tyres. *Anopheles spp.* and *Culex spp.* lay their eggs on the waters surface, where they undergo development for a further 1-3 days before hatching into larvae. House flies and blowflies can breed in damaged food, dead animals or wet animal faeces. The disaster situations that are applicable to mosquitoes and other flies are:

**i) Cyclones with destructive winds and flooding.**

Flooding from cyclones can come in two forms: a) the associated torrential rainfall and b) possible storm surge created by a significant rise in tides. In wet tropic areas, wet season rainfall has usually flooded most mosquito breeding sites, so that additional flooding will not increase the extent of mosquito breeding. However, in periods of dry weather or in drier areas (such as Katherine to Alice Springs), flooding associated with cyclones could produce significant numbers of *Oc. normanensis* and *Cx. annulirostris*. Extensive local flooding could have also the beneficial effect of flushing out breeding sites. However as waters recede, mosquitoes will colonize the pools as they dry up. Mosquitoes hatched by flooding associated with cyclones would emerge within 1-2 weeks depending on the temperatures. House flies and blowflies can begin breeding in 1-2 days after a disaster and need control within 4-5 days before they reach the wandering maggot stage and become difficult to treat with insecticides. As biting midges have a long larval stage, significant increases in *Culicoides* populations would not be expected for up to 2-3 weeks after the cyclone, although excessive flooding will not produce higher numbers of *Culicoides*.

Apart from the flooding of breeding sites for mosquitoes, strong winds associated with cyclones could cause widespread damage to housing and other structures. Insect screens, walls and roofs could be damaged allowing increased access of mosquitoes, biting midges and flies into otherwise protected houses. Structural damage of water supply and sewage drainage will provide a wide range of habitats for container breeding species such as *Ae. aegypti*, *Oc. notoscriptus* and *Cx. quinquefasciatus* (a nocturnal biter that breeds in polluted water), near human habitation.

Severe cyclones could require the relocation of residents to temporary housing in tents, schools or community halls. Without adequate screening, a great percentage of these people would become exposed to mosquito and biting midge bites and flies.

## ii) Flooding of Coastal Rivers, Creeks and Floodplains

Torrential rain, causing flooding of coastal rivers, creeks and floodplains (e.g. Daly, Mary, South and East Alligator Rivers and around the Roper River) may result in a large hatch of mosquitoes in 1-2 weeks after the waters abate. Typically, flooding of coastal rivers and swamps creates localized flooding, so damage to residential areas will not be as widespread as that encountered after a cyclone. The mosquitoes hatched during these floods would be mainly *Oc. vigilax* and *Cx. annulirostris*.

## iii) Flooding of Inland Rivers

The flooding of inland rivers and low lying areas (e.g. Roper, Katherine and the Todd River) would result in large hatchings of mosquitoes. There are three separate types of flooding of inland rivers:

- a) Heavy rains in the upper catchment causing flooding downstream, resulting in the production of large numbers of mosquitoes. The flushing of the streams may result in reduction of mosquito breeding sites in the upper catchment and extreme mosquito breeding where flooding occurs (e.g. Katherine River).
- b) Local heavy rains causing flooding of low country with only minor stream rises. This would stimulate mosquito breeding in temporary swamps and storm drains (e.g. around Tennant Creek).
- c) General heavy rain causing high stream flow plus local flooding. Under these conditions, large numbers of mosquitoes are produced over wide areas (e.g. Barkly, VRD and Central Australia Regions).

Mosquitoes would not be expected to become a problem with inland flooding until the water level has dropped, and isolated pools without wave motion form (Figure 2). Mosquito species that could potentially reach plague proportions after inland flooding include *Oc. normanensis* and *Cx. annulirostris*.

DAY	FLOODING	MOSQUITOES
0		
1		
2		
3		
4		
5		
6		
7		
8		<i>Ochlerotatus</i> MOSQUITO EGGS HATCH
9		<i>Culex sp</i> LAY EGGS
10		
11		
12		FIRST LARVAE PUPATE
13		
14		FIRST ADULT MOSQUITOES
15		MATE, SEEK BLOOD MEAL
16		
17		
18		HIGH MOSQUITO ATTACK RATE
19		
20		
21		MOSQUITO NUMBERS
22		DECREASING
23		
24		

Figure 2. Chronology of mosquito and blackfly production following flooding.

## **CONTROL OF MOSQUITOES ASSOCIATED WITH DISASTER**

Each disaster will produce a unique mosquito problem, so no strict set of guidelines for control will apply. Instead, flexibility and competent planning must be done before, during and following a disaster situation.

### **BEFORE THE DISASTER**

Local councils should periodically undertake adult and larval mosquito surveys to locate potential mosquito breeding sites, and identify particular species that may become a pest in the advent of flooding of breeding sites. Appropriate larval and adult control strategies can then target these specific areas. Local Government Authorities should liaise with Environmental Health and Medical Entomology personnel to assist in mosquito surveys. Any reports of previous mosquito outbreaks can provide valuable information on potential breeding sites, adult behavior and control methods employed.

Local councils should also ensure they have sufficient equipment and supplies to cope with any outbreak of mosquitoes or flies. Councils should have access to necessary pesticides and pesticide application equipment, repellents, maps of affected areas, etc. It is important to have a resource list available to allow rapid identification of deficiencies in equipment and other resources. If the situation overwhelms the resources of the Local Authority, the Medical Entomology and Environmental Health Branches of Territory Health Services should be contacted to provide consultation and support on appropriate mosquito prevention strategies. Additional support and assistance can be provided by other Local Government Authorities, who may possess the necessary equipment, personnel and expertise to deal with problems such as drainage or rubbish collection. Larger councils may have the necessary mosquito control equipment, such as vehicle-mounted foggers or all terrain vehicles, which are ideal for surveys in outbreak situations. It is therefore necessary for smaller local authorities to liaise with larger councils in their region, to organize any support that may be required during an outbreak following a disaster.

### **DURING THE DISASTER**

During the disaster and in the first day or two after, mosquitoes are not a priority, so resources should be concentrated on other issues. Again, refer to figure 4 for the chronology for the production of mosquito populations. However, preparation for larviciding and adulticiding can be done. In addition, contact should be made with relevant authorities for support and assistance.

## AFTER THE DISASTER

### MOSQUITO CONTROL

#### Larval control

Mosquitoes will not become a problem until a week after the floodwaters recede. Known mosquito breeding sites, as well as any new sites created by flooding or torrential rains, should be surveyed and treated with appropriate larvicides. Larvicides that will provide adequate control include:

#### **Methoprene (trade name Altosid®)**

Methoprene is what is known as an insect growth regulator. It is a synthetic juvenile hormone that prevents the mosquito larva from maturing into an adult mosquito. Altosid® formulations include liquid, sand, granules, pellets and extended residual briquettes, each with different applications and control periods. When used as directed Altosid® products do not harm mammals, waterfowl and other non-target organisms. It is approved by the World Health Organization to control container-breeding mosquitoes in drinking water receptacles. It should be noted that due to the mode of action of methoprene, larvae would not actually die. Instead pupae should be sampled and emergence inhibition monitored.

#### ***Bacillus thuringiensis var. israelensis* (trade names Vectobac®, Skeetal® and Teknar®)**

*Bacillus thuringiensis var. israelensis* (or B.T.I.) is a bacteria (actually crystalline spores and protein byproducts) that kill mosquito larvae. B.T.I. is ingested by the mosquito larva where it destroys the midgut epithelium, causing paralysis and death within 24 hours. The most common formulation of B.T.I. is a liquid suspension that can be applied through vehicle mounted boom sprayers, hand-operated pump sprayers and Ultra Low Volume (ULV) misters.

### **Temephos (trade name Abate®)**

Abate is an organophosphate compound that acts as a nerve poison. Temephos contains esters of phosphoric acid, which inactivate acetylcholine esterase, an enzyme that is essential for nerve transmission. There are three formulations of Abate® 10 SG sand granule, 50 SG sand granule and 100 E emulsifiable concentrate. Unfortunately, widespread use of Abate® has led to resistance in some mosquito species in other areas. Coupled with this has been the toxicity of Abate" to non-target organisms such as crustaceans. Because of these concerns, it is recommended that either B.T.I. or methoprene be used for most larval control, and temephos only be applied where late fourth instar larvae occur in high concentrations and there are no appreciable non-target animals.

### **Adult Control**

Adult mosquitoes will not emerge until at least one week after the flood waters recede. Biting midges will emerge at least three weeks after the flooding abates. Again, this will depend on the species present. Adult control of mosquitoes and biting midges is carried out by either a space spray, which kills flying insects or residual spraying which kills resting adults. There are currently three types of chemicals that are available for adult mosquito and biting midge control.

### **Natural pyrethrins (trade names Drift® and Chemfog® )**

This chemical is extracted from the flowers of the Chrysanthemum plant. These chemicals enter the mosquito through the cuticle. Once inside the body they act as nerve poisons, by preventing the transmission of nerve impulses. The advantages of natural pyrethrins is that they have rapid insecticidal properties, they breakdown rapidly and have very low dermal and oral toxicity to mammals. The disadvantages are that they are relatively expensive, have no residual effect and may be toxic to other aquatic life.

### **Synthetic pyrethrins.(trade names Reslin®, Cislin® and Coopex®)**

These have the same insecticidal action of natural pyrethrins. Depending on the particular synthetic pyrethroid, control may be achieved for periods of up to 3-4 months. Reslin (bioresmethrin) is the insecticide of choice for rapid adult control near residential areas. Cislin (deltamethrin) and Coopex (permethrin) have longer residential effects and should not be sprayed as a large-scale aerosol treatment in residential areas. Synthetic pyrethrins also

have low mammalian toxicity, although they can kill fish, so should be used carefully near water.

### **Organophosphate compounds (Malathion, trade name Maldison<sup>®</sup>)**

These chemicals act as nerve poisons, which interrupt nerve impulse transmission in insects. Maldison has a rapid insecticidal effect, with low toxicity to mammals. Unfortunately, it has a strong odour, which may draw complaints from residents. Maldison<sup>®</sup> also has a detrimental effect on non-target insects.

### **Pesticide Application Equipment**

Equipment for vector control is mainly of three types:

- a) sprayers used to apply liquid larvicides or residual deposits on surfaces;
- b) sprayers designed to produce aerosols, mists and fogs, principally as adult space spray applicators (Ultra Low Volume (ULV) misters and thermal foggers are examples of space spray applicators); and
- c) granular spreaders that are used to apply granular and pellet forms of larvicide.

Each of these types of pesticide application equipment can either be hand held, motor vehicle mounted, boat mounted or aircraft mounted. Adulticides and larvicides may have to be applied using a wide variety of application equipment. Again, each disaster situation may require different vehicles or a combination of vehicles to access difficult areas. For instance in the Katherine floods in 1998, Territory Health Services sprayed large areas of mosquito breeding with Bti by helicopter and rapidly reduced the number of adult mosquitoes for up to 3 weeks after spraying. For aerial application of pesticides, the Disaster District Coordinator should liaise with the Territory Health Services to assist in the organization of procedures for the use of helicopters or aeroplanes.

When using larvicides and adulticides, the dosage rate on the label should be strictly observed. Always ensure that the correct safety equipment and correct handling procedures are used. Furthermore, when using adulticides, there are several other factors that should be observed. Always inform the public (especially apiarists and butterfly farmers) before carrying out adulticiding activities. Adulticiding should not be carried out in winds that exceed 15km per hour. Adulticides should never be applied or disposed of where they may enter watercourses or other marine habitats. Finally, never apply adulticide to areas that have beehives or other insect colonies (i.e. butterfly farms).

Adulticides should not be applied to residential areas unless there is a disease outbreak or a demonstrated high risk of an outbreak, and rapid reduction of adult mosquitoes is required.

## **FLY CONTROL**

A previous survey of wheelie bins in Darwin indicated that over 50% of bins and up to 70 % of bins could be infested with maggots. If wheelie bins or other garbage receptacles are collected once per week, maggots can readily develop to the wandering stage and crawl out of the receptacle before the next collection. During disasters the non-collection of garbage or the exposure of spoiled food or dead animals can produce prolific amounts of maggots.

The prevention of domestic fly breeding relies on the correct treatment, storage and disposal of household garbage by the householder or sanitation officers. The shorter the period of exposure of the garbage to flies, the less production of flies. Adult flies can readily burrow into loosely packaged garbage.

Double bagging of garbage with plastic bags can reduce blow fly production in wheelie bins by up to 600 % compared with non bagged garbage. Although double bagging can reduce blow fly production, it is important to also prevent exposure of garbage before bagging. Garbage left exposed for as little as two minutes can become full of maggots. Double bagging of 300 g of waste food including meat scraps can reduce blowfly production from 6000 maggots in unbagged garbage to 3000 maggots after 30 minutes exposure before bagging, and to 1000 maggots after 2 minutes exposure before bagging. In practice with the use of kitchen tidies and the ability of flies to quickly enter wheelie bins it is difficult to prevent exposure of garbage to flies. During disasters meticulous care is required to prevent exposure of flies to garbage in all stages of production until the garbage is disposed in landfill.

However control of adult flies or maggots in wheelie bins can be very effectively achieved with off the shelf products such as impregnated insecticide strips or blocks. The installation of impregnated pest strips in wheelie bins can kill adult flies in 30 minutes and maggots in a few hours. For effective use of pest strips, the bins should be in a sunny position and the lid left closed. If all wheelie bins or garbage holding receptacles were installed with pest strips there would be a dramatic reduction in domestic fly numbers.

## Adult fly control

Many methods may be used to reduce adult flies in and around the home, including screening, air curtains, fly swats, knock down insecticides containing resmethrin or similar, fly traps, electrocution devices, and fly baits. Screening can be very effective in separating food and people from flies and is vital in most Top End residential areas and food preparation and consumption sites. Fly traps and fly baits, while useful for survey purposes outside the house, usually only harvest a proportion of the large population of flies. They do not clear a residential area of flies and offer little control unless the breeding sites are also removed. The other devices are very useful inside buildings by destroying those flies that enter, but offer little in the way of controlling the outside population of flies. Electronic sound repellents do not work against insects and are completely useless as fly control devices.

Electrocution devices with attracting ultra violet light are excellent devices for killing adult flies in food preparation premises. They are best positioned close to fly entry points. They should be out of sight of flies outside the premises to prevent attracting flies inside. They must be well away from food preparation or consumption surfaces as dead fly debris can contaminate food. With disasters, large-scale aerial immediate knockdown sprays may need to be used. For example after cyclone Tracy in Darwin, aerial ULV sprays of maldison was used to reduce the fly problem.

## PERSONAL PROTECTION

Personal protection can be employed by residents to reduce pest problems with mosquitoes or flies. Residents should be encouraged to use repellents when being bitten. Any repellent containing DEET (Diethyl-m-toluamide) or Picaridin are suitable for use (common repellent trade names include Aerogard<sup>®</sup>, Rid<sup>®</sup> Repel<sup>®</sup> and Bushman<sup>®</sup>). Note that Aerogard<sup>®</sup> is formatted for flies while Aerogard Tropical Strength<sup>®</sup> is formatted for mosquitoes. It should be noted that repellents containing DEET should not be applied to children less than 12 months. Residents can also be encouraged to use mosquito coils (any commercially available brand will suffice) to repel biting insects in sheltered areas. In housing or emergency accommodation, people can be protected from biting insects by using bed nets (these are available from army surplus or camping equipment stores). It should be noted that some mesh sizes would not be small enough to exclude biting midges. Finally, residents should be encouraged to wear light, long-sleeved, loose-fitting clothing, and avoid times and locations where biting insects are a problem. Local Government Authorities should ensure that they have an adequate supply of the above materials, especially repellent, or access to suppliers immediately

following a major disaster. This can facilitate the rapid dispersal of materials to emergency accommodation camps and unscreened/damaged houses.

## **DISSEMINATION OF INFORMATION**

In the advent of a large outbreak of mosquitoes, flies or biting midges, a media campaign should be implemented to update the public on the nature of the situation, provide information on the Council or government control program and to recommend the best methods to avoid being bitten. Each Local Government Authority and State Government body has their own media release policies, which should be strictly adhered too. Apart from using the media, information can be disseminated to the public through appropriate health promotion procedures, such as brochures and posters, as well as liaison with community groups (such as Neighborhood Watch).

## **CONCLUSION**

Each disaster situation will provide a unique insect problem, so thorough knowledge and planning are the best weapons against any possible outbreak of mosquitoes or flies. Each State or Local Government Authority should be aware of potential problems following a disaster, their available resources and which government organizations to collaborate with to obtain the necessary cooperation or resources. Control programs should be thoroughly planned, so that swift implementation can limit the impact of mosquitoes, flies and biting midges on the community.

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## **IMPORTANT ADDRESSES AND TELEPHONE NUMBERS**

### **State Health Offices:**

Medical Entomology Branch  
Territory Health Services  
PO Box 40596  
Casuarina NT 0811  
Ph. 08 8922 8901

Fax. 08 8922 8820

Center for Disease Control  
Territory Health Services  
PO Box 40596  
Casuarina NT 0811  
Ph. 08 8922 8044

**Pesticides:**

Biorational Resources (Altosid®)  
PO Box 58  
Scarborough Qld. 4020  
Ph. 07 3880 1830  
Fax. 07 3880 1831

Garrard's Pesticides Pty. Ltd.  
PO Box 36972  
Winnellie NT 0821  
Ph. 08 8947 2856  
Fax 08 8947 2918

Barnyard Trading  
PO Box 31  
Palmerston NT 0831  
Ph. 08 8932 3997  
Fax. 08 8932 2842

Wesfarmers Dalgety Ltd  
PO Box 619  
Palmerston NT 0831  
Ph. 08 8932 2000

**Pesticide Application Equipment:**

Airscape Pty. Ltd.  
PO Box 47  
Wamberal NSW 2260  
Ph. 043 85 2631  
Fax 043 85 1898

Barnyard Trading  
PO Box 31  
Palmerston NT 0831  
Ph. 08 8932 3997  
Fax. 08 8932 2842

**Repellents:**

Reckitt and Coleman Products (Aerogard®)  
33 Hope St.  
Ermington NSW 2115  
Ph. 02 9857 2000  
Fax 02 9858 5721