Shoal Bay Receiving Station Mosquito Investigation

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## Table of Contents

Table of Contents ........................................................................................................... 2  
List of Figures .................................................................................................................. 3  
List of Tables .................................................................................................................... 3  
List of Appendices ........................................................................................................... 3  
1.0  Introduction .................................................................................................................. 3  
2.0  Methods ....................................................................................................................... 4  
3.0  Results .......................................................................................................................... 4  
   3.1  Mosquito trapping 17th-18th November 2006 ............................................................... 5  
   3.2  Desktop Assessment of potential mosquito breeding sites .......................................... 5  
   3.3  Holmes Jungle 12 months trapping data .................................................................... 5  
4.0  Discussion .................................................................................................................... 6  
   4.1  Mosquito species ....................................................................................................... 6  
      4.1.1 Aedes vigilax ......................................................................................................... 6  
           Potential breeding sites ......................................................................................... 6  
           Seasonal abundance .............................................................................................. 6  
           Dispersal .................................................................................................................. 7  
           Pest numbers ........................................................................................................ 7  
           Disease significance .............................................................................................. 7  
      4.1.2 Culex annulirostris ................................................................. 7  
           Breeding sites ......................................................................................................... 7  
           Seasonal abundance .............................................................................................. 8  
           Dispersal .................................................................................................................. 8  
           Pest numbers ........................................................................................................ 8  
           Disease significance .............................................................................................. 9  
      4.1.3 Anopheles farauti s.l. .......................................................................................... 9  
           Breeding sites ......................................................................................................... 9  
           Seasonal abundance .............................................................................................. 9  
           Dispersal .................................................................................................................. 9  
           Pest numbers ........................................................................................................ 9  
           Disease significance .............................................................................................. 9  
      4.1.4 Anopheles bancroftii ........................................................................................... 10  
      4.1.5 Coquillettidia xanthogaster ................................................................................ 10  
      4.1.6 Mansonia uniformis ............................................................................................ 10  
4.2  Mosquito control and personal protection ............................................................. 10  
   4.2.1 Residual barrier insecticides ................................................................................ 10  
   4.2.2 Artificial receptacles ............................................................................................ 11  
   4.2.3 Personal protection .............................................................................................. 11  
   4.2.4 Fogging with insecticides .................................................................................... 12  
5.0  Conclusions .................................................................................................................. 13  
   5.1  Mosquito breeding sites affecting the Shoal Bay Receiving Station ......................... 13  
   5.2  Seasonal abundance and pest problems ................................................................. 13  
   5.3  Mosquito borne disease and malaria ........................................................................ 14  
   5.4  Mosquito control and avoidance ............................................................................. 14  
6.0  Recommendations ...................................................................................................... 15  
7.0  Acknowledgements ..................................................................................................... 16
List of Figures

Figure 1 – Shoal Bay Receiving Station Adult Salt Marsh Mosquito Trapping Locations 17th-18th November 2006, potential nearby mosquito breeding sites and Holmes Jungle Trap Site location.

Figure 2 – Darwin Mosquito Monitoring Program – CO₂ traps. Holmes Jungle 2005-06.

List of Tables

Table 1 – Mosquito Investigation Shoal Bay Receiving Station 17th-18th November 2006. Total number of female adult mosquitoes trapped using Carbon Dioxide baited EVS traps.

List of Appendices

Appendix 1 – Problem mosquito species in the Top End of the NT. Pest and Vector Status, Habitats and Breeding sites.

Appendix 2 – Arbovirus Disease Risk Periods in the Northern Territory.

Appendix 3 – Personal protection from mosquitoes and biting midges in the NT.

Appendix 4 – Field evaluation of Bistar SC as an effective insecticide harbourage treatment for biting midges (Culicoides) and mosquitoes infesting peri domestic situations in an urban environment.
1.0 Introduction

The Medical Entomology Branch of the Department of Health and Community Services was requested by the Department of Defence to investigate high mosquito numbers at the Shoal Bay Receiving Station. The high mosquito numbers were encountered in the late dry season months, which included day biting, indicating the problem mosquito was most likely the salt marsh mosquito *Aedes vigilax*. The Shoal Bay Receiving Station is situated on a peninsular between Mickett Creek and King Creek. The location of the Shoal Bay Receiving Station indicated there was a high likelihood of severe salt marsh mosquito pest problems. As well as being a severe pest mosquito, the salt marsh mosquito *Aedes vigilax* is also a potential vector of Ross River virus (RRV) and Barmah Forest virus (BFV). Other pest and disease carrying mosquito species were also likely to be present in significant numbers at the Shoal Bay Receiving Station.

The Medical Entomology Branch conducts extensive helicopter control of salt marsh mosquitoes from the small upper tidal creek and reed swamp bordering the west side of the Shoal Bay Receiving Station to the edge of the Darwin Suburb of Leanyer, which includes Micket Swamp and Holmes Jungle Swamp, as well as numerous other upper tidal areas associated with the Leanyer, Holmes Jungle and Micket Swamps. No mosquito control is conducted in the coastal areas to the east and south of the Shoal Bay Receiver Station, and it is likely that these uncontrolled swamps are the major source of mosquitoes to the Shoal Bay Receiving Station.

The Medical Entomology Branch mosquito investigation was to include peak season salt marsh mosquito trapping, to determine peak numbers and possible sources, and an examination of aerial photography to determine potential mosquito breeding sites. An examination of 12 months data from the routine Darwin adult mosquito monitoring trap site at Holmes Jungle, from July 2005 to June 2006, was also conducted to determine other mosquito species that may affect the Shoal Bay Receiving Station, and which periods of the year mosquito problems were likely to occur. Recommendations were then to be provided on the best method of controlling or avoiding pest mosquito problems at the Shoal Bay Receiving Station.

2.0 Methods

Four carbon dioxide (CO$_2$) baited encephalitis virus surveillance (EVS) traps (Rohe & Fall 1979) were set within the Shoal Bay Receiving Station area, three along the outskirts of the cleared area, and one within the secured compound (Figure 1). The traps consisted of an insulated bucket, a suction fan powered by two ‘D’ cell batteries, a ‘grain of wheat’ light, and a rigid collection container (4 litre, 220 mm in diameter) fitted with a muslin sleeve and very fine wire mesh vents. The traps were set around chest height and baited with approximately 1kg of dry ice.

Medical Entomology Branch Officers set the four CO$_2$ baited EVS traps on the afternoon of Friday, 17$^{th}$ of November after 1400 hours, and collected the traps the following morning after 0800 hours. Traps were set 11 days after the predicted November monthly high tide of 7.8m on November 6, to monitor peak populations of salt marsh mosquitoes dispersing from their tidal breeding sites. Catch containers were brought back to the MEB laboratory in Darwin, the mosquitoes were killed by freezing and then sorted into petri dishes for identification.

For mosquito collections under 300 individuals, all mosquitoes were individually identified. For mosquito collections over 300 individuals, a sub-sample of approximately 300 individuals was taken for identification and weighed, with the remaining bulk sample also weighed. The bulk weight was divided by the sub-sample weight, to determine the multiplication factor for which the sub-sample was multiplied by to determine total mosquito numbers. All individuals in the sub-sample were identified, with the remaining bulk scanned for any species not detected in the sub-sample. Any additional species located in the bulk were entered into an access database with the species from the sub-sample, but were excluded from multiplication.
In order to determine likely seasonal trends in salt marsh mosquito populations, as well as seasonal populations of other pest and disease carrying mosquito species at the Shoal Bay Receiving Station, 12 months data from the Holmes Jungle routine adult mosquito trap site from July 2005 to June 2006 was evaluated in conjunction with an examination of aerial photography, as well as evaluating information regarding seasonal trends in various mosquito species in the Top End of the NT (Whelan 1997a).

3.0 Results

3.1 Mosquito trapping 17th-18th November 2006
The results from the mosquito trapping are displayed in Table 1, with site locations shown in Figure 1. A total of 11,451 mosquitoes were collected in the four traps, with the salt marsh mosquito *Aedes vigilax* the most abundant mosquito species, accounting for 99% of all mosquitoes. Other mosquito species trapped in very low numbers included *Anopheles hilli*, *Culex annulirostris*, *Culex quinquefasciatus*, *Culex sitiens*, *Aedes tremulus*, *Aedes pecuniosus* and *Verrallina funerea*.

The most productive trap site was Site 4, which accounted for 62% of all mosquitoes. Trap Site 4 was located at the forest edge to the east of the Receiving Station. The next most productive trap site was Site 2 (22%), located at the entrance to the cleared area, on the east side of the road. Trap Site 3 (15%), located in the *Paperbark* forest at the south west edge of the cleared area, was the third most productive trap site, while Trap Site 4, located inside the fenced compound, caught the least mosquitoes (1%).

3.2 Desktop Assessment of potential mosquito breeding sites
The Shoal Bay Receiving Station is located within close proximity to extensive tidal and brackish water swamps that are large breeding sites for various mosquito species. The major source of salt marsh mosquitoes to the Shoal Bay Receiving Station is expected to be Noogoo Swamp, other upper tidal areas associated with King Creek including Milners Swamp (Figure 1), as well as upper tidal areas associated with the Howard River located to the east and south east of King Creek. The interdune areas to the north and north east of the Shoal Bay Receiving Station may also contain salt marsh mosquito breeding habitat.

There may be some low dispersal from the tidal swamps to the west and south west of the Shoal Bay Receiving Station. The Medical Entomology Branch targets salt marsh mosquito breeding in these swamps for aerial control, therefore any dispersal is likely to be from small, localised sites that could not be detected during helicopter operations.

The reed swamp adjacent to the west edge of the Shoal Bay Receiving Station is likely to be a breeding site for *Aedes vigilax*, *Culex annulirostris*, *Anopheles farauti s.l.*, *Anopheles bancroftii*, *Mansonia uniformis* and *Coquillettidia xanthogaster*. This reed swamp is controlled by MEB for salt marsh mosquito breeding only, as the distance of this swamp from the urban populated areas of Darwin means it is not likely to be a source of other mosquito species to Darwin Urban. Noogoo Swamp, which is located approximately 3km from the Shoal Bay Receiving Station fenced compound, is also likely to be a significant source of *Cx. annulirostris* and *Cq. xanthogaster* to the Shoal Bay Receiving Station, and minor source of *An. bancroftii*.

3.3 Holmes Jungle 12 months trapping data
Data from 12 months trapping at the Holmes Jungle trap site, located on the outskirts of the Northern Suburbs of Darwin, is displayed in Figure 2. This data represents the seasonal trends in six of the most common and important mosquito species in the Darwin area. The seasonal abundance of these species at the Shoal Bay Receiving Station is likely to be similar to the seasonal abundance of these species at Holmes Jungle.
Aedes vigilax was most abundant in the months of September to January inclusive, with peak abundance in the months of October to December inclusive. Low abundance was recorded in August, and Ae. vigilax was virtually absent during the other months.

Culex annulirostris was most abundant in the months of December to July inclusive, with a peak in abundance during the mid wet season months of January and February, and during the post wet season months of May and June. Low abundance was recorded during the other months, with the exception of November, when this species was virtually absent.

Anopheles farauti s.l. was recorded in peak numbers in the months of April and May, with low abundance in June and January to March. This species was absent during the other months.

Anopheles bancroftii was most common during the months of February, and April to July, with a peak in abundance in the months of April to June. This species was virtually absent during the other months.

Coquillettidia xanthogaster was most abundant during the months of February, and April to July, with peaks in February and June. Mansonia uniformis was most abundant in the month of February, with a minor peak in May.

4.0 Discussion

4.1 Mosquito species

4.1.1 Aedes vigilax
Potential breeding sites
The salt marsh mosquito breeds in tidal and brackish water in coastal areas, such as salt marshes, brackish water reed swamps and upper reaches of tidal creeks (Whelan 1997a). Breeding sites affecting the Shoal Bay Receiving Station are likely to be Noogoo Swamp, other nearby upper tidal areas associated with King Creek, Milners Swamp (Figure 1), upper tidal areas associated with the Howard River, with probably some minor dispersal from small, localised upper tidal breeding sites located to the west and south west of the Shoal Bay Receiving Station that could not be detected by the MEB aerial control program.

The adjacent reed swamp would be a source of Ae. vigilax when wind conditions disrupt aerial control of the swamp, or when extensive flooding occurs in all swamps in the MEB control area and all areas can not be controlled within the limited time available to control salt marsh mosquitoes. The November trap results revealed highest numbers on the east and south east side of the Shoal Bay Receiving Station, indicating tidal areas to the east and south are the major sources of this species.

The interdune areas to the north and north east of the Shoal Bay Receiving Station may also contain significant breeding sites for this species (Figure 1).

Seasonal abundance
Aedes vigilax is most abundant around coastal areas of the NT in the months of September to January inclusive, with adults dispersing from their breeding sites around 9 days after significant tides or rainfall in these months. During the less humid months in coastal areas, Ae. vigilax abundance usually lasts for one week, while in the more humid months of November to January inclusive, abundance lasts for up to two weeks. Low numbers can be encountered in coastal areas in May or June in some years, depending on late wet season rainfall or significant high tides, while this species is virtually absent during other months.
Aedes vigilax was most abundant during the months of September to January inclusive at Holmes Jungle in 2005/06, which followed the usual trend in peak abundance. This is an indication that Ae. vigilax is likely to follow this usual trend in seasonal abundance at the Shoal Bay Receiving Station.

Dispersal

Aedes vigilax can disperse in pest numbers up to 50km from extensive tidal breeding sites with favourable winds. Very high numbers of this species will originate from breeding sites within 5km to the east and south of the Shoal Bay Receiving Station, with significant dispersal also from breeding sites associated with the Howard River and Milners Swamp. Dispersal would also occur from the adjacent reed swamp, when environmental conditions disrupt control of this swamp. Some minor dispersal may also occur from upper tidal areas to the west and south west of the Shoal Bay Receiving Station, from small, isolated breeding sites that could not be detected by the MEB aerial control program.

The November 2006 trap results revealed highest Ae. vigilax numbers on the east and south east side of the Shoal Bay Receiving Station, indicating the majority of dispersal was occurring from the east and south. The extreme numbers at Trap Site 4, as compared to Trap Site 2, which was located closer to the extensive Noogoo Swamp, indicates the dense forested area where Trap Site 4 was set was either a more favourable harbourage site, or that very productive breeding sites existed in the tidal areas nearby to the trap site, or a combination of both.

Pest numbers

Generally 50 or more Ae. vigilax females in a CO2 baited EVS trap set outside of residential areas indicates a pest problem. This species is a painful and persistent biter, and will bite during the day in shaded areas and during the night (Whelan 1997a, Appendix 1). The persistent and day biting habits of this species make Ae. vigilax probably the most important pest mosquito in coastal areas of the NT.

Aedes vigilax was encountered in very high to extreme pest numbers at Trap Sites 2 and 4, located on the east and south east edge of the cleared area associated with the Shoal Bay Receiving Station. The low numbers in comparison at Trap Site 1, located within the fenced compound, was probably due to alternative attractants to the CO2 trap, such as humans and lights. The 140 females collected in Trap Site 1 equates to around 140 bites an hour at the peak biting period on an unprotected person (Whelan 2004), indicating a high pest problem. The biting rate was probably higher due to the likelihood that Trap Site 1 underestimated Ae. vigilax populations within the compound, due to lights and possibly human activity diverting adults away from the trap. MEB officers encountered very high daytime biting while setting the trap in the early afternoon, indicating peak period biting around sunset would have been very high.

Disease significance

Aedes vigilax is a vector of Ross River virus (RRV) in the Top End of the NT (Tai et al 1993, Whelan & Weir 1993). This species is also a vector of Barmah Forest virus (BFV) (Merianos et al 1992, Whelan et al 1993). The greatest potential for virus transmission from this species is in November to January inclusive, when this species occurs in peak numbers, and the humid conditions in these months increases the longevity of mosquitoes, increasing the chance of an individual female Ae. vigilax obtaining a virus from a vertebrate host and passing it onto a human. However, RRV and BFV transmission can occur during most months of the year (Whelan 1997b, Appendix 2), therefore there is the potential for virus transmission whenever this species is present in significant numbers.

4.1.2 Culex annulirostris

Breeding sites

Culex annulirostris generally breeds in freshwater and brackish water swamps with emergent vegetation such as grasses and semi-aquatic reeds, freshwater streams with vegetation, as well as temporary flooded grasslands, sewage ponds with vegetation and semi-polluted stormwater drains (Whelan 1997a, Appendix 1).
Breeding sites for this species nearby to the Shoal Bay Receiving Station will include the small reed swamp adjacent to the west boundary of the Shoal Bay Receiving Station, while distant breeding sites will include Noogoo Swamp (Figure 1). Any grassy depressions in the cleared area of the Shoal Bay Receiving Station that can hold water for periods greater than five consecutive days will also be potential breeding sites for this species.

**Seasonal abundance**

*Culex annulirostris* is generally most common in the months of January to August inclusive in the Top End of the NT (Whelan 1997a). At Holmes Jungle during the 2005/06 financial year, this species was most abundant in the months of December to July inclusive, with mid wet season peaks in January and February, and post wet season peaks in May and June. The mid wet season peak was larger, although in some years, highest numbers at the Holmes Jungle trap site have peaked during the post wet season months (MEB annual report 2005/06).

Mid wet season peak abundance (January and February) at the Shoal Bay Receiving Station will occur when extensive flooding of the nearby reed swamp occurs, and aquatic predators of mosquito larvae are absent or present in minimal numbers, allowing *C. annulirostris* to breed in high numbers. Post wet season peaks will occur when floodwaters recede and reeds and grasses fall over and lodge, creating isolated areas with restricted predator access to mosquito larvae. Post wet season peaks will most likely begin in April in dry years, and in May in years of heavy late wet season rain, which was what occurred in the 05/06 wet season, when heavy rain fell in March and April.

The reed swamp adjacent to the Shoal Bay Receiving Station is expected to be mostly dry by the end of June in most years, at it relatively small and does not appear to be fed by a significant creek line compared to the Holmes Jungle Reed Swamp, which is fed by Palm Creek and can stay flooded into August in years of high rainfall. The extensive Noogoo Swamp is likely to be the major source of this species in the mid wet season.

Therefore, *C. annulirostris* is likely to be most abundant from January to August, with mid wet season peaks in January and February, and post wet season peaks from April to June, from breeding in the nearby reed swamp. Low to moderate numbers are likely to be encountered in July and August, from dispersal from Noogoo Swamp. Low to moderate numbers may also be encountered in December in years of heavy early wet season rainfall.

**Dispersal**

*Culex annulirostris* can disperse up to 10km from extensive breeding sites, although are most common within 4km of breeding sites (Whelan 1997a). There is usually a significant drop in *C. annulirostris* numbers up to 2km away from significant breeding sites (Whelan 2004).

The small reed swamp adjacent to the Shoal Bay Receiving Station is expected to be the most significant source of *C. annulirostris*, as it is located within 1km of the fenced compound. The northern edge of Noogoo Swamp is located approximately 3km from the fenced compound at the Shoal Bay Receiving Station (Figure 1), indicating significant dispersal will also occur from this swamp.

**Pest numbers**

*Culex annulirostris* reaches pest levels when there are more than 100 per CO2 baited EVS trap per night, for those traps set away from residential areas (Whelan 1997a). It is likely that seasonally moderate to high numbers will occur at the Shoal Bay Receiving Station, translating to a potentially moderate to high pest problem. However, this species is not as significant as a pest mosquito compared to *Ae. vigilax*, due to its habit of only biting after sundown, and being less persistent in the presence of lights, personal protective clothing and repellents.
Disease significance

*Culex annulirostris* is the most important vector of arboviruses in the NT (Whelan & Weir 1993). It is recognised as a good vector of Murray Valley encephalitis virus (MVEV), Kunjin virus (KUNV), RRV and BFV (Merianos et al 1992, Whelan et al 1993). Many other arboviruses have been isolated from this species (Whelan & Weir 1993). The main risk months for RRV and BFV transmission at the Shoal Bay Receiving Station will be when this species is present in the warmer, humid months of December to March (Whelan 1997b, Appendix 2), when the longevity of this species is increased, increasing the potential of a female *Cx. annulirostris* obtaining a virus from a vertebrate host and passing it on to a human. The main risk months for MVEV and KUNV transmission will be the months of February to May (Whelan 1997b, Appendix 2).

4.1.3 Anopheles farauti s.l.

**Breeding sites**

The North Australian malaria mosquito *Anopheles farauti* s.l. is a species complex that includes three species that are impossible to separate morphologically. The three species in this complex are *Anopheles farauti* s.s. (also known as *An. farauti* no. 1), which is a brackish water breeder, and the freshwater breeders *Anopheles hinesorum* (also known as *An. farauti* no. 2) and *Anopheles torresiensis* (also known as *An. farauti* no. 3). Habitat indicators for *An. farauti* are brackish water *Schoenoplectus* and *Eleocharis* reed swamps and upper reaches of mangrove creeks with freshwater influence, while habitat indicators for *An. hinesorum* and *An. torresiensis* are freshwater reed swamps and vegetated creeks.

The brackish water species *An. farauti* s.s. is likely to be the main species in the *An. farauti* s.l. complex present at the Shoal Bay Receiving Station, sourced from the adjacent reed swamp (Figure 1).

**Seasonal abundance**

*Anopheles farauti* s.l. is generally most abundant in the late wet season and early dry season months of March to June (Whelan 1997a, Appendix 1). *Anopheles farauti* s.l. was most common at the Holmes Jungle Trap site in the months of April and May in the 2005/06 financial year, with low numbers in January and February (Figure 2). This species is likely to follow the usual trend in peak abundance as outlined by Whelan (1997a) at the Shoal Bay Receiving Station. It is likely that at least low to moderate, and potentially high numbers of this species may be encountered at the Shoal Bay Receiving Station.

**Dispersal**

*Anopheles farauti* s.l. can disperse up to 3km, although they are most common within 1.5km of breeding sites (Whelan 1997a, Appendix 3). The Shoal Bay Receiving Station fenced compound is located within 1km of the small reed swamp (Figure 1), indicating significant dispersal is likely to occur from this reed swamp. Noogoo Swamp is probably too far away to be a significant source of this species to the Shoal Bay Receiving Station (Figure 1).

**Pest numbers**

Pest numbers of this species in a CO2 trap is generally regarded to be 50 per trap per trap night (Whelan 1997a, Appendix 3). However, this species is a more timid biter compared to *Ae. vigilax, Ae. normanensis* and *Cx. annulirostris*, therefore will be of lower pest significance. It is probable that *An. farauti* s.l. will be periodically present in numbers high enough to cause a low to moderate pest problem to exposed workers after sundown, in the months of March to June.

**Disease significance**

The species *An. farauti* is a known vector of malaria in Vanuatu, Solomon Islands and PNG (Russell & Kay 2004), therefore is regarded as a potential vector of malaria in Australia. The vector competence of *An. hinesorum* and *An. torresiensis* is not known, although it is possible that *An. torresiensis* was/is a potential vector of malaria in Australia, and *An. hinesorum* may be a potential malaria vector in some parts of PNG (N. Beebee pers comm.), therefore these species may be potential...
malaria vectors in Australia. The risk threshold for malaria transmission from *An. farauti* s.l. per trap is generally regarded to be 10 females per trap per trap night. This threshold is likely to be well exceeded at the Shoal Bay Receiving Station in the months of March to June.

Malaria is not endemic to Australia, so a risk of malaria transmission will only arise if a person returning from overseas with the infectious stages of malaria is exposed to *An. farauti* s.l. at the Shoal Bay Receiving Station. Therefore any personnel sourced or returning from overseas who suddenly becomes ill with high fever should be considered as possibly having malaria, and should not be exposed to mosquito bites at the Shoal Bay Receiving Station after sundown until cleared of having malaria, or cleared of the infectious stages of malaria by a health care practitioner.

4.1.4 *Anopheles bancroftii*

*Anopheles bancroftii* is a potential vector of malaria, although it may not pose a significant risk, as it is not as long lived as other *Anopheles* species (Russell 1987). This species is generally most abundant during the months of February to July (Whelan 1997a), and is generally most common within 3km of breeding sites. Breeding sites for this species affecting the Shoal Bay Receiving Station are likely to include the adjacent reed swamp and *Paperbark* Swamp, with probable dispersal also occurring from Noogoo Swamp (Figure 1). This species is likely to be present in seasonally moderate to high numbers at the Shoal Bay Receiving Station, with peak numbers occurring in the months of February to June when breeding occurs in the nearby reed swamp, and low numbers in July, dispersing from Noogoo Swamp. This species bites at night.

4.1.5 *Coquillettidia xanthogaster*

This species is not regarded as a vector of human disease in Australia, therefore will only be of pest significance at the Shoal Bay Receiving Station. This species is generally most abundant in the months of March to August, and is most common within 3km of breeding sites, although this species is a strong flier and can disperse up to 5km from large breeding sites (Whelan 1997a). Breeding sites for this species affecting the Shoal Bay Receiving Station are likely to include the adjacent reed swamp and *Paperbark* Swamp, and also Noogoo Swamp (Figure 1). This species is likely to be present in seasonally moderate to high numbers at the Shoal Bay Receiving Station, with highest numbers in the months of March to June, when breeding occurs in the nearby reed swamp, with low to moderate numbers in July and August, dispersing from Noogoo Swamp. *Coquillettidia xanthogaster* bites mainly at night, but can be a pest in cool shaded areas near their breeding sites during the daytime.

4.1.6 *Mansonia uniformis*

This species is not regarded as a vector of human disease in Australia, therefore will only be of pest significance at the Shoal Bay Receiving Station. This species is generally most abundant in the months of March to June, and is most common within 2km of breeding sites (Whelan 1997a). The major breeding sites for this species affecting the Shoal Bay Receiving Station will be the adjacent reed swamp (Figure 1). This species is not as common as *Coquillettidia xanthogaster* in the Darwin Region (MEB annual report data), therefore is likely to be present in seasonally low to moderate numbers at the Shoal Bay Receiving Station. *Mansonia uniformis* bites mainly at night, but can be a severe pest in cool shaded areas near their breeding sites during the daytime.

4.2 Mosquito control and personal protection

4.2.1 Residual barrier insecticides

The Medical Entomology Branch currently controls the major salt marsh breeding sites in the coastal swamps to the west and south-west of the Shoal Bay Receiving Station, while no control is conducted to the east and south of the Shoal Bay Receiving Station in Noogoo Swamp, Milners Swamp, other upper tidal areas associated with King Creek and upper tidal areas associated with the Howard River. It is unlikely that the Shoal Bay Receiving Station could effectively control mosquito breeding sites affecting their area, as it would involve large scale helicopter operations, a dedicated team of field officers and significant funds.
The best method of mosquito control would be to periodically apply a suitable residual barrier insecticide to adult mosquito harbourage areas at the Shoal Bay Receiving Station. A very effective residual insecticide for adult mosquito control is bifenthrin (WHO 2002, WHO 2003), as it has low irritancy to adult mosquitoes, hence increases mosquito-insecticide contact time to achieve better control. A formulation of bifenthrin has been trialled in Hervey Bay in QLD for adult mosquitoes and biting midges, with very good control of mosquitoes (94% mean reduction of mosquitoes achieved over a 6 week period) (Standfast et al 2003, Appendix 4). Bifenthrin has not been trialled under local conditions, but is likely to be effective for at least 4 weeks in the Darwin climate.

Bifenthrin should be applied to mosquito harbourage areas, such as shrubs, hedges, ornamental plants, external walls, doors, sheds, under demountables, fences, insect screens, shady or damp areas around buildings and any other shady areas where mosquitoes area likely to harbour at the Shoal Bay Receiving Station. To increase the effectiveness of bifenthrin barrier insecticide, dark shade netting could be installed on the security fence surrounding the compound and then treated with bifenthrin.

Bifenthrin barrier insecticide should be applied 7-8 days after the monthly highest tide in the months of September to January inclusive, which is a day or two before salt marsh mosquito problems will occur at the Shoal Bay Receiving Station (salt marsh mosquito numbers usually increase significantly nine days after the highest tide of the month). These applications are also likely to cover for salt marsh breeding associated with significant rainfall in the months of October to January inclusive.

It is likely that adult mosquito control may also be required during the late wet season to mid dry season months, when peak numbers of many freshwater and brackish water mosquito species occur, or when the risk of arbovirus infection is high. The Medical Entomology Branch issues media warnings when the risk of arbovirus infection is high. A certified pest controller should be contacted to apply bifenthrin at the Shoal Bay Receiving Station.

4.2.2 Artificial receptacles

Any artificial receptacle at the Shoal Bay Receiving Station could become breeding sites for the receptacle mosquito *Aedes notoscriptus*, which is a potential vector of RRV, or the brown house mosquito *Culex quinquefasciatus*, which is a pest species only. Artificial receptacles can include various containers, blocked roof guttering, used tyres, stormwater pits and bunded areas. Periodic surveys should be conducted around the Shoal Bay Receiving Station during the wet season, with any water holding receptacle removed, stored under cover away from rain or provided with drainage holes. If stormwater pits are present at the Shoal Bay Receiving Station, they should be inspected for the potential to hold water, with any pit with the potential to hold water rectified to ensure it is free draining.

4.2.3 Personal protection

It is most likely that even with appropriate residual insecticide application, there will still be some pest mosquito problems encountered at the Shoal Bay Receiving Station, although at much lower levels. Comprehensive information on personal protection can be found in Appendix 3.

Personal protection measures including the use of repellents, loose fitting long sleeve shirts and trousers (light colours), and avoidance of exposure to mosquito bites (when practical) is recommended. Supervisors should also warn staff of impending salt marsh mosquito problems periods, which is a 1-2 week period starting 9 days after monthly high tides in the months of September to January inclusive, and starting 9 days after significant rainfall in the months of October to January inclusive. This could be achieved by marking monthly high tides on a calendar, and marking the date 8 days after the highest monthly tide, to act as a reminder that salt marsh mosquito problems are likely to begin the following day and that employees need to be alerted.
The late wet season to mid dry season months of April to July should also be marked on a calendar, as these months are likely to have extended mosquito problems after sundown. Employees should then be reminded to practice personal protection after dark in these months.

4.2.4 Fogging with insecticides
Fogging is not recommended to control pest mosquito problems at the Shoal Bay Receiving Station, as the success of fogging operations is highly dependant on wind direction, and will only provide short term control of mosquito populations, as once the insecticide has dispersed, mosquitoes will re-colonise the Shoal Bay Receiving Station from adjacent areas. Fogging would be required in the morning and evening for every day that mosquito numbers are high, which will be time consuming and costly in the long term, and is not likely to be as effective as barrier insecticide treatments.
5.0 Conclusions

5.1 Mosquito breeding sites affecting the Shoal Bay Receiving Station

- Noogoo Swamp, Milners Swamp, other upper tidal areas associated with King Creek, interdune areas located to the north and north east of the Shoal Bay Receiving Station and upper tidal areas associated with the Howard River are likely to be the major sources of the salt marsh mosquito *Aedes vigilax* to the Shoal Bay Receiving Station. The reed swamp located to the west of the Shoal Bay Receiving Station would be a source when wind conditions hamper aerial control of the swamp, or when extensive flooding occurs in all swamps in the MEB control area and all areas can not be controlled within the limited time available to control salt marsh mosquitoes.

- Upper tidal areas and swamps to the west and south west are routinely surveyed and controlled by the Medical Entomology Branch for salt marsh mosquito breeding, and are not expected to be significant sources of salt marsh mosquitoes to the Shoal Bay Receiving Station.

- The reed swamp located to the west of the Shoal Bay Receiving Station is not controlled for other mosquito species. This reed swamp is likely to be a significant breeding site for *Culex annulirostris*, *Anopheles farauti s.l.*, *Anopheles bancroftii*, *Coquillettidia xanthogaster* and *Mansonia uniformis*.

- The mosquito species *Cx. annulirostris*, *Cq. xanthogaster* and *An. bancroftii* are also likely to be dispersing to the Shoal Bay Receiving Station from their breeding sites in Noogoo Swamp.

5.2 Seasonal abundance and pest problems

- The salt marsh mosquito *Aedes vigilax* will be the principal pest mosquito at the Shoal Bay Receiving Station. This species will be present in very high to extreme numbers during the months of September to January inclusive, with high numbers starting nine days after monthly high tides or significant rainfall, and lasting for around one week in September and October, and up to two weeks in the more humid months of November to January inclusive. Pest problems will be noticed in shaded areas during the daytime, and throughout the night. This species is a painful and persistent biter.

- The common banded mosquito *Culex annulirostris* is likely to be seasonally present in moderate to high numbers, with peak abundance during the mid wet season months of January and February, and the post wet season months of April to June, with low to moderate numbers in December, March, July and August. Pest problems will be noticed after sundown. This species is a less aggressive biter compared to *Ae. vigilax*, but is still a significant pest mosquito.

- *Coquillettidia xanthogaster* is likely to be present in seasonally moderate to high numbers, with peak numbers in the months of March to June, and low to moderate abundance in July and August. *Anopheles bancroftii* is likely to be present in seasonally moderate to high numbers, with peak numbers in the months of February to June, and low to moderate abundance in July. Both species are significant pest mosquitoes, and bite mainly at night.

- *Mansonia uniformis* and *An. farauti s.l.* will be most common in the months of March to June, with low to moderate numbers of both species expected, although *An. farauti s.l.* may also be seasonally present in high numbers. *Mansonia uniformis* is a significant pest mosquito, and bites mainly at night but also in shaded areas during the daytime near their breeding sites. *Anopheles farauti s.l.* bites only at night, and is not as significant a pest mosquito compared to the other species.
5.3 Mosquito borne disease and malaria

- *Aedes vigilax* will pose a very high risk of Ross River virus (RRV) and Barmah Forest virus (BFV) transmission. Peak risk months for this species will be in the humid months of November to January inclusive, when abundance is high and the longevity of adult females is enhanced.

- *Culex annulirostris* will pose a moderate to high risk of RRV and BFV transmission, with peak risks in the humid mid wet season months of December to March, although this species will pose a risk whenever it is present in significant numbers, which will be the wet season months and early to mid dry season. This species will also pose a potential Murray Valley encephalitis virus (MVEV) and Kunjin virus (KUNV) risk, mainly in the months of March to May, which are the peak risk months for MVEV and KUNV transmission (Whelan 1997b).

- *Anopheles farauti s.l.* will pose a significant risk of potential malaria transmission in the months of March to June. This species will only pose a risk if a person with the infectious stages of malaria is bitten by *Anopheles* species mosquitoes at the Shoal Bay Receiving Station. *Anopheles bancroftii* is a potential vector of malaria, but will pose a much lower risk compared to *An. farauti s.l.* as it is not as long lived as other *Anopheles* species.

5.4 Mosquito control and avoidance

- The use of insecticide barrier treatments, in particular bifenthrin, will be the most effective method of adult mosquito control at the Shoal Bay Receiving Station. Barrier insecticides such as bifenthrin should be applied to external mosquito harbourage areas such as shrubs, hedges, ornamental plants, external walls, doors, sheds, under demountables, fences, insect screens, shady or damp areas around buildings and any other shady areas where mosquitoes area likely to harbour at the Shoal Bay Receiving Station. Dark shade cloth erected on the security fence, and then treated with bifenthrin, could also be utilised to provide better control of adult mosquitoes dispersing into the Shoal Bay Receiving Station.

- Artificial receptacles could become breeding sites for the receptacle breeding mosquito *Aedes notoscriptus*, which is a potential vector of RRV. Artificial receptacles can include various water holding containers, used tyres, stormwater pits, blocked roof guttering and bunded areas. Another pest mosquito, *Culex quinquefasciatus*, also breeds in artificial receptacles.

- Personal protection will still be periodically required at the Shoal Bay Receiving Station even if barrier insecticides are used, as very high numbers of mosquitoes will be dispersing from adjacent swamps and upper tidal areas, and residual insecticides will not kill 100% of mosquitoes.
6.0 Recommendations

- Adult salt marsh mosquito control should be achieved using an appropriate residual insecticide such as bifenthrin, applied to all likely adult mosquito harbourage areas at the Shoal Bay Receiving Station by a certified pest controller. Bifenthrin barrier insecticide should be applied monthly (unless advised otherwise by the pest controller) at the Shoal Bay Receiving Station 7-8 days after the monthly high tides in the months of September to January inclusive.

- Bifenthrin barrier control of other mosquito species, which mainly bite after sundown, should be conducted as required when mosquito activity is high or if the risk of arbovirus infection is high.

- A relevant officer at the Shoal Bay Receiving Station should have a calendar with potential problem periods marked out, to allow timely use of barrier insecticide applications, and to allow workers to be warned of impending problem periods for mosquitoes. Salt marsh mosquito problems will begin nine days after the monthly high tides during the months of September to January inclusive, with mosquito problems lasting up to two weeks in the humid months of November to January inclusive, and around one week in September and October. Other mosquito species may be periodically encountered in moderate to high numbers during the wet season and early to mid dry season, with January and February, and April to June likely to contain high mosquito abundance, with low to moderate abundance in March, July and August.

- All workers should be supplied with the MEB handout ‘Personal protection from mosquitoes and biting midges in the NT’, provided as Appendix 3.

- Any worker returning from an overseas country where malaria is endemic, who develops high fever, should be considered as having malaria and should not be exposed to mosquito bites after sundown at the Shoal Bay Receiving Station, until cleared of having malaria or treated for malaria by a health professional.

- Weekly inspections should be conducted around the Shoal Bay Receiving Station in the wet season, with any water holding receptacle removed, stored under cover away from rain or have drainage holes provided. If stormwater pits are present, these should be inspected for the potential to hold water, with any potential water holding pit rectified to be free draining.
7.0 Acknowledgements
The Medical Entomology Branch would like to thank Ron Parker from the Shoal Bay Receiving Station for arranging access.

Mosquitoes were identified by Graham Goodwin from the Medical Entomology Branch (MEB). The report was reviewed by Nina Kurucz, Operations Manager MEB.
8.0 Bibliography


Medical Entomology Branch Report 2005/06. Medical Entomology Branch, Department of Health and Community Services.


**WHO. 2002.** Report of the fifth WHOPES working group meeting: review of Olyset Net and Bifenthrin 10%WP. WHO/CDS/WHOPES/2001.4
Reed Swamp, potential Ae. vigilax, Cx. annulirostris, An. farauti s.l., An. bancroftii, Cq. xanthogaster and Ma. uniformis

Paperbark Swamp, potential An. bancroftii and Cq. xanthogaster

Holmest Swamp

Noogoo Swamp, potential source of Ae. vigilax, Cx. annulirostris, Cq. xanthogaster and An. bancroftii

Mikett Swamp, potential Ae. vigilax

Interdune areas, potential Ae. vigilax

Figure 1 - Shoal Bay Receiving Station adult salt marsh mosquito trapping locations 17th - 18th November 2006, potential nearby mosquito breeding sites and Holmes Jungle Trap Site location.
DARWIN MOSQUITO MONITORING PROGRAM - CO₂ TRAPS

HOLMES JUNGLE - 2005/06

NUMBER OF FEMALES PER TRAP NIGHT

- An. (Ano) bancroftii
- An. (Cel) farauti s.l.
- Cq. (Coq) xanthogaster
- Cx. (Cux) annulirostris
- Ma. (Mnd) uniformis
- Oc. (Och) vigilax
TABLES
Table 1: Mosquito investigation Shoal Bay Receiving Station 17th-18th November 2006. Total number of mosquitoes trapped using Carbon Dioxide baited EVS traps.

<table>
<thead>
<tr>
<th>Trap location</th>
<th>An. (Cel) hilli</th>
<th>Cx. (Cav) annulirostris</th>
<th>Cx. (Cav) quinquefasciatus</th>
<th>Cx. (Cav) sitiens</th>
<th>Ae. (Mac) tremulus</th>
<th>Ae. (Mol) pærnitus</th>
<th>Ae. (Och) vigilax</th>
<th>Ve. (Ver) funerea</th>
<th>Total</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoal Bay Receiving Station Site 1 - Inside fenced compound in outdoor seating area</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>140</td>
<td>0</td>
<td>141</td>
<td>1.23</td>
</tr>
<tr>
<td>Shoal Bay Receiving Station Site 2 - at forest edge at entrance to cleared area, east side of road</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2485</td>
<td>0</td>
<td>2492</td>
<td>21.76</td>
<td></td>
</tr>
<tr>
<td>Shoal Bay Receiving Station Site 3 - At Paperbark forest fringe, south west edge of cleared area</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1692</td>
<td>0</td>
<td>1702</td>
<td>14.86</td>
<td></td>
</tr>
<tr>
<td>Shoal Bay Receiving Station Site 4 - At forest edge east end of cleared area</td>
<td>18</td>
<td>0</td>
<td>36</td>
<td>18</td>
<td>36</td>
<td>6990</td>
<td>1</td>
<td>7116</td>
<td>62.14</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>17</td>
<td>36</td>
<td>18</td>
<td>36</td>
<td>1</td>
<td>11307</td>
<td>18</td>
<td>11451</td>
<td>100.00</td>
</tr>
<tr>
<td>% of total</td>
<td>0.16</td>
<td>0.15</td>
<td>0.31</td>
<td>0.16</td>
<td>0.31</td>
<td>0.01</td>
<td>98.74</td>
<td>0.16</td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX 1
PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT
PEST AND VECTOR STATUS HABITATS
AND BREEDING SITES

P.I. Whelan
Medical Entomology Branch
Department of Health and Community Services
1997

Minor update January 2004

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These summary tables are intended as a guide and for assistance to environmental health officers and other public health officers involved in mosquito awareness, surveillance and control programs. They are of a general nature only. They are based on selected literature and my 25 years of field experience as an entomologist in the NT.

**Flight range**

Adult mosquitoes generally disperse in reasonable numbers, at least 1.6 km from their breeding site. However, some fly much longer distances in search of blood meals (eg. *Oc. vigilax*, *Oc. normanensis* and *Cq. xanthogaster*) and some generally do not fly far at all (eg. *Ve. funerea*, *Oc. kochi*, *Oc. tremulus*, *Cx. quinquefasciatus* and *Ma. uniformis*)

**Species identities**

Where there are species complexes which are difficult or impossible to separate morphologically, there is no data regarding the vector capacity of the individual members of the complex. For example, *An. farauti* (formerly *An. farauti* No. 1) is a probable vector of malaria in New Guinea and was probably responsible for the Cairns epidemic in 1942. However, there is no indication of the vector performance of *An. hinesorum* (formerly *An. farauti* No. 2) or *An. torresiensis* (formerly *An. farauti* No. 3) in Australia.

**Pest levels**

Pest level is very subjective and depends on the population of people subjected to attack and their habits/clothing/location at sunset in an overall setting of size and productivity of nearest breeding sites. CO2 trap levels below the threshold may still be a localised nuisance but are not regarded as at a significant pest level. CO2 trap thresholds generally hold for the Top End of the NT but may vary under different local conditions such as, proximity to breeding site and productivity of breeding site, the topography and vegetation between breeding sites and residential areas, and location and exact position of mosquito traps.

Total of all species present at a given location gives an indication of the total pest level. For protected people, (people inside screened houses at night after sundown) there is no real pest problem even at very high levels. Before sundown the pests in residential areas are primarily *Ochlerotatus vigilax* and *Ochlerotatus notoscriptus* within flight range of breeding sites and on a seasonal basis. Other species can be pests in shaded/heavily vegetated areas at times during the day but generally have peak biting levels in the first two hours after sundown.
# Major Pest and Vector Mosquito Species in the Top End of the NT*

**Peter Whelan, Medical Entomology Branch, Department of Health and Community Services 1997**

<table>
<thead>
<tr>
<th>Species</th>
<th>Pest Status</th>
<th>Vector Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>An. annulipes s.l.</td>
<td>Widespread pest, bites at night and will enter houses.</td>
<td>Potential malaria vector.</td>
</tr>
<tr>
<td>An. bancroftii</td>
<td>Major pest, widespread, bites anytime near breeding site, nightly or shaded areas elsewhere.</td>
<td>Potential malaria vector.</td>
</tr>
<tr>
<td>An. farauti s.l.</td>
<td>Local pest, bites at night. Uncommon, except near mostly sub-coastal and extensive freshwater or brackish swamps.</td>
<td>Major potential vector of malaria.</td>
</tr>
<tr>
<td>An. hilli</td>
<td>Coastal pest, bites at night, enters houses. Common near brackish water swamps.</td>
<td>Potential malaria vector.</td>
</tr>
<tr>
<td>Cx. annulirostris</td>
<td>Major pest, very common and widespread in both urban and rural areas. Bites mainly in evening and at night.</td>
<td>Major arbovirus vector of Murray Valley encephalitis virus (MVEV), Kunjin virus, Ross River virus (RRV) and Barmah Forest virus (BFV) and dog heart worm. Vector of numerous other arboviruses.</td>
</tr>
<tr>
<td>Cx. quinquefasciatus</td>
<td>Major urban pest, bites at night, indoors, rests outdoors, populations common with polluted water in dry season.</td>
<td>Potential arbovirus vector (MVEV). Vector of heartworm of dogs.</td>
</tr>
<tr>
<td>Cx. sitiens</td>
<td>Localized coastal pest, breeds in brackish or tidal waters, disperses widely, bites at night.</td>
<td>Probably no diseases. Possible RRV disease.</td>
</tr>
<tr>
<td>Cq. xanthogaster</td>
<td>Major localized pest near extensive reed swamps, disperses widely, bites at night, or in dense shade in day, attracted to lights.</td>
<td>No diseases. Filariasis in frill neck lizard</td>
</tr>
<tr>
<td>Ma. uniformis</td>
<td>Localized pest, bites at night near the breeding site, attracted to lights, does not disperse far from breeding sites.</td>
<td>No diseases.</td>
</tr>
<tr>
<td>Fl. kochi</td>
<td>Local pest at breeding site, does not disperse. Restricted to Pandanus thickets.</td>
<td>No diseases.</td>
</tr>
<tr>
<td>Oc. normanensis</td>
<td>Major pest, bites in evening and night within 3 km of breeding sites. Plagues in inland areas a week after widespread flooding rains in wet season.</td>
<td>Major vector of Ross River and Barmah Forest viruses. Potential vector of MVEV. Potential vector of many other arboviruses.</td>
</tr>
<tr>
<td>Oc. notoscriptus</td>
<td>Local urban pest, receptacle or tree hole breeder, bites persistently, anytime in cool shade. Found naturally in forest areas.</td>
<td>Potential Ross River virus vector. Major vector of heartworm of dogs.</td>
</tr>
<tr>
<td>Oc. tremulus</td>
<td>Local urban pest, receptacle or tree hole breeder, bites at sundown and dawn. Often caught in forest areas.</td>
<td>No diseases.</td>
</tr>
<tr>
<td>Oc. vigilax</td>
<td>Major pest, bites day or night within 5 km of breeding sites. Plagues associated with high tides in late dry season, early wet season. Fly up to 60 km in pest numbers.</td>
<td>Major vector of Ross River and Barmah Forest virus diseases and dog heartworm. Potential vector of many other arboviruses.</td>
</tr>
<tr>
<td>Ve. funerea</td>
<td>Local pest near breeding grounds, does not disperse. Common by day only locally inclosed forest near tidal brackish swamps &amp; Creeks.</td>
<td>Potential RRV and BFV arbovirus vector.</td>
</tr>
</tbody>
</table>

* Adapted and revised from P. Liehne et al. “Mosquitoes and biting midge investigation, Palmerston 1982 -85”.

F:\ENTO\ento_files\public_information\general_information\mosquitoes\probmos Top End.doc
BIOLOGICAL ATTRIBUTES OF THE MAJOR PEST AND VECTOR MOSQUITO SPECIES IN THE TOP END* OF THE NT*

Peter Whelan, Medical Entomology Branch, Department of Health and Community Services 1997

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>IMMATURE STAGES</th>
<th>ADULT STAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>An. annulipes</em> s.l.</td>
<td>Eggs laid singly on water surface; any freshwater body but numerous near <em>Eleocharis</em> reed swamps; temporary or permanent; some receptacles; larvae float on water surface and feed on particles on top of water.</td>
<td>Feeds on a variety of mammals including cattle and humans. Bites at night, especially dawn and dusk. Flies up to 2 km from breeding site; rests in cool shady locations such as stream margins, drains etc.</td>
</tr>
<tr>
<td><em>An. bancroftii</em></td>
<td>Eggs laid singly. Dark larvae, feeds at water surface; found in heavily shaded fresh to slightly brackish ground pools or swamps, especially in paperbark or <em>Eleocharis</em> reed swamps.</td>
<td>Feeds on all mammals readily; will fly up to 4 km from breeding site; bites any time near breeding site, nightly or in shade elsewhere.</td>
</tr>
<tr>
<td><em>An. farauti</em> s.l. (Includes <em>An. farauti, An. hinesorum</em> and <em>An. torresiensis</em>)</td>
<td>Eggs laid singly on surface; larvae feed on water surface. <em>An. farauti</em> breeds in brackish water; <em>An. hinesorum</em> and <em>An. torresiensis</em> breed in freshwater swamps and pools. Larval habitat often sunlit.</td>
<td>Bites readily at night; feeds on humans, other mammals and birds. Will fly approximately 2 km from the breeding site.</td>
</tr>
<tr>
<td><em>An. hilli</em></td>
<td>Eggs laid singly on surface; larvae feed at surface; sunlit or shaded brackish to saline ground pools or swamps. Numerous in <em>Schoenoplectus</em> reed swamps near coast.</td>
<td>Bites humans, cattle and horses; mainly after sunset. Disperses up to 4 km from breeding site.</td>
</tr>
<tr>
<td><em>An. meraukensis</em></td>
<td>Eggs laid singly on surface of water; larvae feed at the surface; usually in freshwater <em>Eleocharis</em> reed swamps, sunlit or shaded.</td>
<td>Bites readily at dusk, feeds on humans and other mammals.</td>
</tr>
<tr>
<td><em>Cx. annulirostris</em></td>
<td>Eggs deposited as rafts of up to 200 on the water surface; larvae hang from surface and feed on suspended particles; breed in freshwater pools and swamps with emergent vegetation temporary or permanent; will colonize domestic receptacles and breed readily in semi polluted water in storm drains or sewage effluent with vegetation.</td>
<td>Adults are the most common species encountered in the NT and are present throughout the year; feed at night and will bite humans, other mammals and birds; will fly distances of up to 10 km from the breeding site, although common up to 4 km from breeding site.</td>
</tr>
<tr>
<td><em>Cx. quinquefasciatus</em></td>
<td>Eggs laid as rafts on the surface; breeding grounds are polluted to fresh domestic waters; major sources are septic tanks, leach drains, primary sewage ponds and other polluted ground waters.</td>
<td>Severe domestic pest of humans but will feed on poultry and dogs as well; will feed and rest indoors; bites at night; flies up to 1 km from breeding site.</td>
</tr>
<tr>
<td><em>Cx. sitiens</em></td>
<td>Eggs laid as rafts on surface; brackish coastal ground pools under tidal influence with or without vegetation; larvae hang from the surface and rest on bottom. Feed on suspended matter or on substrate.</td>
<td>Bites mammals and birds at night; pest near coast, will fly up to 5 km but common within 2 km of breeding site.</td>
</tr>
<tr>
<td><em>Cq. xanthogaster</em></td>
<td>Eggs laid as small raft on the surface; larvae attach themselves to the stems of aquatic plants by a modified siphon and obtain oxygen from the plants; breed in semi-permanent to permanent swamps with emergent vegetation; associated with <em>Eleocharis</em> and <em>Typha</em> reeds, water lilies and paperbark; larvae feed on suspended material in the water.</td>
<td>Adults are strong flyers and will disperse widely up to 3 - 5 km. Readily feed on birds and mammals including humans; rest in cool vegetation and bite mainly at dusk, also shade during day. Strongly attracted to light and easily disturbed.</td>
</tr>
<tr>
<td><em>Ma. uniformis</em></td>
<td>Eggs laid as small cluster attached to the under surface of floating leaves water lilies and plant stems; larval habitats and breeding area similar to <em>Cq. xanthogaster</em>.</td>
<td>Adults bite humans, other mammals and birds readily at night. Severe pest in cool shade near breeding site during the day and evening; generally does not fly more than 1 - 2 km from breeding sites; strongly attracted to light; adults rest in dense vegetation; pest in the wet season near breeding areas only.</td>
</tr>
<tr>
<td>SPECIES</td>
<td>IMMATURE STAGES</td>
<td>ADULT STAGES</td>
</tr>
<tr>
<td>-----------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><em>Oc. vigilax</em></td>
<td>Eggs deposited singly in the mud or near plant stems in suitable habitats; breeds in tidal pools and marshes, usually those filled by tides in upper tidal zone associated with <em>Schoenoplectus littoralis</em> or landward ill draining mangrove areas; larvae browse on substrate.</td>
<td>Major and severe pest species; adults feed very readily on humans, other mammals and birds, day or night; will fly up to 60 km; shelter in thick vegetation.</td>
</tr>
<tr>
<td><em>Fl. kochi</em></td>
<td>Eggs laid singly on the axils of <em>Pandanus</em> leaves. Larvae feed on detritus and debris in the water collected in the axil space.</td>
<td>Severe pests near the breeding sites. Do not disperse far from the breeding habitat.</td>
</tr>
<tr>
<td><em>Oc. normanensis</em></td>
<td>Eggs deposited singly in drying mud substrate in poorly draining floodways. Pale larvae can be inconspicuous in colloidal clay suspension water. Tend to dive to bottom when disturbed. Feed by browsing on substrate. Mainly inland rural habitats.</td>
<td>Major pest species. Extreme numbers after flooding rains for 1-2 weeks. Feeds readily on humans and other mammals, mainly in evening and night. Will fly 3-5 km in pest numbers.</td>
</tr>
<tr>
<td><em>Oc. notoscriptus</em></td>
<td>Eggs laid singly on the sides of tree holes. Dark larvae hang from the surface by siphon and feed by browsing on the substrate. Common in domestic receptacle habitats.</td>
<td>Feeds on humans and all mammals; bites day or evening in the cool shade. Does not disperse widely.</td>
</tr>
<tr>
<td><em>Ve. funerea</em></td>
<td>Eggs laid singly on moist substrate at edge of breeding area, usually shaded with some salt influence. Dark larvae hang from water surface, generally feeding by browsing on the bottom of the water body.</td>
<td>Vicious biter in cool shaded vegetation near breeding site in day and in evening. Does not continue biting in sun. Do not disperse far from the breeding habitat.</td>
</tr>
</tbody>
</table>

* Adapted, revised and expanded from P. Liehne et al. “Mosquitoes and biting midge investigation, Palmerston 1982-85”.
^ Applicable for general area of Top End north of and including Mataranka, Larrimah, from Victoria River to Roper River mouths.
SEASONAL PREVALENCE OF THE MAJOR PEST AND VECTOR MOSQUITO SPECIES IN THE TOP END OF THE NT*

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>SUMMARY OF BIOLOGY &amp; SEASONAL PREVALENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>An. annulipes s.l.</td>
<td>Freshwater streams and vegetated swamps. Low to moderate numbers in the wet season, the persistence of populations after the wet season dependent on surface water.</td>
</tr>
<tr>
<td>An. bancroftii</td>
<td>Freshwater, paperbark and <em>Eleocharis</em> reed swamps and creeks. High to very high numbers at post wet and early dry season, when emergent vegetation at peak and standing water starting to recede.</td>
</tr>
<tr>
<td>An. farauti s.l.</td>
<td>Brackish and freshwater species, in vegetated swamps or creeks. Low to moderate numbers in late wet and early post wet season.</td>
</tr>
<tr>
<td>An. hilli</td>
<td>Brackish/saltwater breeder, often associated with <em>Schoenoplectus</em> reed swamps or creeks or remnant pools in landward mangroves. Low numbers except near extensive brackish water swamps in late wet and early dry season.</td>
</tr>
<tr>
<td>An. meraukensis</td>
<td>Open shallow freshwater <em>Eleocharis</em> reed swamps and creeks. Moderate to high numbers in the late and immediate post wet season.</td>
</tr>
<tr>
<td>Ma. uniformis</td>
<td>Same as <em>Cq. xanthogaster</em> but more associated with floating vegetation, (water lilies). Moderate to very high numbers near habitats in late wet, early dry season.</td>
</tr>
<tr>
<td>Cx. annulirostris</td>
<td>Breeds in the vegetated margins and pools in permanent and semi-permanent swamps, creeks and floodways. Exploits temporary vegetated ground pools in wet season. High numbers in polluted or wastewater with vegetation in dry season. High to very high numbers in the early to mid dry season.</td>
</tr>
<tr>
<td>Cx. quinquefasciatus</td>
<td>Domestic water sites, often with organic pollution. Moderate numbers in mid to late dry season, but can be present all year.</td>
</tr>
<tr>
<td>Cx. sitiens</td>
<td>Breeds in salt to brackish coastal pools or swamps. Low numbers except locally in tidal pools in upper tide zone in late dry, early wet season, and late wet season.</td>
</tr>
<tr>
<td>Cq. xanthogaster</td>
<td>Breeds in freshwater <em>Eleocharis</em> reed swamps and creeks. Very high numbers in mid to late dry season when maximum plant growth present in permanent and semi permanent swamps and creeks.</td>
</tr>
<tr>
<td>Fl. kochi</td>
<td>Breeds in <em>Pandanus</em> axils. Moderate numbers in wet season in <em>Pandanus</em> thickets.</td>
</tr>
<tr>
<td>Oc. normanensis</td>
<td>Floodwater, ground pool breeder in poorly draining floodways associated with creeks and rivers. Very high numbers during wet season, absent at other times.</td>
</tr>
<tr>
<td>Oc. notoscriptus</td>
<td>Tree hole or artificial receptacle breeder. Low numbers in wet season but persists in dry season with artificial breeding sites.</td>
</tr>
<tr>
<td>Oc. tremulus</td>
<td>Tree hole or receptacle breeder. Low numbers in wet season and early dry season.</td>
</tr>
<tr>
<td>Oc. vigilax</td>
<td>Breeds in tidal to brackish swamp or tidal pools in creeks. Extreme numbers in the very late dry and early wet season.</td>
</tr>
<tr>
<td>Ve. funerea</td>
<td>Brackish to tidal ground pools in tidal creeks and swamps, often in shade. Localised pest numbers in the pre wet and wet.</td>
</tr>
</tbody>
</table>

* Adapted, revised and expanded from P. Liehne et al. “Mosquitoes and biting midge investigation, Palmerston 1982-85”.
PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT
PEST AND DISEASE VECTOR STATUS
Peter Whelan 1997
Medical Entomology Branch, Department of Health and Community Services

<table>
<thead>
<tr>
<th>Species/ (Common Name)</th>
<th>Nuisance status</th>
<th>Disease Vector Status</th>
<th>Potential vectors in the NT</th>
<th>Peak Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ochlerotatus vigilax (Salt marsh mosquito)</td>
<td>++++</td>
<td>+++</td>
<td>+++</td>
<td>RRV, BFV</td>
</tr>
<tr>
<td>Ochlerotatus normanensis (Floodwater mosquito)</td>
<td>++++</td>
<td>+++</td>
<td>+++</td>
<td>RRV, BFV</td>
</tr>
<tr>
<td>Culex annulirostris (Common banded mosquito)</td>
<td>++++</td>
<td>++++</td>
<td>++++</td>
<td>MVEV, KUNV, RRV, BFV, JEV, others</td>
</tr>
<tr>
<td>Culex gelidus (The frosty mosquito)</td>
<td>+</td>
<td>+</td>
<td>+++</td>
<td>MVEV, KUNV, RRV, BFV, JEV, others</td>
</tr>
<tr>
<td>Culex palpalis (Freshwater banded mosquito)</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
<td>MVEV, KUNV, RRV, BFV, JEV, others</td>
</tr>
<tr>
<td>Anopheles bancroftii (Black malaria mosquito)</td>
<td>+++</td>
<td>Nil</td>
<td>+</td>
<td>Malaria (possible)</td>
</tr>
<tr>
<td>Coquillettidia xanthogaster (The golden mosquito)</td>
<td>+++</td>
<td>Nil</td>
<td>Nil</td>
<td>None known</td>
</tr>
<tr>
<td>Mansonia uniformis (Waterlily mosquito)</td>
<td>+++</td>
<td>Nil</td>
<td>Nil</td>
<td>None known</td>
</tr>
<tr>
<td>Anopheles farauti s.l. (Australian malaria mosquito)</td>
<td>+</td>
<td>Nil</td>
<td>++++</td>
<td>Malaria (probable)</td>
</tr>
<tr>
<td>Culex quinquefasciatus (Brown house mosquito)</td>
<td>+++</td>
<td>+</td>
<td>+</td>
<td>MVEV (possible)</td>
</tr>
<tr>
<td>Ochlerotatus notoscriptus (Receptacle mosquito)</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>RRV (probable)</td>
</tr>
<tr>
<td>Verallina funerea (Brackish water mosquito)</td>
<td>+++</td>
<td>+</td>
<td>++</td>
<td>RRV, BFV (probable)</td>
</tr>
</tbody>
</table>

LEGEND
RRV - Ross River virus
BFV - Barmah Forest virus
MVEV - Murray Valley encephalitis virus
JEV - Japanese encephalitis virus
KUNV - Kunjin virus

**PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT**

**INDICATIVE PEST LEVELS**

Peter Whelan 2002

Medical Entomology Branch, Department of Health and Community Services

<table>
<thead>
<tr>
<th>Species</th>
<th>Main distribution</th>
<th>Peak Period</th>
<th>CO\textsubscript{2} Trap at Residence *</th>
<th>CO\textsubscript{2} Trap at Monitoring Site #</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ochlerotatus vigilax</em></td>
<td>Top End, north of Wave Hill, Larrimah and Borroloola</td>
<td>September - January</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td><em>Ochlerotatus normanensis</em></td>
<td>Subcoastal Top End south to Ti Tree</td>
<td>January - April</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td><em>Culex annulirostris</em></td>
<td>NT wide</td>
<td>January to August</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td><em>Anopheles bancroftii</em></td>
<td>Top End north of Victoria and Roper River, south to Larrimah</td>
<td>February - July</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td><em>Coquillettidia xanthogaster</em></td>
<td>Top End north of Victoria and Roper River, south to Larrimah</td>
<td>March - August</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td><em>Mansonia uniformis</em></td>
<td>Top End south to Larrimah</td>
<td>March - June</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td><em>Anopheles farauti s.l.</em></td>
<td>Top End north of Port Keats, Pine Creek, and Numbulwar</td>
<td>March - June</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td><em>Culex quinquefasciatus</em></td>
<td>NT wide, primarily near residential areas</td>
<td>January - June</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td><em>Ochlerotatus notoscriptus</em></td>
<td>NT wide, generally near residential areas</td>
<td>January - June</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td><em>Verrallina funerea</em></td>
<td>Top End primarily coastal and sub-coastal but occasionally south to Larrimah</td>
<td>Nov - March</td>
<td>20</td>
<td>100</td>
</tr>
</tbody>
</table>

**Pest Levels**

* Indicative significant pest threshold levels (mosquitoes per CO\textsubscript{2} trap per night) at residence for relatively unprotected people at peak biting times.

# Indicative significant pest threshold levels (mosquitoes per CO\textsubscript{2} trap per night) in residential areas from monitoring sites close to but outside of residential areas, and for monitoring sites between the residential areas and major mosquito breeding areas that are within 2km of residential areas.
<table>
<thead>
<tr>
<th>Species/Common name</th>
<th>Habitat Description</th>
<th>Habitat Indicators</th>
<th>Flight Range &amp; Pest Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ochlerotatus vigilax (Salt marsh mosquito)</td>
<td>Brackish reed swamps, Upper mangrove margin and tidal creek extremities</td>
<td>Extensive mangrove areas with freshwater creek entry. Tidally or sea spray affected rock pools, depressions in coastal sand dunes and vegetated areas above tidal limit. Disturbed upper tidal areas. Tidal brackish swamps with <em>Schoenoplectus</em> reeds.</td>
<td>0 - 5 km major pest 5 - 50 km pest numbers 50 - over 200 km dispersal</td>
</tr>
<tr>
<td>Ochlerotatus normanensis (Floodwater mosquito)</td>
<td>Flooded freshwater sub-coastal or inland floodways and creeks</td>
<td>Broad, flat sub-coastal and inland drainage floors of minor and major creeks.</td>
<td>0 - 2 km major pest 2 - 5 km pest numbers</td>
</tr>
<tr>
<td>Culex annulirostris (Common banded mosquito)</td>
<td>Freshwater and coastal reed swamps. Streams, storm drains, and sewage effluents</td>
<td>Extensive reed swamps with <em>Eleocharis</em> or <em>Typha</em> reeds. Temporary flooded grasslands in sub-coastal and inland areas with organic matter. Sewage effluent and organic waste water with grass, <em>Lemna</em> (Duckweed), <em>Azolla</em> (water fern).</td>
<td>0 - 3 km major pest 2 - 10 km pest numbers 10 - 15 km dispersal</td>
</tr>
<tr>
<td>Anopheles bancroftii (Black malaria mosquito)</td>
<td>Freshwater and coastal reed swamps. Shaded streams and swamps</td>
<td>Extensive seasonally inundated <em>Melaleuca</em> paperbark swamps. <em>Eleocharis</em> and <em>Typha</em> reed swamps.</td>
<td>0 - 3 km major pest 3 - 5 km pest numbers</td>
</tr>
<tr>
<td>Coquillettidia xanthogaster (The golden mosquito)</td>
<td>Freshwater swamps with reeds, Vegetated streams</td>
<td>Extensive <em>Eleocharis</em> and <em>Typha</em> reed swamps. Paperbark creek lines.</td>
<td>0 - 3 km major pest 3 - 5 km pest numbers</td>
</tr>
<tr>
<td>Mansonia uniformis (Waterlily mosquito)</td>
<td>Extensive freshwater reed swamp</td>
<td>Extensive <em>Eleocharis</em> and <em>Typha</em> reed swamps with water lilies.</td>
<td>0 - 2 km major pest 2 - 3 km dispersal</td>
</tr>
<tr>
<td>Anopheles farauti s.l. (Australian malaria mosquito)</td>
<td>Coastal and brackish reed swamps, Freshwater swamps and vegetated streams</td>
<td>Brackish <em>Schoenoplectus</em> and <em>Eleocharis</em> reed swamps. Upper reaches of mangrove creeks with freshwater influence.</td>
<td>0 - 1.5 km minor pest 1.5 - 3 km dispersal</td>
</tr>
<tr>
<td>Culex quinquefasciatus (Brown house mosquito)</td>
<td>Storm drains, artificial receptacles, Septic tanks, Waste water ponds</td>
<td>Polluted ground or artificial receptacles. Filamentous green algae, <em>Lemna</em> (Duckweed), <em>Azolla</em> (water fern), or high organic water. Tyres, drums and other receptacles</td>
<td>0 - 500 m major pest 500 m - 1 km pest numbers</td>
</tr>
<tr>
<td>Ochlerotatus notoscriptus (Receptacle mosquito)</td>
<td>Tree holes or artificial receptacles</td>
<td>Trees with natural collections of water including <em>Eucalyptus</em>, <em>Ficus</em>, <em>Poinciana</em> and <em>Adansonia</em>. Tyres, drums, pot plant drip trays, roof gutters, rainwater tanks.</td>
<td>0 - 500 m minor pest 500 m - 1 km dispersal</td>
</tr>
</tbody>
</table>
ARBOVIRUS DISEASE RISK PERIODS IN THE NORTHERN TERRITORY

<table>
<thead>
<tr>
<th>VIRUS</th>
<th>FROM VECTORS/ABUNDANCE &amp; LONGEVITY</th>
<th>FROM VIRUS ISOLATION</th>
<th>FROM SENTINEL ANIMALS</th>
<th>FROM CASE DATA</th>
<th>PEAK RISK PERIOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVE</td>
<td>JAN-SEPT</td>
<td>MAR</td>
<td>DEC-OCT</td>
<td>FEB-JULY</td>
<td>FEB-MAY</td>
</tr>
<tr>
<td>KUNJIN</td>
<td>JAN-SEPT</td>
<td>APRIL-JUN</td>
<td>DEC-SEPT</td>
<td>MAY-JUN</td>
<td>FEB-MAY</td>
</tr>
<tr>
<td>RRV</td>
<td>NOV-SEPT</td>
<td>JAN-APR</td>
<td>-</td>
<td>JAN-DEC</td>
<td>JAN-MAR</td>
</tr>
<tr>
<td>BF</td>
<td>NOV-SEPT</td>
<td>DEC-APR</td>
<td>-</td>
<td>DEC-OCT</td>
<td>JAN-MAR</td>
</tr>
</tbody>
</table>
APPENDIX 3
PERSONAL PROTECTION
FROM MOSQUITOES & BITING MIDGES
IN THE NT

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April 2004*


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* Minor revisions 2004
1.0 MOSQUITO & BITING MIDGE BITES

Mosquitoes and biting midges (genus Culicoides and sometimes erroneously called sand flies) can reach sufficient numbers in various localities to be considered serious pests. The bites themselves can be painful and extremely annoying, and people suffer varying degrees of reaction to bites (Lee 1975). However the possibility of the spread of various diseases by their blood sucking habits to either humans or animals is a more serious outcome. Mosquitoes can carry viruses such as Murray Valley encephalitis, Kunjin, Ross River, and Barmah Forest virus, which cause human disease (Russell 1995). Biting midges do not carry any pathogens in Australia that cause human disease.

Female mosquitoes or biting midges bite to take blood from their hosts, which is necessary for the development of eggs.

Mosquitoes and biting midges show considerable variation in their preference for hosts. Some species feed selectively on cattle, horses, marsupials, amphibians, birds or humans, while other species are relatively indiscriminate feeders.

The time of feeding varies for different species. Many mosquitoes feed just after sunset while others are more active at other times including late in the night, in the late afternoon, or in the early morning. Biting midges are most active in the evening and early morning.

The place of feeding by mosquitoes or biting midges is varied. Some species, such as the brown house mosquito, readily entering houses to feed on people, while others will only bite people outdoors.

When a mosquito or biting midge bites, fine stylets sheathed in the proboscis are inserted into the skin. Blood is sucked up through one of the channels in the stylets, while saliva is injected down an adjacent channel. This saliva contains substances that the human body recognises as foreign and often stimulates a bite reaction. Sometimes the saliva can contain viruses or other pathogens that can cause disease.

Some people can become very sensitive after being bitten and suffer a general reaction from further bites. The bites may itch for days, producing restlessness, loss of sleep and nervous irritation. Scratched bites can lead to secondary infections and result in ugly scars. On the other hand, some people become tolerant to particular species and suffer little after-effects from repeated bites.
Biting insects create problems in the enjoyment of outdoor activities, causing a reluctance to enter certain areas after sundown or forcing people to be confined to insect-proof areas at certain times of the year. Personal protection and avoidance measures can offer considerable protection from bites, as well as offering protection against mosquito-borne disease.

2.0 MOSQUITO & BITING MIDGE AVOIDANCE

A sensible precaution to prevent biting insect attack is to avoid areas that are known to have high biting insect activity.

The upper high tide areas near creeks or low-lying areas, particularly near salt marsh habitats, can be significant sources of salt marsh mosquitoes (particularly *Ochlerotatus vigilax* and various other pest mosquitoes (Russell 1995). The period of high salt marsh mosquito activity is usually during the late dry season and early wet season in tropical latitudes. Generally they are prevalent for one to two weeks after the highest tides of the month or significant rain. Dense vegetation near the breeding sites should be avoided during the day over this period. Pest problems during the evening and night can occur within 3 km of productive breeding sites (Whelan, Merianos et al., 1997).

Other areas of high mosquito activity are the large seasonally flooded areas associated with rivers or drainage lines, flooded coastal swamps, extensive reed swamps and lagoons, ill defined or poorly draining creeks, extensive irrigation areas, and wastewater disposal facilities. Densely shaded areas near these habitats should be avoided during the day, and accommodation areas should be at least 3 km from extensive areas of these habitats.

Extensive areas of mangroves or estuarine areas with sandy beaches are potential sources of biting midges. These midges have seasonal and monthly population peaks with the monthly peaks usually associated with the tidal regime. When camping or choosing a permanent living site, a separation distance of at least 2 km from these areas is recommended unless specific biting insect investigations indicate there are no seasonal pest problems (Whelan 1990, Whelan, Hayes et al., 1997).

If camping or selecting house sites near creeks, rivers or lagoons, choose localities of the water body which have steep margins or little marginal emergent vegetation, have swiftly running water with little marginal pooling or vegetation, or do not arise from or empty into a nearby swamp area. Exposed beaches or cliffs away from mangrove or estuary areas are preferred sites to avoid both mosquitoes and biting midges. In more inland areas, locations on hills or rises at least 3 km from ill defined drainage lines, poorly flowing creeks and seasonally flooded areas should avoid the worst mosquito problems.

In residential areas, a local source of mosquitoes may be the cause of the problem. Check nearby potential artificial sources of mosquitoes such as disused swimming pools, receptacles such as tyres and drums, blocked roof gutters, old fishponds, or localised ponding of drains. Sites with mosquitoes breeding can be rectified by physically removing the source or through the use of insecticides.
3.0 SCREENING

The best method of avoiding attack at night is to stay inside insect-screened houses. Screens can be made of galvanised iron, copper, bronze, aluminium or plastic. Near the coast, iron or copper screens are not recommended because of the corrosive action of salt sprays. Homes near biting midge breeding sites require either fine mesh screens or lightproof curtains.

Screens should be of the correct mesh, fit tightly and be in good repair. Biting insects frequently follow people into buildings and for this reason, screen doors should open outward and have automatic closing devices. Insecticides such as permethrin or deltamethrin sprayed on or around screens may give added protection against mosquitoes or biting midges, but care is needed as some insecticides affect screens.

It is advisable to use an insect proof tent when camping near potential biting insect areas. Coastal areas subject to attack by biting midges require tents to be fitted with a finer mesh screening.

4.0 MOSQUITO NETS

Mosquito nets are useful in temporary camps or in unscreened houses near biting insect breeding areas. Generally standard mosquito nets are not sufficient to prevent biting midge attack. White netting is best as mosquitoes accidentally admitted into the net are easily seen and killed. The net is suspended over the bed and tucked under the mattress. An aerosol pyrethrin spray can be used to kill mosquitoes that enter the net. Care is needed not to leave exposed parts of the body in contact with the net, as mosquitoes will bite through the net. Nets can be made more effective by impregnation with permethrin (Lines et al. 1985).

5.0 INSECT PROOF CLOTHING

Head nets, gloves and boots can protect parts of the body, which are not covered by other clothing. Head nets with 1-1.5 meshes to the centimetre are recommended for good visibility and comfort, and additional treatment of the net with a repellent will discourage insect attack. Thick clothing or tightly woven material offers protection against bites. Light coloured, long sleeved shirts and full-length trousers are recommended. For particular risk areas or occupations, protective clothing can be impregnated with permethrin or other synthetic pyrethroid insecticides such as bifenthrin to give added protection (Burgess et al. 1988). Sleeves and collars should be kept buttoned and trousers tucked in socks during biting insect risk periods. Protection is very necessary near areas of salt marsh, mangroves, or large fresh water swamps where the various species of mosquitoes may be very abundant during the day in shaded situations, as well as at night.

6.0 REPELLENTS

Relief from biting insect attack may be obtained by applying repellents to the skin and clothing (Schreck et al. 1984). Many repellents affect plastics and care is needed when applying them near mucous membranes such as the eyes and lips.
Repellents with the chemical diethyl toluamide (DEET) or picaridin give the best protection. Some specific repellent products, such as Aerogard, which are formulated to repel flies, are generally not efficient against mosquitoes or biting midges. Brands such as Rid, Tropical Strength Aerogard, Bushman’s, Muskel, or Repel include specific products that are effective. Those products with higher amounts of DEET or picaridin are usually the most efficient.

Application of repellents over large areas of the body or on extensive areas of children is not recommended particularly those repellents with high concentrations of DEET. Protection from mosquito penetration through open weave clothes can be obtained by applying a light application of aerosol repellent to the exterior of clothing. Repellents should be supplementary to protective clothing and should not be regarded as substitutes.

Personal repellents are available as sprays, creams or gels. The creams or gels usually last longer than the aerosol formulations. Repellents can prevent bites from 2 to 4 hours, depending on the repellents, the species of biting insect, or the physical activity of the wearer.

Electronic insect repellers that emit ultrasonic or audible sounds do not offer any protection against mosquitoes or biting midges. They are based on a false premise and have been found to have no repellent effect under scientific testing (Curtis 1986). Electronic ultrasonic repellers do not repel mosquitoes or biting midges and should not be relied upon for personal protection (Mitchell 1992).

Plants with reported insecticidal properties such as neem trees and the citrosa plant have not been shown to act as mosquito repellents just by growing in the vicinity of people (Mitchell 1992, Matsuda et al. 1996). Growing or positioning these plants near evening activity areas will not prevent mosquito attack. However some plants have some repellency effects as smoke or liniments (see section 12, emergency biting insect protection).

7.0 ANIMAL DIVERSION

Camping upwind near congregations of stock or domestic animals will serve to divert mosquitoes or biting midges to alternative hosts. Similar considerations can be made when planning residential sites and animal holding areas in a rural situation. Dogs of darker colour tend to attract some species of mosquitoes more than lighter colours and can divert some pest problems from people in close vicinity in outdoor situations in the evening.

8.0 LIGHTING DIVERSION

Many mosquito and biting midge species are attracted to light. This can cause pest problems in unscreened houses or when camping. The use of yellow or red incandescent bulbs or fluorescent tubes rather than white light will reduce the attractiveness of lights to insects. An incandescent or ultra violet light placed at a distance from a house or camp can serve to attract insects to an alternative area. This is more effective if the light is close to the breeding site, or between the breeding site and the accommodation area. The attractive lights should not be close to accommodation or directly down wind of accommodation areas. Light proof
curtains or similar screening can be very effective in reducing the attraction of biting insects to areas that are illuminated at night.

9.0 ADULT INSECT CONTROL

If mosquitoes or biting midges have entered a screened area they can be knocked down with pyrethrin aerosols. Care should be taken by reading the label to ensure only knockdown aerosols suitable for spraying in the air are used in proximity to people or food.

Other devices that can be effective at killing and/or repelling biting insects include mosquito coils (Charlwood & Jolley 1984) and electric insecticide pads. These devices are only effective in relatively closed areas such as inside buildings or where there are only slight breezes. They should be backed up with other measures such as suitable protective clothing or repellents.

Large scale adult biting insect control can be achieved for short terms (hours) by using portable or industrial fog generators, backpack misters, or heavy duty ultra-low-volume aerosol generators to knock down active adult insects. The insecticides of choice in these machines are Maldison or Bioresmethrin. Control relies on good access, open vegetation, and light breezes in the direction of the breeding or harbouring sites. Application should only be during the peak biting insect activity period of those insects actually causing the problem, which is usually the late evening and early night.

There are some synthetic pyrethroid aerosol products available as outdoor yard or patio repellents. Control will only be temporary (hours) and re-invasion will usually occur within hours or from one to a few days, depending on the species, nearby vegetation, proximity to breeding sites, environmental conditions and times of activity of the pest species.

Application of residual insecticides such as maldison, permethrin or other synthetic pyrethroids sprayed as a mist spray to point of run off on building surfaces or nearby vegetation can sometimes give short term (a few days) relief. This method is useful as a barrier protection when large numbers of mosquitoes or biting midges are present near accommodation or outdoor use areas (Helson & Surgeoner 1985). There are some longer term residual synthetic pyrethroids such as bifenthrin that can be used as barrier sprays and provide a number of weeks protection (Standfast et al 2003). These residual insecticides can be applied according to label recommendations with the aid of a garden sprayer. Care must be taken with all synthetic pyrethroids around fishponds, fish tanks and other nearby fish habitats to avoid spray drift or run off, as these insecticides are efficient fish poisons.

10.0 INSECTOCUTORS AND INSECT TRAPS

Electric insect insectocutors and other trap or killing devices utilising an attracting light or carbon dioxide have been claimed to clear areas of biting insects and thus protect people. These claims have not been substantiated in outdoor situations with people nearby. While trap devices can attract biting insects, as well as a range of other insects, these devices cannot be relied on for protection from biting insect attack (Mitchell 1992). When used in outdoor situations it is possible that they can increase local problems by attracting insects to...
the vicinity of people. Attractive odours and carbon dioxide emitted by humans then divert the insects from the trap device to the people.

11.0 TREATMENT OF BITES

Relief from bites and prevention of secondary infection can be obtained by the application of various products, either to the skin or internally. The effectiveness of various products is variable, depending on individual reaction. Skin application products include proprietary products such as Eurax, Stingose, Medicrem, Katers lotion, Dermocaine and Paraderm creme, and non-proprietary products such as tea tree oil, eucalyptus oil, aloe vera gel, ice, or methylated spirits.

Ice packs to the general bite site will give usually give immediate relief for painful and itchy bites and swelling or blisters from of mosquitoes and biting midges in particular. The sooner the ice pack is applied after bites or reactions, the better the relief, and can often avoid more intense reactions.

Other products for internal application for more general symptoms include antihistamine products such as Phenergan, Telfast and Vallergan. Check with your doctor or pharmacist for any products for the latest product and safety information.

12.0 EMERGENCY BITING INSECT PROTECTION

There are a number of emergency measures that can be taken when exposed to biting insects with no protection. Sheltering downwind next to smoky fires can offer considerable protection. Burning dung or aromatic and oil producing foliage from plants such as Hyptis (horehound), Vitex (black plum), Calytrix (Turkey bush), Melaleuca species (Paper bark) and Eucalyptus species (gum trees) can make the smoke more effective. A small native plant Pterocaulon serrulatum (warnulpu) has sticky strongly aromatic leaves, and branches are burnt or the moist leaves are rubbed on the skin by Aborigines in the Katherine district to repel mosquitoes (Aborigines of the NT 1988). Climbing relatively high trees or choosing locations exposed to the wind can also offer protection from some species.

Some protection can be obtained by rubbing exposed skin areas with the leaves of certain plants such as eucalypts, turkey bush, warnulp, paperbarks or tea-trees that contain volatile oils. However these are not as efficient as proprietary repellents containing deet or picaridin. Other emergency protection measures include coating the skin with mud, or burying yourself in shallow sand with some form of head protection. If all else fails, keep running. The best form of protection, and the most comfortable, require an awareness of the potential problems and adequate preparation.

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FIELD EVALUATION OF BISTAR 80SC AS AN EFFECTIVE INSECTICIDE HARBOURAGE TREATMENT FOR BITING MIDGE (CULICOIDES) AND MOSQUITOES INFESTING PERIDOMESTIC SITUATIONS IN AN URBAN ENVIRONMENT

By

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Abstract

Excellent residual control of adult biting midges and mosquitoes was recorded at River Heads, Hervey Bay, by applying Bistar 80SC (FMC Chemicals) as a 0.1% bifenthrin in water mix to external resting surfaces in peri-domestic situations. Application of the mix as a coarse spray (150-200 micron droplets) resulted in a 97%-75% reduction in biting midge numbers in the first month of field evaluation, with a 65% mean reduction in numbers at six weeks post-treatment. Of the midge species controlled during this evaluation, 81% were Culicoides ornatus, and 19% Culicoides subimmaculatus.

With regards to the mosquitoes controlled during the evaluation, an even higher level of efficacy was achieved, with a 99%-94% reduction in numbers during the first month, and 94% mean reduction in numbers over the six week evaluation period. Of these, the saltmarsh arbovirus vector Ochlerotatus vigilax represented 78%.

These are significant results, as the authors are unaware of any other method which has achieved an effective, sustained reduction in adult biting midge numbers. Accordingly, the suitability of the method for provision of household protection and integration with existing vector control programs is discussed, and recommendations made for future management of this valuable insecticide.
Introduction

It is well documented that mosquitoes (Russell 1998) and biting midges (Culicoides spp.) (Kettle 1965, Howie 2002) seriously impact on human health in Australia. With respect to mosquitoes, several Ochlerotatus, Aedes and Culex species have been implicated in the transmission of arboviruses and canine filaria (Boreham and Marks 1986, Watson and Kay 1998, Hanna et al. 1999, Ryan et al. 1999, Boyd and Kay 2000). With biting midges, it is females from the genus Culicoides which impact most severely on the health and comfort of humans and animals (Kettle 1965, Linley et al. 1983, Kay and Standfast 1987). This biting behaviour can result in adverse economic effects on land development, property values, tourism, recreation and work-related activities (Linley and Davies 1971, Howie 2002). In Hervey Bay in 2002, the biting midge problem is estimated to have cost residents $61 million (Ratnayake et al. 2003). Additionally, Culicoides are also known to transmit protozoans, filarial worms, and viruses (Kettle 1965, Blanton and Wirth 1979, Linley et al. 1983).

In response to this threat, some larger coastal Queensland Local Governments allocate significant resources towards broadscale larviciding for mosquitoes (Brown et al. 1999). Unfortunately, there is no registered larvicide for biting midges. This is because the larvae occur in environmentally sensitive areas of the inter-tidal zone, and dispersal patterns are poorly know (Shivas 2001). Also, required dosages are environmentally damaging (Standfast unpub data). This leaves aerosol (thermal fogging and ULV) insecticide applications against adults as the only option available. The method only provides short-term relief from biting, and repeated applications are necessary and expensive. It is for these reasons that a sustained effective method is required, and one that provides household protection has been identified as a priority (Shivas 2001).

Accordingly, Bifenthrin (FMC Chemicals) was selected for evaluation as an effective insecticide surface treatment for biting midges and mosquitoes harbouring on ornamental plants, fences and walls surrounding domestic situations at River Heads, Hervey Bay (Queensland, Australia). This suburb was selected as a test site, as a recent public health study found that residents experience reduced health levels as a consequence of biting midges, and that an effective control method is desperately needed (Howie 2002). Bifenthrin, a non-alpha cyan (low skin irritant) synthetic pyrethroid, which is used world-wide against a range of agricultural pests, was considered an ideal candidate insecticide as it is characterized by:

1) low irritancy to mosquitoes, and thus increases mosquito-bifenthrin contact time (WHO 2002);
2) very low vapor pressure (1.81 10-7 mmHg);
3) low water solubility (<1 µg/litre) and good stability to hydrolysis and photolysis (2 years at 500C. under natural daylight); and
5) safety to humans: “Noting its safety and efficacy, Bifenthrin 10WP is recommended for indoor residual spraying” (WHO/CDS/WHOPES/2001.4).

In house-scale trials in India, Bifenthrin (10% wettable powder) applied at a rate of 25 mg/m² provided persistent (>80% mortality for 24 weeks) insecticidal activity against Anopheles culicifacies on mud and brick surfaces (Yadav 2003).
It was these characteristics that led to selection of an 8% water-based, no-odor, non-irritant, suspension concentrate (SC) formulation for evaluation in Queensland against biting midges. Although this FMC Chemicals formulation is registered in Australia as a surface treatment for mosquitoes, it has not been evaluated for efficacy against biting midges infesting domestic situations. Therefore, this study was undertaken to produce efficacy data for biting midges, and in doing so provide a tool for control of these insects of public health and economic importance. Additional efficacy data was also collected for mosquitoes.

Materials and Methods

Study Site. Public support for this evaluation at River Heads (Plate 1) was received at a River Heads public forum, held on the 2nd October 2002. There was 80% positive support from the public for this evaluation. The Environmental Protection Agency, and Department of Primary Industries – Fisheries, also supported the evaluation as it did not impact on the environmentally sensitive marine park surrounding River Heads. The evaluation was conducted under NRA Research Permit 5547.

Plate 1. River Heads, Hervey Bay, Queensland. Clean estuarine sand and muddy sand surrounding River Heads provides larval habitat for *Culicoides subimmaculatus* Lee & Reye, while estuarine mud produces *Culicoides ornatus* Taylor. Saltmarsh and mangrove habitats produce the mosquito arbovirus vector, *Ochlerotatus vigilax* (Skuse).
Once the above detailed approval had been obtained, eight houses comprised of four randomized pairs (1 treatment + 1 untreated control) were selected, and the householders consent obtained ca. 2 weeks prior to the treatment date (29th October, 2002).

Plate 2. On the properties selected for evaluation, external surfaces where mosquitoes and midges rest (fences, walls, ornamental plants and bushes) were identified for treatment.

**Application of Bistar 80 SC (Active Ingredient: 8% bifenthrin).** In order to obtain the required efficacy data for biting midges, the 8% SC formulation was applied as per the label directions for applications against mosquitoes under conditions of high pest pressure, and when maximum residual protection is desired. The label directions state that at a recommended rate of 125 mL/10L: “on non-porous surfaces apply as a coarse spray at the rate of 1 litre of emulsion per 20 m². When treating non-porous surfaces do not exceed the point of run-off. On porous surfaces or use through power equipment, spray at the rate of 1 litre of emulsion per 10 m². When treating porous surfaces do not exceed the point of run-off. To control mosquitoes apply prepared emulsion to surfaces where insects rest or harbour. Reapply as necessary.”
Accordingly, a 0.1% mix (125 mL/10L water) was applied as per the label instructions described above, to external building and ornamental plant surfaces (Plate 2). To do this a Solo Back Pack Sprayer (Solo, Germany) was calibrated by the Centre for Pesticide Application and Safety (University of Queensland, Gatton Campus) to deliver a dilute spray comprised of large (150-200 micron) droplets.

### Table 1. Property treatment rates.

<table>
<thead>
<tr>
<th>Treatment Property No.</th>
<th>Property Size</th>
<th>Volume of 8% SC Applied$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1012 m$^2$</td>
<td>875 ml</td>
</tr>
<tr>
<td>2</td>
<td>1012 m$^2$</td>
<td>750 ml</td>
</tr>
<tr>
<td>3</td>
<td>1012 m$^2$</td>
<td>500 ml</td>
</tr>
<tr>
<td>4</td>
<td>1012 m$^2$</td>
<td>625 ml</td>
</tr>
</tbody>
</table>

$^1$ The volume of 8% SC applied to the various properties varied according to house size and % ornamental coverage.

**Surveillance and Identification.** CDC-type light traps powered by a rechargeable 6 volt battery, were used to measure peri-domestic biting midge and mosquito populations in Plate 3.

**Plate 3.** Median midge and mosquito numbers caught overnight in unbaited vs baited light traps.
treatment and control properties. Light trap collections were made on the evening prior to
treatment, and then each night for 9 nights post-treatment. Sampling frequency was then
reduced to weekly collections for six weeks post-treatment.

To do this, one trap was hung from a tree within the fenced-off yard of each treatment
and control property. On each sampling occasion, each trap was baited with 750 g dry ice
and 2.5 ml Octenol (1-Octen-3-ol). The dry ice was housed in the purpose built 1 litre ice
container, and the Octenol contained in a 4 ml microreaction vial. An exposed cotton pipe
cleaner wick was used to release the Octenol. The traps were operated from 1500 to 0700
hours. Each day the collections were transported to the laboratory for sorting, counting,
and identification according to the descriptions in Marks (1982). All collections were
stored in 70% ethanol. The above described baited light trapping method was chosen on
the basis of catches recorded in an evaluation of trapping efficacy conducted between
1500 and 0700 hours, 7 days prior to the application of the 8%SC formulation. In order to
determine if un-baited traps would provide sufficient numbers for statistical analyses, the
catches recorded from 5 x un-baited light traps were compared with what was caught in 5
x light traps baited with CO2 and Octenol.

Environmental data. Environmental parameters in terms of wind speed, direction,
temperature and humidity were measured on a vacant allotment at River Heads using a
portable EnvironData Weather Master 2000 (EnvironData, 44 Percy St, Warwick, QLD.
4370 Australia).

Statistical Quantification of Treatment Efficacy. For both biting midges and
mosquitoes, 12 hours pre-treatment and six weeks post-treatment field data, comprising
62 light trap collections were made. As the pre-treatment data was normally distributed, a
t-test was used to test for significant differences between treatment and control
properties. For the post-treatment data, and pre-treatment comparison of light trapping
efficiency, a non-parametric Mann-Whitney Rank Sum Test was used to test for
statistically significant differences in the median values between counts from treatment
and control properties, and baited vs un-baited light-traps, respectively. This non-
parametric test was utilized as the collected data failed a test for normality (see skewness
values Table 5). We did not expect the long-term data to be normally distributed as
biting midge and mosquito populations exhibit both spatial and temporal variability
(Shivas 2001). Factors such as wind direction and speed, humidity, topography,
harborage and emergence patterns all contribute to patchy distribution. Accordingly, we
utilized the Henderson & Tilton (1955) formula to calculate weekly % reduction for
fluctuating test populations:

\[
\text{% control} = 100 \times \left[ 1 - \frac{Ta \times Cb}{Tb \times Ca} \right]
\]

Where:
- \(Ta\) = population in treatment post-treatment
- \(Tb\) = population in treatment pre-treatment
- \(Ca\) = population in control post-treatment
- \(Cb\) = population in control pre-treatment
Results

The field evaluation from late October to mid December was conducted in warm, humid, calm conditions (Table 2).

Table 2. Mean ± SD 24 hour environmental conditions during field evaluation.

<table>
<thead>
<tr>
<th>Temperature °C.</th>
<th>% Relative Humidity</th>
<th>Wind Speed km/hr</th>
<th>Wind Direction (Degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 ± 3</td>
<td>78 ± 17</td>
<td>7 ± 3</td>
<td>118 ± 66</td>
</tr>
</tbody>
</table>

In the pre-treatment evaluation of trapping efficiency, baited light traps caught significantly ($P<0.01$) higher biting midge and mosquito numbers (Plate 3). On the night prior to treatment, there was no statistically significant difference in the numbers of biting midges ($P<0.43$) or mosquitoes ($P<0.51$) collected from properties identified for treatment or untreated controls (Table 3).

Table 3. 12-hour pre-treatment biting midge and mosquito numbers on properties selected for evaluation of Bistar 80SC efficacy.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std Dev</th>
<th>t</th>
<th>Df</th>
<th>95%CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biting Midge</td>
<td>4</td>
<td>51</td>
<td>81</td>
<td>0.84</td>
<td>6</td>
<td>-65 to 134</td>
<td>0.43</td>
</tr>
<tr>
<td>Control  Biting Midge</td>
<td>4</td>
<td>17</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mosquitoes</td>
<td>4</td>
<td>56</td>
<td>38</td>
<td>0.70</td>
<td>6</td>
<td>-408 to 227</td>
<td>0.51</td>
</tr>
<tr>
<td>Control  Mosquitoes</td>
<td>4</td>
<td>147</td>
<td>257</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In contrast, over the six week post-treatment period, a statistically highly significant difference in the median numbers of biting midges ($P<0.02$) and mosquitoes ($P<0.01$) collected from treated and control properties was recorded (Table 4). In contrast to an average of 441 biting midges and 25 mosquitoes collected from treated properties, 2,989 biting midges and 169 mosquitoes were collected from untreated control properties (Table 5). In terms of species composition, 78% of the collected mosquitoes species were the saltmarsh Oc. vigilax, with C. ornatus and C. subimmaculatus representing 81% and 19% of the collected biting midge species, respectively.
Table 4. Mann-Whitney Rank Sum analysis for six weeks biting midge and mosquito field data.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Median Number</th>
<th>25%</th>
<th>75%</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biting Midge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatments</td>
<td>54</td>
<td>276</td>
<td>66</td>
<td>682</td>
<td>2652</td>
<td>&lt;0.02</td>
</tr>
<tr>
<td>Controls</td>
<td>54</td>
<td>425</td>
<td>122</td>
<td>1856</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mosquitoes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatments</td>
<td>54</td>
<td>8</td>
<td>4</td>
<td>34</td>
<td>1802</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Controls</td>
<td>54</td>
<td>106</td>
<td>46</td>
<td>210</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Descriptive Statistics for 6 weeks field Data.

<table>
<thead>
<tr>
<th></th>
<th>Skewness</th>
<th>Range</th>
<th>Max</th>
<th>Min</th>
<th>Median</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biting Midge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>1.46</td>
<td>2,011</td>
<td>2,012</td>
<td>1</td>
<td>276</td>
<td>441</td>
</tr>
<tr>
<td>Control</td>
<td>2.21</td>
<td>21,914</td>
<td>21,948</td>
<td>34</td>
<td>425</td>
<td>2,989</td>
</tr>
<tr>
<td>Mosquitoes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>2.50</td>
<td>186</td>
<td>186</td>
<td>0</td>
<td>8</td>
<td>25</td>
</tr>
<tr>
<td>Control</td>
<td>2.40</td>
<td>875</td>
<td>879</td>
<td>4</td>
<td>106</td>
<td>169</td>
</tr>
</tbody>
</table>

In terms of % reduction over time, biting midge numbers were reduced by 97% to 75% in the first month, with a 65% mean reduction over the 6 week study period (Fig. 1). Mosquito numbers were reduced by 99% to 94% in the first month, with a 94% mean reduction over the 6 week study period. Rainfall events were recorded in the first, third, fifth and sixth weeks of the study (Hervey Bay Airport Meteorological Data) (Fig. 1).
**Discussion**

The authors are unaware of any other study which details effective, sustained reduction in adult biting midge numbers. The successful Bistar 80SC application was achieved during periods of peak biting midge and saltmarsh mosquito emergence, and despite rainfall events on six occasions. In doing so, the method meets Shivas (2001) recommendation for biting midge control, in that a sustained, effective method is required, and one that provides household protection is a priority. The peri-domestic applications also satisfied the EPA and Fisheries concerns, as they provide a safe alternative to broadscale application of organophosphates to sensitive estuarine habitats, at rates that would be ecologically disastrous. Also, in terms of comfort to the Local Government personnel.
applying the product, and the residents of treated properties, the bifenthrin molecules non-alpha-cyano characteristics were appreciated. No skin or eye irritation characteristics occurred, and as expected with a bifenthrin SC formulation, no staining of peoples properties or phyto-toxic effects were recorded.

This study also highlights the fact that harborage treatments are suitable for integration with existing Local Government vector control programs. Mosquito arbovirus vectors such as *Oc. vigilax* and *Culex annulirostris* Skuse have the ability to disperse over great distances (Johansen et al. 2001). This makes thorough treatment of the numerous and often unidentified larval habitats expensive, problematic, and often impossible. Effective vector control programs are required, as arboviruses such as dengue in north Queensland, and West Nile in the USA are increasing in prevalence.

In refining this method, accurate laboratory determination of the Bistar 80SC concentration-mortality relationship for major biting midge and mosquito species of public health importance is essential. The incorporation of a discriminating dose test (2x LC$_{95}$) in routine monitoring programs will aid early detection of developing bifenthrin tolerance if it occurs. Future research efforts should also be dedicated towards determination of the longevity of control effected by Bistar 80SC applications on various resting surfaces. Surfaces such as treated and untreated wood, bricks, and waxy leaf surfaces would all retain bifenthrin at differing concentrations over time. Re-treatment strategies could vary depending on the predominant harborage or resting surface present in a given domestic situation. Accordingly, the authors recommend that a resistance management strategy be developed to safeguard the longevity of this valuable formulation. Bistar 80SC is one of the few effective options we have available for control of these adult insects of major public health significance.

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