

Appendix H

Biting Insects

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**Northern
Territory
Government**

Department of Health
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Biting Insect Assessment Andranangoo Creek West & Lethbridge Bay West Mining Prospects, Tiwi Islands.

**Supplementary Trapping November 2005, January and May
2006.**

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**Allan Warchot and Peter Whelan
Medical Entomology Branch
Department of Health and Community Services**

For further information contact:

Medical Entomology Branch
Centre for Disease Control
Department of Health and Community Services
PO Box 40596
Casuarina NT 0811

Telephone: 08 8922 8901
Fax: 08 8922 8820
email: medicalentomologyrdh@nt.gov.au

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1.0 Background

A biting insect assessment was conducted at the Andranangoo Creek West and Lethbridge Bay West mining prospects from the 29th September to the 1st of October 2005. This included detailed ground surveys for actual and potential mosquito breeding sites, assessment of aerial photography for potential mosquito and biting midge breeding sites, and initial adult biting insect trapping at both mining prospects.

The report 'Biting Insect Assessment Andranangoo Creek West & Lethbridge Bay West Mining Prospects, Tiwi Islands (Warchot & Whelan 2005)' was produced early upon request by the Environmental Consultants URS Australia Pty Ltd, to allow information from the biting insect investigation to be available for reproduction in the Environmental Impact Statement for this mining project. The detailed report highlighted the findings of the initial assessment, with conclusions and recommendations provided based on the findings (Warchot & Whelan 2005). The early report production meant that information from subsequent peak season adult biting insect trapping in November 2005, and January and May 2006 had to be produced in a separate supplementary report. Therefore some conclusions in the first report were drawn based on field inspections and desktop observations, and not on trap data. The following report highlights the findings of the supplementary trapping, with new conclusions in regards to mosquitoes and biting midges. Trapping conducted for the Andranangoo Creek West and Lethbridge Bay West Biting Insect Assessment Report (Warchot & Whelan 2005) is referred to as 'initial trapping' in this supplementary report.

2.0 Methods

Methods for the initial investigation are provided in the initial biting insect assessment report (Warchot & Whelan 2006). Adult biting insect traps for the supplementary trapping were set by Dennis McCamish from Matilda Minerals Ltd on the afternoons one night before the full moon on the nights of November 1st 2005, January 13th 2006 and May 12th 2006, and collected the following mornings. During the supplementary trapping in November 2005 and January and May 2006, two traps were set at each mining prospect, at traps sites utilised during the 29th September to 1st October 2005 initial trapping. The trap sites chosen were:

Trap Site 1 – Andranangoo Creek West. North edge of Andranangoo Creek West reed swamp, adjacent to NW arm of swamp.

Trap Site 3 – Andranangoo Creek West. Approximately 50m north of construction camp, in Eucalypt woodland.

Trap Site 5 – Lethbridge Bay West. In Paperbark forest northwest edge of proposed mining area, adjacent to northwest edge of extensive mudflat.

Trap Site 7 – Lethbridge Bay West. In Eucalypt open woodland near proposed construction camp.

Only two trap sites from each mining prospect were utilised during the supplementary trapping, instead of the four trap sites that were utilised at each prospect during the initial trapping in late September/early October 2005. This was due to logistical reasons, as the travel time by road between the Andranangoo Creek West and Lethbridge Bay West mining prospects meant that only two traps could effectively be set at each mining prospect on any one night. Therefore the trap sites chosen were those that would best reflect potential biting insect problems in the mining prospects, with one trap set adjacent to the largest potential mosquito breeding sites at each mining prospect, and one trap set adjacent to the construction camp sites at each mining prospect.

Traps were set one night before the full moon in an effort to locate peak monthly abundance of pest biting midge species and monthly mosquito activity.

Dry ice for the biting insect traps was dropped off by MEB to Direct Air at Darwin International Airport in a foam esky, which was then transported to Melville Island via light aircraft. The ice was collected from an airstrip on Melville Island by Dennis McCamish. After collection, trap containers were transported inside an esky to an airstrip for transport back to Darwin, and the esky was placed inside a freezer at Direct Air until collection by MEB. Traps were then processed at the MEB laboratory in Darwin (refer to the Andranangoo Creek West and Lethbridge Bay West Biting Insect Assessment Report for further details).

3.0 Results

3.1 Supplementary biting midge trapping

3.1.1 Species present

Trap locations are shown in Figure 1, with results shown in Tables 1-4. A total of 2,996 female biting midges were collected during trapping in November 2005, and January and May 2006, representing 12 different species (Table 4). The most abundant species was *Culicoides ornatus*, accounting for 41.4% of all biting midges trapped, followed by *Culicoides bundyensis* (22.4%), *Culicoides narrabeenensis* (9.6%), *Culicoides marksi* (6.8%), *Culicoides* undescribed sp. No. 6 (6.1%), and *Culicoides austropalpalis* (6%). Other biting midge species were recorded in very low numbers.

3.1.2 Spatial abundance (Table 4)

Trap Site 7 recorded the most biting midges during the trapping, accounting for 45% of all biting midges trapped, followed by Trap Site 1 (39.6%), Trap Site 5 (11.7%) and Trap Site 3 (3.7%).

Culicoides ornatus was most abundant at Trap Site 1, with a total of 803 females collected during trapping at this site. This was followed by Trap Site 7 (213), Trap Site 5 (109) and Trap Site 3 (16).

Culicoides marksi, *Culicoides* undescribed sp. No. 6, *Culicoides bundyensis*, *Culicoides austropalpalis* and *Culicoides narrabeenensis* were most abundant at Trap Site 7, with minor numbers at the other trap sites.

3.1.3 Seasonal abundance (Tables 1-3)

The May 2006 trap results revealed significantly higher overall biting midge numbers compared to November 2005 and January 2006. *Culicoides ornatus*, *Culicoides marksi*, *Culicoides* undescribed species No. 6, *Culicoides*, *Culicoides austropalpalis*, *Culicoides narrabeenensis* and *Lasiohelia* sp. were all recorded in highest numbers in May 2006. Very low numbers of biting midges were recorded in November and January (Tables 1 & 2).

3.2 Supplementary mosquito trapping

Trap locations are shown in Figure 1. Results are shown in Tables 5-8.

3.2.1 Species present

November 2005 (Table 5)

The November trap results revealed extreme numbers of *Aedes vigilax* at Trap Site 1 (1952 females), with high numbers at Trap Site 5 (807) and Trap Site 7 (634), and minimal numbers at Trap Site 3 (13). *Aedes vigilax* accounted for 85% of all mosquitoes trapped during November. The next most abundant species in November was *Anopheles hilli*, with a high of 122 females collected at Trap Site 1, with low numbers collected at Trap Site 5 (54) and minimal numbers collected at Trap Sites 7 (30) and Trap Site 3 (1), which accounted for 5% of all mosquitoes trapped during November.

Culex sitiens was the third most abundant species during November, accounting for 3% of all mosquitoes trapped, with highest numbers at Trap Site 1 (56), followed by Trap Site 5 (51) and Trap Site 7 (16), with nil recorded at Trap Site 3. *Culex annulirostris* was the fourth most abundant species, accounting for 2.6% of all mosquitoes trapped during November, with highest numbers recorded at Trap Site 1 (44), followed by Trap Site 5 (39), Trap Site 7 (20) and Trap Site 3 (2). This was followed by *Anopheles farauti* s.l., which accounted for 1.6% of all mosquitoes trapped during November. Highest numbers of *An. farauti* s.l. were recorded at Trap Site 5 (30), followed by Trap Site 1 (22) and Trap Site 7 (13).

January 2006 (Table 6)

The most abundant mosquito species trapped during the January trapping was *Aedes vigilax*, accounting for 85% of all mosquitoes trapped. Highest numbers of this species was recorded at Trap Site 5 (795), followed by Trap Site 7 (499), Trap Site 1 (331) and Trap Site 3 (275). The next most abundant species was *Anopheles farauti* s.l., which accounted for 7% of all mosquitoes trapped during January, with highest numbers recorded at Trap Site 1 (68), followed by Trap Site 7 (52), Trap Site 5 (25) and Trap Site 3 (10). *Culex annulirostris* and *Culex sitiens* were the next most abundant species, accounting for 2.9% and 2% respectively of all mosquitoes trapped during January.

May 2006 (Table 7)

The most abundant mosquito species trapped during May was *Mansonia uniformis*, which accounted for 37.3% of all mosquitoes trapped. This was mainly due to very high numbers recorded at Trap Site 1 (1381), with minor numbers recorded at Trap Site 3 (59), Trap Site 7 (12) and Trap Site 5 (10). The next most abundant species was *Anopheles farauti* s.l., which accounted for 36.8% of all mosquito species trapped, with highest numbers at Trap site 1 (1273), followed by Trap Site 7 (82), Trap Site 5 (66) and Trap Site 3 (22).

Culex annulirostris was the third most abundant species, accounting for 6.3% of all mosquitoes trapped during May, with highest numbers at Trap Site 7 (164), followed by Trap Site 1 (54), Trap Site 5 (26) and Trap Site 3 (5). *Coquillettidia xanthogaster* was the next most abundant species, accounting for 6.2% of all mosquitoes trapped during May, with highest numbers at Trap Site 7 (120), followed by Trap site 3 (52), Trap Site 1 (43) and Trap Site 5 (28). This was followed by *Anopheles bancroftii*, which accounted for 5.7% of all mosquito species trapped, with highest numbers at Trap Site 1 (151), followed by Trap Site 7 (41) and Trap Site 5 (33). Other mosquito species were recorded in relatively low numbers.

3.2.2 Spatial abundance (Table 8)

Trap Site 1, located adjacent to the large reed swamp associated with Andranangoo Creek, recorded significantly more mosquitoes compared to the other trap sites, recording 57% of all mosquitoes trapped. The next most productive trap site was Trap Site 5, recording 20% of all mosquitoes trapped, followed by Trap Site 7 (18%) and Trap Site 3 (5%).

Aedes vigilax was recorded in very high overall numbers at Trap Site 1, although high overall numbers were also recorded at Trap Sites 5 & 7, with moderate numbers at Trap Site 3. *Anopheles farauti* s.l. and *Mansonia uniformis* were both recorded in very high overall numbers at Trap Site 1, with relatively low numbers at the other trap sites. *Anopheles bancroftii* was recorded in highest numbers at Trap Site 1, with minor numbers at the other trap sites, *Cq. xanthogaster* was recorded in highest numbers at Trap Site 7, with minor numbers at the other trap sites, *Cx. sitiens* was recorded in highest numbers at Trap Sites 1 & 5, with very low numbers at the other trap sites. *Anopheles hilli* was recorded in highest numbers at Trap Site 1, with minor numbers at the other trap sites, *Cx. annulirostris* was recorded in highest numbers at Trap Sites 7 & 1, with minor numbers at the other trap sites, and *Verrallina funerea* was recorded in highest numbers at Trap Site 1, with very low numbers at Trap Site 5.

3.2.3 Seasonal abundance (Tables 5-8)

Aedes vigilax was most abundant in November, with a total of 3,406 females collected at the four trap sites (Table 5). This was followed by January, with 1,900 females collected at the four trap sites, and May, with 39 females collected at the four trap sites (Tables 6 & 5 respectively).

Anopheles farauti s.l. was most abundant in May, with a total of 1,443 females collected at the four trap sites (Table 7). This was followed by January, with 155 females collected at the four trap sites (Table 6). Lowest numbers of this species were recorded in November, with a total of 65 females collected at the four trap sites (Table 5).

Mansonia uniformis was most abundant in May, with a total of 1,462 females collected at the four trap sites. This species was virtually absent during January, with only 3 females collected at the four trap sites (Table 6), and was virtually absent in November, with only 1 female collected at the four trap sites (Table 5).

Other important mosquito species were recorded in relatively low numbers, although still showed seasonal variation. *Culex annulirostris* was most abundant in May, *Anopheles bancroftii* was only recorded in May, *Anopheles hilli* was most abundant in November, *Culex sitiens* was most abundant in November, and *Ve. funerea* was most abundant in January.

4.0 Discussion

4.1 Biting midges

4.1.1 Species present

There were three biting midge species collected that were of potential pest significance, *Culicoides ornatus*, *Culicoides marksi* and *Lasiohelia* sp. These species were also collected during initial trapping (Warchot & Whelan 2005). *Culicoides ornatus* was the most important pest biting midge species trapped at the Andranangoo Creek West and Lethbridge Bay West prospects, as *C. ornatus* is a widespread species that has caused major problems throughout coastal areas of northern Australia and along the east coast of Queensland (Shivas and Whelan 2001). *Culicoides marksi* and *Lasiohelia* sp. are also known human biters but have not been implicated as serious pest species in the Northern Territory. For further information on common biting midge species in the NT, please refer to Appendix 1.

4.1.2 Probable breeding sites

Probable breeding sites for *C. ornatus*, *C. marksi* and *Lasiohelia* sp. were described in detail in the initial Biting Insect Assessment report for this mining project. Based on the November 2005, and January and May 2006 trap results, the most important *C. ornatus* breeding site affecting the Andranangoo Creek West prospect will most likely be the upper reaches of small tidal tributaries in Andranangoo Creek (Figure 1), with the upper tidal reaches of the small creek to the west of the Andranangoo Creek West prospect also likely to contain breeding sites for this species. The most important *C. ornatus* breeding site affecting the Lethbridge Bay West prospect is likely to be the upper reaches of the small tidal creek to the east of the prospect area (Figure 2).

Culicoides marksi was almost solely recorded at Trap Site 7 in May 2006, which was located at the proposed construction camp site at the Lethbridge Bay West prospect area. This species breeds at the edges of freshwater lakes and streams. The adjacent large brackish swamp, in the upper reaches where seasonal stream flows occur, was the most likely source of this species. Initial trapping results revealed moderate numbers at Trap Site 3, indicating the Andranangoo Creek reed swamp to the east of the Andranangoo Creek West prospect area is also a potential breeding site for this species.

Lasiohelia sp. was recorded in very low numbers at all sites, indicating minor breeding sites for this species existed nearby to all trap sites. The breeding sites for most Australian *Lasiohelia* sp. are unknown, although some species are thought to breed in damp, surface-terrestrial environments, which can include patches of tropical rainforest, and general vegetation ranging from wet-sclerophyll forest to open grassland (Debenham 1983). *Lasiohelia* larvae have previously been collected on habitats such as mosses, algae on rocks, soil and wet wood (Debenham 1983). In the NT, *Lasiohelia* sp. have been recorded from monsoon vine forests (Whelan et al 1997c). The development site contains areas of monsoon vine forest, which probably contain small breeding sites for some *Lasiohelia* species.

4.1.3 Spatial abundance and dispersal

Culicoides ornatus was recorded in moderate numbers at Trap Site 1, which was located approximately 1km from the nearest areas of significant mangroves associated with Andranangoo Creek (Figure 1). *Culicoides ornatus* are found in highest numbers from 1 to 1.5km from the mangrove margin, with high numbers up to 2km inland from the mangrove margin and dispersal up to 3.5km from the mangrove margin (Shivas and Whelan 2001). Trap Site 3 recorded very low numbers of *C. ornatus*, which reflected the distance of this trap site from the nearest mangrove margin, located approximately 3km to the east and west of this trap site (Figure 1). The trap results revealed that the highest numbers of *C. ornatus* at the Andranangoo Creek West prospect would occur within 1.5km of the mangrove margin, with elevated numbers up to 2km from the mangrove margin.

Trap Site 7, at the Lethbridge Bay West prospect, recorded low numbers of *C. ornatus* during the trapping, with minor numbers recorded at Trap Site 5. The source of this species to Trap Site 7 was most likely the upper tidal reaches of the small mangrove creek located approximately 1.5km to the east of the trap site. The source of this species to Trap Site 5 could have been the same upper tidal reaches of the small tidal creek, located approximately 2.5km to the east of the trap site, with minor breeding sites potentially associated with the mangrove areas at the mouth of the large swamp. The trap results revealed that this species is likely to be present throughout the Lethbridge Bay West mining prospect.

Culicoides marksii was mainly recorded at Trap Site 7 during the supplementary trapping, although this species was recorded in moderate numbers at Trap Site 3 during initial trapping. Little information is known about the dispersal characteristics of this species, although initial trapping at the Andranangoo Creek West prospect area indicates *C. marksii* can disperse at least 1km from their breeding sites. Therefore it can be expected that this species will be most common within at least 1km of the large swamps at both prospects.

Lasiohelia sp. was only recorded in very low numbers at all trap sites. Little information is known about the spatial abundance and dispersal characteristics of *Lasiohelia* species in Australia, although Reye (1992) states that the pest range of *Lasiohelia townsvillensis* appears to be around 50 metres unless the breeding area is large and productive, so it is possible that *Lasiohelia* sp. at both prospects will be most abundant within 50m of their breeding sites.

4.1.4 Seasonal abundance

Peak season *Culicoides ornatus* abundance generally occurs in the months of August to November (Shivas & Whelan 2001). A smaller peak in abundance also occurs in the early dry season (April and May) (Shivas & Whelan 2001). Lowest numbers are usually encountered in the wet season and mid dry season, due to lower landward dispersal (Shivas & Whelan 2001). In some areas of Darwin Harbour, two peaks in *C. ornatus* numbers occur over a 4 day period during the full and new moons, the first peak resulting from females leaving the mangrove foreshore (*Sonneratia*) breeding sites, and the second peak occurring four days later resulting from females leaving the upper tidal creek breeding sites (Shivas and Whelan 2001). The presence of two waves of dispersing females results in heightened midge levels for at least 6 days in each fortnight (Shivas and Whelan 2001).

The supplementary trap results revealed highest numbers of *C. ornatus* in May, with very low numbers in November and January. The low numbers collected in January was expected, due to lower emergence of *C. ornatus* during the wet season (Shivas 1999).

The low numbers in the month of November were unusual as it was expected that November would record the highest numbers of *C. ornatus* compared to January and May. There was high rainfall in the Darwin area in the week before the trapping, therefore it is possible that high rainfall was also experienced near the proposed mine sites, which may have affected breeding sites and resulted in the low abundance. Shivas (1999) noted that surface sheet flow caused by the first heavy downpours of the wet season was observed to wash away the upper couple of centimetres of mud from an upper tidal creek breeding site, resulting in a loss of *C. ornatus* larval habitat and thus lowering the level of adult emergence.

The reason for the low numbers of *C. ornatus* in November as compared to the highest numbers in May could also have been a result of the timing of trapping. Numbers of this species can vary significantly from one day to another in areas inland of the mangrove margin during the peak fortnightly abundance period (Shivas & Whelan 2001). Peak *C. ornatus* dispersal occurs one day before the full moon in the warmer months (Shivas & Whelan 2001), although it is possible that trapping one day before the full moon missed the dispersal peak for *C. ornatus* in November, as the traps at both prospects were set inland of the mangrove margin. It is possible that the trapping in May was conducted at the time of peak fortnightly abundance, explaining the higher numbers. Alternatively

various unknown environmental factors may have played some kind of role in the low abundance of *C. ornatus* during the November trapping.

However, the May trap results did show that *C. ornatus* will be seasonally present in low numbers at the Lethbridge Bay West Prospect, and in moderate to high numbers at the Andranangoo Creek West Prospect during the late wet season/early dry season. This species is expected to be present in high numbers during the peak season August to November period at the Andranangoo Creek West prospect, and in moderate numbers at the Lethbridge Bay West prospect in these months. Wet season abundance is likely to be relatively low, with lower numbers also expected in the cooler mid dry season months (June/July), as little landward dispersal occurs during these periods of the year (Shivas & Whelan 2001).

Wet season *C. ornatus* abundance is lower than dry season abundance, as breeding from the high productivity creek bank habitat shifts to the less productive *Ceriops* transition zone at the back edge of the creek bank forest, and breeding in the medium productivity *Sonneratia* foreshore areas shifts to the adjacent less productive *Rhizophora* zone (Shivas 1999). Combined with the effects of rainfall on upper tidal tributary breeding sites, this helps to explain the low numbers collected during the January 2006 trapping.

Culicoides marksii has been described by Whelan (1998) as being most abundant in the early wet and post wet to mid dry seasons, with low populations in the late dry season. The supplementary trapping located this species in May, with initial trapping also locating this species in late September/early October, indicating *C. marksii* is likely to follow the usual seasonal trend in abundance at both mining prospects.

Lasiohelia sp. was most abundant from January to March inclusive during the baseline trapping program at Wickham Point (Warchot and Whelan 2004), and were most abundant from January to May inclusive during the baseline trapping program at Durack (Fairway Waters) (Whelan et al 1998). This indicates that *Lasiohelia* sp. in the Darwin region generally occur in the mid to late wet season and early dry season. Supplementary trapping revealed highest numbers in May, with minimal numbers in January. Based on the supplementary trap results, and the initial trap results, it appears that *Lasiohelia* sp. will be most abundant during January to May.

4.1.5 Pest problems and public health

The supplementary trap results revealed that *C. ornatus* is the only biting midge species expected to cause a pest problem at both mining prospects, with the levels recorded at Trap Site 1 in May high enough to cause a moderate-high pest problem to exposed people in the 2 hours either side of sunset and sunrise. The levels recorded at Trap Site 7 in May were high enough to cause a nuisance/low pest problem, and the levels recorded at Trap Site 5 may represent a minor nuisance problem to some people. The very low numbers of *C. ornatus* at Trap Site 3 indicates pest problems are unlikely at that area, due to the distance from the mangroves.

Based on general information on the seasonal abundance of *C. ornatus*, highest pest problems can be expected in the months of August to November at both prospect sites, with greatest pest problems within 1.5km of the mangrove margin, and pest problems likely to be encountered up to 2km from the mangrove margin at both mining prospects. Pest problems will be greatest during a 3-4 day period around the full and new moons, with full moon problems generally twice as large as new moon problems (Shivas & Whelan 2001). High pest problems are expected in the Andranangoo Creek West prospect during these months, while moderate pest problems are likely to be experienced in the Lethbridge Bay West prospect in these months.

Moderate to high pest problems are also likely to be encountered in the late wet/early dry season (April-May) at the Andranangoo Creek West prospect, with low pest problems likely to be experienced at the Lethbridge Bay West prospect in these months. Other periods of the year should have relatively low levels of *C. ornatus*, which should not pose any serious pest problems.

Culicoides marksi was only recorded in low numbers during the supplementary trapping at Trap Site 7 in Lethbridge Bay West, although this species was recorded in moderate numbers at the Andranangoo Creek West construction camp during initial trapping. As this species is not considered a serious human pest midge, at most, it is only expected to cause minor nuisance problems at both development sites within 1km of the adjacent large swamps.

The trap results revealed *Lasiohelius* sp. is not expected to cause any pest problems at the development site, although as limited information is available on this genus of biting midges, it is possible that *Lasiohelius* sp. were present at the mining prospects in higher number than what was recorded during trapping. *Lasiohelius* sp. has not been implicated as the cause of any public biting insect complaints in the Darwin Region.

4.1.6 Limitations

The supplementary biting midge trap results highlighted the deficiencies with conducting trapping for biting midges on only one night around the full moon. As *C. ornatus* abundance varies greatly from day to day during peak fortnightly abundance period, trapping on only one of these days during the peak period can lead to an underestimate of peak populations, which appears to have happened for the peak season biting midge trapping during November 2005. Trapping over a 3-4 day period around the full moon would be the best method of sampling peak monthly *C. ornatus* abundance. Monthly trapping for 12-months would also have provided a better indication of seasonal *C. ornatus* abundance.

Trapping once a month for 12-months would have also provided a better indication of the seasonal abundance other biting midges species at both mining prospects.

4.2 Mosquitoes

4.2.1 Species present

A total of 31 species of mosquitoes were recorded during supplementary trapping in November 2005 and January and May 2006, representing a total of 10,141 adult female mosquitoes. All of the common pest and disease vector mosquitoes in the Top End of the NT were recorded during trapping. For further information on the mosquito species mentioned in this report, please refer to Appendix 2 and the initial Biting Insect Assessment Report for the Andranangoo Creek West and Lethbridge Bay West mining prospect. The important mosquito species collected are discussed below.

4.2.2 Probable breeding sites

Potential breeding sites for the salt marsh mosquito *Aedes vigilax*, the common banded mosquito *Culex annulirostris*, the North Australian malaria mosquito *Anopheles farauti* s.l., the golden mosquito *Coquillettidia xanthogaster*, the black malaria mosquito *Anopheles bancroftii*, the saltwater mosquito *Culex sitiens*, the waterlily mosquito *Mansonia uniformis* and the brackish water mosquito *Verrallina funerea* at both mining prospects have been described in the initial Biting Insect Assessment Report for the Andranangoo Creek West and Lethbridge Bay West mining prospects, please refer to this report for further details.

The floodwater mosquito *Aedes normanensis* was another potentially important mosquito species collected during supplementary trapping. This species was collected in very low numbers at Trap Sites 3 and 5. The main breeding sites for this species are poorly draining floodways associated with creeks and rivers, with highest numbers occurring in inland areas. This species only occurs in very low numbers in the Darwin urban area each wet season, reflecting a lack of suitable breeding sites near coastal areas. Very small breeding sites for this species may be present in the poorly draining flowlines in the dune areas at both mining prospects (Figure 1).

The receptacle mosquito *Aedes notoscriptus* was recorded as a single specimen at Trap Site 5. Natural breeding sites for this species are tree holes, although this species will breed in artificial receptacles such as used tyres, drums, pot plant drip trays, bird baths, discarded bottles etc.

The saltwater *Anopheles* species *Anopheles hilli* was recorded in low numbers at both prospects. Probable breeding sites at both prospects will be the tidal/brackish water areas of the large swamps adjacent to both prospects, particularly where *Schoenoplectus* reeds occur.

4.2.3 Spatial abundance and dispersal

Aedes vigilax

Trap Site 1, adjacent to the Andranangoo Creek West reed swamp, recorded significantly more *Ae. vigilax* than the other three trap sites. Trap Site 3, at the Andranangoo Creek West construction camp, recorded the lowest overall numbers during the supplementary trapping. The low numbers at the construction camp site compared to the other trap sites may have been due to lights/human activity providing a more attractive source for *Ae. vigilax*, even though the trap was located approximately 50m north of the construction camp site.

Both trap sites at Lethbridge Bay West recorded very high overall numbers of *Ae. vigilax*, with Trap Site 5 being moderately more productive, most likely due to the trap site being located closer to the upper reaches of the adjacent swamp, which is likely to be the most productive area of *Ae. vigilax* breeding as it appears to be vegetated with suitable reed and grass habitats (Figure 1).

Aedes vigilax can disperse in pest numbers up to 50km from extensive breeding sites (Whelan 1997a). Due to the dispersal characteristics of this species and the close distance of both mining prospects to extensive breeding sites, *Ae. vigilax* will be present in very high numbers throughout all areas of both mining prospects. Initial trapping also recorded this species in high numbers at the Andranangoo Creek West and Lethbridge Bay West prospects (Warchot & Whelan 2005).

Culex annulirostris

Culex annulirostris was recorded in highest numbers at Trap Site 7 and Trap Site 1, with relatively low numbers at Trap Sites 3 & 5. Trap Sites 7 & 1 were located closer to potential breeding sites, which explains the higher numbers (Figure 1). With a dispersal range of up to 10km in pest numbers from extensive breeding sites, with highest numbers within 3km of breeding sites (Whelan 1997a), this species can be expected to be widespread throughout both mining prospects.

Anopheles farauti s.l.

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.

Anopheles farauti s.l. was recorded in by far the highest numbers at Trap Site 1, adjacent to the Andranangoo Creek West reed swamp, indicating the presence of significant breeding sites for *An. farauti s.l.* Low numbers of this species were recorded at both Trap Sites at Lethbridge Bay West, indicating the adjacent swamp does not contain the extensive breeding sites that are present in the Andranangoo Creek West reed swamp, but still contains significant breeding sites for this species.

The species in the *An. farauti s.l.* complex are generally most common up to 1.5km from their breeding sites, therefore the portion of the Andranangoo Creek West prospect within 1.5km of the swamp is

likely to experience the greatest numbers of *An. farauti s.l.*, with low numbers up to 2km from the swamp. Most areas of the Lethbridge Bay West mining prospect are likely to experience low numbers of *An. farauti s.l.*

Coquillettidia xanthogaster

This species was recorded in minor numbers at Trap Sites 1, 3 & 5, and low numbers at Trap Site 7. This species disperses widely from breeding sites, generally up to 3-5km, so is likely to be present throughout both mining prospects.

Mansonia uniformis

A very large peak in overall numbers was recorded at Trap Site 1, with minimal overall numbers at the other trap sites, indicating the presence of extensive breeding sites in the Andranangoo Creek West swamp, and minimal breeding sites in the Lethbridge Bay West swamp. This species has a limited flight range, and is generally most abundant within 1-2km of breeding sites, indicating the areas of the Andranangoo Creek West mining prospect within 2km of the reed swamp will contain the highest numbers of this species. The apparent absence of extensive *Ma. uniformis* breeding sites at the Lethbridge Bay West swamp indicates that most areas of this prospect is likely to only experience minor numbers of this species.

Anopheles bancroftii

This species was recorded in low overall numbers at Trap Site 1, with minor overall numbers at Trap Sites 5 & 7. This species was not recorded at Trap Site 3 during supplementary trapping. *Anopheles bancroftii* generally disperses up to 3km in pest numbers from their breeding sites (Whelan 1997a), therefore is likely to be encountered in low numbers throughout both prospects.

Verrallina funerea

This species was most abundant at Trap Site 1 in November 2005, with very low numbers recorded at Trap Site 5 during the same month, and very low numbers recorded at Trap Sites 1 & 5 in January 2006. This species is most common within 500m of breeding sites (Whelan 1997a), which indicates breeding sites exist for this species in the Andranangoo Creek West reed swamp and Lethbridge Bay West swamp, due to the presence of this species in early November 2005. This species is also likely to be present adjacent to any coastal depressions that flood at both mining prospects during the wet season.

Culex sitiens

This species was recorded in minor numbers during supplementary trapping, with Trap Sites 1 & 5 being the most productive. This species is generally most common within 2km of breeding sites (Whelan 1997a), therefore will be most abundant at both mining prospects within 2km of the tidal reaches of the adjacent swamps.

Anopheles hilli

This species was recorded in low numbers at Trap Site 1, and in minor numbers at Trap Sites 5 & 7. This species is most common within 4km of breeding sites (Whelan 1997a), therefore is likely to be present throughout both prospects.

Aedes normanensis

This species was recorded in very low numbers at Trap Sites 3 & 5. This species is generally only encountered in significant numbers in inland areas, therefore it is not expected that this species will be present in any significant numbers at both mining prospects.

Aedes notoscriptus

Only a single specimen was recorded at Trap Site 5 during the supplementary trapping. This species can reach low levels in areas with an abundance of artificial receptacles.

4.2.4 Seasonal abundance

Aedes vigilax

The supplementary trapping, and initial trapping at both mining prospects, revealed *Ae. vigilax* would follow the usual trend in seasonal abundance of highest numbers in September to January inclusive (Whelan 1997a). High to severe numbers can be expected in the months of September to January inclusive at both mining prospects. Low numbers may also be present at both mining prospects in May if significant late wet season rainfall occurs, which occurred a few weeks before the May 2006 trapping, and low numbers may also be present at both mining prospects in August, in those years when significant high tides occur in August. Moderate to high numbers could also occur in February, if there are extensive interdune areas that flood at both prospects. Elevated numbers will occur for around 1 week in the cooler months, and up to 2 weeks in the high humidity months of November to February inclusive.

Culex annulirostris

In the Top End of the NT, *Culex annulirostris* is most abundant from January to August, with highest numbers occurring during the early to mid dry season months of April to August (Whelan 1997a). The supplementary trapping, and initial trapping at both mining prospects, revealed that *Cx. annulirostris* would be most abundant at both mining prospects during the dry season months of April to late September/early October.

It is highly likely that the initial trapping and supplementary trapping missed peak season abundance of *Cx. annulirostris*. Only minor numbers of this species were recorded during the peak season months of January and May at both prospects, when levels of this species was expected to be higher. Due to the Andranangoo Creek West swamp in particular containing expansive areas of potential breeding habitat for this species, it is likely that this species will be present in high numbers during the April to August peak abundance period at the Andranangoo Creek West prospect. High numbers are also expected at the Lethbridge Bay West prospect during the April to August peak abundance period, as there appears to be significant habitat for this species in the upper reaches of the Lethbridge Bay West swamp (Figure 2). Low to moderate numbers can be expected at both prospects from January to March and September to early October.

Anopheles farauti s.l.

This species occurs in highest numbers in the Top End of the NT from March to June (Whelan 1997a). The supplementary trapping and initial trapping at both mining prospects indicates this species is likely to follow the usual trend in seasonal abundance, as highest numbers were recorded in May. The trapping revealed minor to low numbers of this species are also likely to occur for most other months of the year.

Coquillettidia xanthogaster

This species generally peaks in abundance in the months of March to August. Relatively low numbers were recorded at both mining prospects during supplementary trapping and initial trapping, with highest numbers recorded during initial trapping in late September/early October and second highest numbers in May 2006.

Due to the availability of extensive habitat in the Andranangoo Creek West reed swamp, and probably also in the upper reaches of the Lethbridge Bay West swamp, it is likely that higher numbers than what was recorded during trapping will be present at both mining prospects. Therefore, moderate to high numbers of this species are expected to be present at both prospects during the peak season months of March to August, with low numbers expected to be present in September/early October at both prospects.

Mansonia uniformis

This species is generally present in highest numbers from March to June (Whelan 1997a), although in some years in Darwin a peak in abundance also occurs during the mid wet season months of January or February. The supplementary trapping and initial trapping only recorded this species in any significant numbers in May 2006, with most specimens collected from Trap Site 1, adjacent to the Andranangoo Creek West reed swamp. This species is likely to follow the usual trend in seasonal abundance, with highest numbers at the Andranangoo Creek West prospect likely to occur from March to June. Highest numbers of this species will also occur from March to June at the Lethbridge Bay West prospect, although not in the same magnitude as what will be experienced at the Andranangoo Creek West prospect.

Anopheles bancroftii

This species was recorded in relatively low numbers at the Andranangoo Creek West prospect during supplementary and initial trapping, with highest numbers recorded in September 2005 and May 2006. Very low numbers were recorded at Lethbridge Bay West. Highest numbers of this species generally occurs from February to July (Whelan 1997a), which is when the greatest numbers are expected at the mining prospects, although the initial trap results revealed this species will be present until at least September/early October at the Andranangoo Creek West prospect.

Due to the availability of extensive habitat in the Andranangoo Creek West reed swamp, and probably also in the upper reaches of the Lethbridge Bay West swamp, it is likely that higher numbers than what was recorded during trapping will be present at both mining prospects. Therefore moderate to high numbers of this species are expected to be present at the Andranangoo Creek West prospect during the peak season months of March to August, and low to moderate numbers of this species are expected to be present at the Lethbridge Bay West prospect. Low numbers of this species may be present in September/early October, at least at the Andranangoo Creek West prospect.

Culex sitiens

This species was recorded in highest numbers during the initial trapping in late September/early October. The November 2005 supplementary trapping recorded the second highest numbers of this species. In other coastal areas of the NT, this species is generally most abundant during the late dry season and early wet season, and late wet season (Whelan 1997a). The seasonal abundance of *Cx. sitiens* at both mining prospects is likely to follow this usual trend in peak abundance.

Anopheles hilli

This species is most common during the late wet/early dry season (Whelan 1997a). Highest numbers were recorded in November at both prospects, most likely a result of high tides or early wet season rainfall flooding breeding sites in the large swamps adjacent to both prospects prior to the November trapping. This species is likely to follow the usual trend in abundance as described by Whelan (1997a).

Verrallina funerea

This species is most common from November to March in coastal areas in the NT (Whelan 1997a), when high tides and rainfall flood breeding sites. The seasonal abundance of *Ve. funerea* at both mining prospects is likely to follow this usual trend in peak abundance.

Aedes normanensis

This species was only recorded in very low numbers in May 2006. Highest abundance in other areas of the NT generally occurs in the months of January to April (Whelan 1997a). The presence of this species in May 2006 would have been a result of the heavy late wet season rainfall in mid April. This species will be most abundant at both mining prospects in the months of January to April in most years, and will be present in May in those years with significant late wet season rainfall.

Aedes notoscriptus

This species is most common during the wet season, although can be present in low numbers during the dry season in urban areas. If breeding in artificial receptacles at the construction camp sites is prevented, this species is only likely to be encountered in very low numbers during the wet season at both mining prospects.

4.2.5 Pest problems

The most important pest mosquito trapped at both mining prospects was the salt marsh mosquito *Ae. vigilax*. This species will cause widespread high to severe pest problems at both prospects during the months of September to January inclusive. Moderate to high pest problems may also be encountered at both prospects in February, depending on the availability of interdune breeding sites at both prospects. Pest problems will last up to a week during the cooler months, and up to 2 weeks during the warmer humid months of November to February inclusive. Pest problems will occur in shaded areas during the daytime, and throughout the night. Low pest problems may be encountered in May in those years with late wet season rainfall, and in August in those years when significant high tides occur in this month.

Mansonia uniformis will cause high to very high pest problems at the Andranangoo Creek West prospect within 2km of the reed swamp during the months of March to June inclusive, and possibly in January or February in some years. No significant pest problems are expected to occur from this species at the Lethbridge Bay West prospect. Pest problems will be noticed mainly at night, although this species will bite in shaded areas near their breeding sites during the daytime.

Culex annulirostris is likely to cause moderate to high pest problems at both prospects during the months of April to August, with low to moderate pest problems likely to be experienced in the January to March period and in September/early October. This species bites at night.

Coquillettidia xanthogaster is likely to cause moderate to high pest problems in the March to August peak season period at both prospects, with low pest problems continuing until early October at both prospects. This species mainly bites at night, but will also bite in shaded areas during the daytime nearby to their breeding sites.

Anopheles bancroftii is likely to cause moderate to high pest problems during the peak season March to August period at the Andranangoo Creek West prospect, and low to moderate pest problems at the Lethbridge Bay West prospect in these months. Low pest problems are likely to continue until late September/early October at the Andranangoo Creek West prospect. This species mainly bites at night, but will also bite in shaded areas during the daytime nearby to their breeding sites.

Anopheles farauti s.l. is not as important as a pest mosquito compared to the other species mentioned above, although the very high levels recorded adjacent to the Andranangoo Creek West reed swamp indicates this species will cause at least moderate pest problems from sunset to sunrise at the Andranangoo Creek West prospect within 2km of the adjacent reed swamp, in the months of March to June inclusive, and minor pest problems at the Lethbridge Bay West prospect within 2km of the upper reaches of the adjacent swamp during the same months. No pest problems are expected during other months of the year at both prospects.

Other species trapped are not expected to cause any significant pest problems. *Culex sitiens* may cause low pest problems at night in areas within 2km of the large swamps at both mining prospects, and *An. hilli* may cause low pest problems at night in areas within 4km of the large swamps at both mining prospects. *Verrallina funerea* may cause low pest problems during the daytime in shaded areas nearby to their breeding sites. *Aedes notoscriptus* may cause minor nuisance problems at the construction camps if artificial breeding sites for this species are created. Other mosquito species are not expected to be present in numbers significant to cause any appreciable pest problems.

4.2.6 Public health

Aedes vigilax is a known vector of Ross River virus (RRV) disease and Barmah Forest virus (BFV) disease, and will pose a high risk of virus transmission whenever it is present in significant numbers. The greatest potential for disease transmission from this species will occur during the warmer humid months of November to January inclusive, when the longevity of this species is increased and abundance is high. This species will also pose a significant RRV and BFV risk if present in significant numbers at both prospects in February.

Culex annulirostris will pose a potentially high risk of RRV and BFV transmission at both prospect areas, with December to June being risk months, and December to March being the peak risk months for virus transmission from this species (Whelan 1997b). This species will also pose a potential seasonal risk for Kunjin virus (KUNV) disease and Murray Valley encephalitis virus (MVEV) disease transmission at both prospect areas, with January to July being the risk period for MVEV, with peak risk from February to May, and December to July being the risk period for KUNV transmission, with peak risk months being February to May (Whelan 1997b).

One of the species in the *Anopheles farauti* s.l. complex will pose a potential risk of local malaria transmission, the brackish water species *Anopheles farauti* s.s. The species *An. farauti* s.s 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 vector in some parts of PNG (N. Beebe pers comm.), therefore these species may be potential vectors in Australia. It is possible that *An. farauti* s.s. was the most common species in the *An. farauti* s.l. complex recorded at both mining prospects, in which case there will be a high risk of potential malaria transmission at both mining prospects in the months of March to June, with a low potential risk of malaria transmission likely to occur for most other months of the year. The risk of potential malaria transmission will occur if a person infected overseas with malaria is exposed to mosquito bites from this species at either mining prospect. *Anopheles hilli* and *Anopheles bancroftii* are also potential vectors of malaria, although due to its short life span, *An. bancroftii* is not considered a significant potential vector (Russell 1987).

Culex sitiens will pose a low potential RRV transmission risk when numbers are elevated in November and December, and *Ve. funerea* will pose a low potential RRV and BFV risk when numbers are elevated in November to March. *Aedes normanensis* is a potential vector of RRV, BFV and MVEV, but is unlikely to be present at the mining prospects in numbers high enough to pose a significant risk. *Aedes notoscriptus* is a potential vector of RRV, and will pose a potential virus risk if breeding sites for this species are created in association with the construction camp.

4.2.7 Limitations

It appears that peak season abundance of some important mosquito species, in particular *Cx. annulirostris* and *Cq. xanthogaster*, were missed during the supplementary trapping, as the relatively low numbers of both species was unexpected considering both mining prospects are located adjacent to very large coastal swamps, which were expected to produce high numbers of these mosquito species. Peak season abundance of other mosquito species may also have been missed, however it is likely that peak season *Ae. vigilax*, *An. farauti* s.l. and *Ma. uniformis* were recorded during the trapping.

5.0 Biting insect control and avoidance

5.1 Biting midges

Barrier treatments using the insecticide bifenthrin have been proven successful in controlling adult biting midges in QLD (Standfast et al 2003). The supplementary trap results revealed there may be periods of the year when adult biting midge control is warranted or requested by workers, particularly at the Andranangoo Creek West construction camp. Areas that could be treated with bifenthrin barrier

treatments include under demountables, external floorboards, walls, insect screens and any dense vegetation surrounding the construction camps. If required, dark shade cloth fencing erected around the construction camps treated with bifenthrin will enhance the effectiveness of any barrier treatment.

Additional measures can be taken to reduce biting midge numbers if required. The use of UV or incandescent lights in non personnel areas can act as a diversion for biting midges, although the use of lights alone is not likely to provide a useful or effective buffer (Shivas & Whelan 2001). Personal protection in the 2 hours around sunset and sunrise during full and new moon periods may be required during the dry season. Further information on personal protection from biting midges can be found in Appendix 3.

5.2 Mosquitoes

5.2.1 Mosquito Control and avoidance

Due to the short term nature of both mine sites, larval mosquito control will not be warranted or feasible. However, due to the seasonal very high numbers of potential virus carrying mosquitoes, some form of adult mosquito control is recommended around the construction camps. Bifenthrin barrier treatments as discussed in Section 5.1 are currently the most effective way of controlling adult mosquitoes (Standfast et al 2003). Barrier control of mosquitoes will reduce the potential for mosquito borne disease transmission, and reduce the numbers of bites that can lead to secondary infection from scratching. The salt marsh mosquito *Ae. vigilax* will bite during the daytime at the construction camps, which means this species will be harder to avoid, therefore bifenthrin barrier treatments for this species in particular is recommended. Most other mosquito species can be avoided by preventing exposure after sundown.

Adult mosquito control by fogging may also be required if there are cases of mosquito borne disease and subsequent entomological investigations indicate a further disease transmission risk. Adult mosquito control by ground based operations would only be successful if the mosquitoes were breeding or harbouring in accessible areas relatively close to where they were causing the problem. In this case, the areas to be targeted for fogging will be the extensive swamps located adjacent to both prospect areas, and the areas surrounding the construction camps.

Personal protection and the appropriate screening of accommodation facilities are further measures that can be utilised to minimise the impact of mosquitoes on the workforce, as well as avoiding being exposed to mosquito bites after sunset. Mess facilities should be indoors or screened, to prevent workers being bitten when mosquito numbers are high, and sleeping quarters should have appropriate insect screens to prevent the entry of mosquitoes. Further information on personal protection from mosquitoes can be found in Appendix 4.

5.2.2 Artificial receptacles

Periodic inspections should be conducted around the construction camps during the wet season, to ensure mosquito breeding in artificial receptacles is prevented. This includes inspecting used tyres, drums, rainwater tanks, disused machinery items, and any other receptacle capable of holding water and breeding mosquitoes. Any receptacle holding water should be tipped upside down, stored under cover away from rain, appropriately disposed of at a well-maintained waste disposal facility, or treated with a residual insecticide until it no longer poses a potential mosquito breeding issue. Septic tanks should also be periodically inspected to ensure the lids on the tanks remain fully sealed, and to ensure absorption trenches are operating correctly and are not ponding effluent.

The appropriate management of artificial receptacles is important to prevent the creation of breeding sites for the dengue vector mosquito *Aedes aegypti*, which may be inadvertently transported to the development sites from North Queensland or overseas, and to prevent the creation of mosquito breeding sites for the dengue vector mosquito *Aedes albopictus*, which may be inadvertently transported to the development sites from overseas.

Machinery or equipment sourced from North Queensland should be inspected for the presence of water ponding and mosquito breeding. Potential water holding receptacles includes used tyres, backhoe buckets, excavator tracks, drums, buckets, rainwater tanks and building equipment. Any receptacle sourced from North Queensland that is found to be holding water should be treated with an appropriate chlorine solution or residual insecticide. This is to prevent the introduction of the dengue carrying mosquito *Aedes aegypti* from North Queensland, where it is endemic.

6.0 Mosquito breeding and development aspects

The potential for increased mosquito breeding at the mining sites will arise from mining activities that penetrate the ground water table, and the ground water is left to pond within the excavation for periods greater than five consecutive days. The proposed mining method (a form of slot mining) is to include a continuous rehabilitation program occurring close behind the mining face (URS, 2005), so it is unlikely that conditions will be suitable for mosquito breeding in excavated areas. Matilda Minerals have also mentioned that excavations will not be made lower than the groundwater table (Dennis McCamish pers. comm.), which will also limit the potential for surface water ponding and mosquito breeding in excavations during the dry season. However, the suitable rehabilitation of mined areas would be required to prevent the creation of new mosquito breeding sites that would be a detriment to the future use of the surrounding areas.

Andranangoo Creek West

Excavations adjacent to the extensive reed swamp have the potential to create further extensive breeding sites for *Ae. vigilax*, *An. farauti s.l.*, *Cx annulirostris*, *An. bancroftii*, *Cx. sitiens*, *Cq. xanthogaster* and *Ma. uniformis*. It is important that mining does not create further mosquito breeding sites, especially as the community of Milikapiti is within flight range of *Ae. vigilax* from the prospect area. Excavations adjacent to the reed swamp should be rectified in a manner that ensures the rehabilitated area has the same topographical level post mining as pre-mining. Rehabilitation works should take into account the likelihood of the backfilled sand consolidating and sinking slightly, potentially creating a low lying area that could become a mosquito breeding site. This situation could be avoided by backfilling the excavations so that the rehabilitated surface is slightly higher than the natural surface level, so that when consolidation and compaction occurs the rehabilitated surface is the same as the natural surface of adjacent undisturbed areas.

It is mentioned in the Notice of Intent Document (URS, 2005) that mining will avoid the *Melaleuca* swamp and associated drainage line where possible, and rehabilitation would be undertaken in a way that reinstates the previous natural pattern of drainage. This rehabilitation work should also include backfilling mined areas as described in the paragraph above, to prevent the expansion of the swamp or creation of new poorly draining areas.

Other areas that are mined should also be rehabilitated in a manner that prevents the creation of low lying areas that could pond water and become mosquito breeding sites, and prevent the creation of areas with impeded drainage.

Lethbridge Bay West

The potential for the creation of new mosquito breeding sites will arise from mining activities that occur adjacent to the large tidal mudflat. Any excavations that occur adjacent to the mudflat should be rehabilitated in a manner that re-instates the existing ground level pre-development, to prevent the creation of new areas where tide and rainwater can pond and breed mosquitoes. Other mined areas in the Lethbridge Bay West prospect should also be rehabilitated in a manner that prevents the creation of low lying areas that can pond water, and prevents the creation of areas with impeded surface water flows, especially as the community of Milikapiti is within flight range of *Ae. vigilax* from the prospect area.

7.0 Conclusions

7.1 Biting midges

- *Culicoides ornatus* will be the most important pest biting midge species affecting the Andranangoo Creek West and Lethbridge Bay West prospects.
- *Culicoides ornatus* pest problems are likely to be moderate-high at the Andranangoo Creek West prospect during the late wet season/early dry season (April-May), and low at the Lethbridge Bay West prospect during these months. High pest problems are likely to be experienced at the Andranangoo Creek West prospect during the peak season months of August to November, and low-moderate pest problems are likely to be experienced at the Lethbridge Bay West prospect during these months. Pest problems will be greatest within 1.5km of the mangrove margin, with pest problems likely to occur at least 2km from the mangrove margin. Greatest pest problems will occur 3-4 days around the full and new moons, with full moon problems generally being twice as large as new moon problems.
- Potential breeding sites for *C. ornatus* affecting the Andranangoo Creek West prospect will be the upper high tide mangrove areas of Andranangoo Creek, and the upper tidal creek area to the west of the prospect. The most important potential *C. ornatus* breeding site affecting the Lethbridge Bay West prospect will be the upper tidal reaches of the small creek to the east of the prospect.
- *Culicoides marksii* is only expected to cause at most a minor nuisance problem at both mining prospects. *Lasiohelia* sp. is not expected to cause pest problems at the mining prospects.
- Insecticide barrier treatments may be required, particularly at the Andranangoo Creek West prospect, during periods of high *C. ornatus* activity. Insecticide barrier treatments are unlikely to be required for other pest biting midge species.

7.2 Mosquitoes

- The salt marsh mosquito *Aedes vigilax* will be the most abundant mosquito species at both mining prospects, and will be the most important pest mosquito. This species will reach very high levels throughout all areas of both prospects in the months of September to January inclusive, and will cause serious pest problems. Moderate to high numbers may also be present in February, and low numbers may be present at both mining prospects in May and August in some years. This species is likely to be present in elevated numbers for up to 2 weeks during the warmer, humid months of November to January inclusive, with elevated numbers lasting about 1 week in the cooler months of their peak abundance period. Pest problems will occur in shaded areas during the daytime and at night.
- *Aedes vigilax* will pose a very high Ross River virus (RRV) disease and Barmah Forest virus (BFV) disease risk during September to January inclusive, and possibly February, with the November to February inclusive period being the highest risk months, due to the high temperatures and humidity increasing the longevity of individual females.
- *Anopheles farauti* s.l. will be present in very high numbers at the Andranangoo Creek West prospect during the months of March to June inclusive, causing at least moderate pest problems, and low numbers at the Lethbridge Bay West prospect during these months, causing at least minor pest problems. Minor to low numbers of this species are likely to be present at both prospects during most other months of the year. Highest numbers at both prospects will be encountered within 1.5km of the adjacent swamps, with dispersal up to 2km from their breeding sites. Pest problems will occur at night.

- *Anopheles farauti* s.l. will pose a high risk of malaria transmission at the Andranangoo Creek West prospect during the months of March to June inclusive, and will pose a low risk of malaria transmission for most other months of the year. This species will pose a low risk of malaria transmission at the Lethbridge Bay West prospect during most months of the year. The risk of malaria transmission will only arise if a person with the infectious stages of malaria is bitten by *Anopheles* mosquitoes at either mine site.
- The common banded mosquito *Culex annulirostris* is likely to be present in moderate to high numbers during the peak season April to August period at both prospects, causing moderate to high pest problems. Low to moderate numbers are also expected to occur during the January to March period at both prospects, as well as during September and early October. Pest problems will occur at night.
- *Culex annulirostris* will pose a potential RRV and BFV risk, mainly during the December to June period, a potential Murray Valley encephalitis virus (MVEV) disease risk, with peak risk months for MVEV transmission being January to July, and a potential Kunjin virus (KUNV) disease risk, with peak risk months from KUNV transmission being December to July.
- *Mansonia uniformis* will be present in very high numbers at the Andranangoo Creek West prospect during the March to June inclusive period, causing very high pest problems. Pest problems will be greatest within 2km of the Andranangoo Creek West reed swamp, with pest problems occurring mainly at night, but also in shaded areas near their breeding sites during the daytime. This species does not transmit human disease in Australia. This species is not expected to cause any significant pest problems at the Lethbridge Bay West prospect.
- *Coquillettidia xanthogaster* is likely to be present in moderate to high numbers during the peak season March to August period at both prospects, causing moderate to high pest problems. Low numbers are expected to continue until late September/early October at both prospects. Pest problems will be noticed mainly at night, although this species will bite in shaded areas during the daytime nearby to their breeding sites. This species does not transmit human disease in Australia.
- The black malaria mosquito *Anopheles bancroftii* is likely to be present in moderate to high numbers during the peak season March to August period at the Andranangoo Creek West prospect, causing moderate to high pest problems, and in low to moderate numbers at the Lethbridge Bay West prospect during these months, causing low to moderate pest problems. Low abundance is likely to continue until late September/early October at the Andranangoo Creek West prospect. Pest problems will be noticed mainly at night, although this species will bite in shaded areas during the daytime nearby to their breeding sites. This species has a low potential for malaria transmission.
- Other species that may cause pest problems at both mining prospects include *Culex sitiens* and *Verrallina funerea*. These species are likely to cause low pest problems at both prospects, and will pose a low RRV risk when present. *Verrallina funerea* will also pose a low BFV risk when present. *Anopheles hilli* is likely to cause low pest problems and a low potential malaria risk when present at both prospects.
- There is the potential for the introduction of the dengue mosquito *Aedes aegypti* from North Queensland, if machinery and other equipment capable of ponding water are sourced from this area.
- *Aedes notoscriptus* has the potential to colonise artificial receptacles at the construction camps, and pose a nuisance and potential RRV problem. The dengue mosquito species *Aedes aegypti* and *Ae. albopictus* has the potential to colonise artificial receptacles at the development sites, if these species are inadvertently transported to the development sites.

- Due to the short term nature of both mining sites, larval mosquito control would not be warranted or feasible. Adult mosquito control using a residual barrier insecticide such as bifenthrin will be the best method of reducing adult mosquito populations around the construction camps.
- The mine sites have the potential to create new mosquito breeding sites, if mined areas are not appropriately rectified.

8.0 Recommendations

8.1 Biting midges

- Workers should be advised of a potential biting midge problem at the Andranangoo Creek West and Lethbridge Bay West prospects, with higher pest problems likely to be experienced at the Andranangoo Creek West prospect. Workers should be advised of appropriate personal protection measures, as outlined in Appendix 3.
- If complaints are received about biting midges, barrier insecticide treatments can be used to lower biting midge populations around the construction camp. Areas that can be treated include under demountables, external floorboards, walls, insect screens and any dense vegetation surrounding the construction camps. Shade cloth fencing erected around the construction camp and treated with bifenthrin will also enhance the effectiveness of any barrier treatment.

8.2 Mosquitoes

- All workers should be advised of the high mosquito problems that will occur at both prospect sites, and the high potential for mosquito borne disease transmission at both prospect areas. Workers should be supplied with a copy of the Medical Entomology Branch handout “Personal protection from mosquitoes and biting midges in the NT” (Appendix 4).
- Adult mosquito control around the construction camps using barrier insecticides such as bifenthrin is highly recommended. Areas that can be treated include under demountables, external floorboards, walls, insect screens and any dense vegetation surrounding the construction camps. Dark shade cloth fencing erected around the construction camp and treated with bifenthrin will also enhance the effectiveness of any barrier treatment.
- Equipment sourced from North Queensland, such as used tyres, backhoe buckets, excavator tracks, drums, buckets, rainwater tanks and building equipment, should be inspected for the presence of water ponding, even very small amounts of water, to prevent the introduction of the dengue mosquito *Aedes aegypti* from North Queensland. Any water holding receptacle should be treated with an appropriate chlorine solution or residual insecticide, to kill any mosquito larvae and eggs that may be present.
- Periodic inspections should be conducted around the construction camps, to ensure mosquito breeding in artificial receptacles is prevented, particularly to prevent the creation of potential breeding sites for exotic dengue carrying mosquito species, as well as to prevent the creation of breeding sites for the endemic *Aedes notoscriptus*, which is a potential vector of RRV.
- Any worker returning or sourced from overseas who experiences an onset of fever should be considered as possibly having malaria and be kept indoors away from mosquitoes, until cleared of having malaria or cleared of the infectious stages of malaria by a health care practitioner.
- Rehabilitation of the mining areas should be conducted in a manner that prevents the creation of new mosquito breeding sites, which could affect the future use of the land, or disperse to existing or future development areas on Melville Island. This includes ensuring all mined and disturbed areas are rehabilitated to be free draining.

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Figures

Figure 1 - Supplementary adult biting insect trapping Matilda Minerals Sandmining Project Melville Island November 2005, and January and March 2006. Adult biting insect trap locations and potential biting insect breeding sites at Andranangoo Creek West.

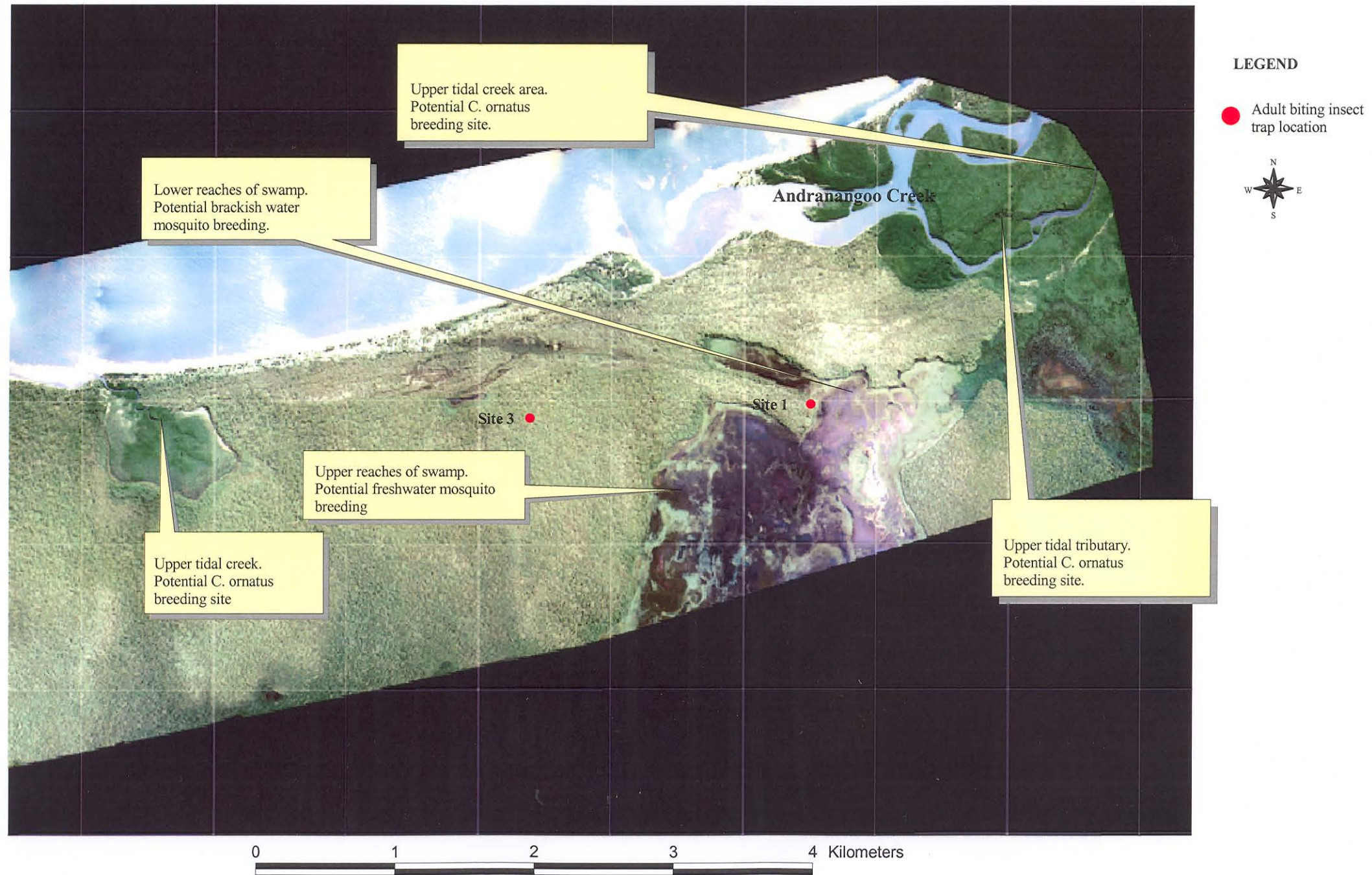


Figure 2 - Supplementary adult biting insect trapping Matilda Minerals Sandmining Project Melville Island November 2005, and January and May 2006. Adult biting insect trap locations and potential biting insect breeding sites at Lethbridge Bay West.

LEGEND

● Adult biting insect trap location



Darker areas indicate probable semi-aquatic reed/grass presence. Potential breeding site for many freshwater and brackish water mosquito species

Upper tidal creek.
Potential *C. ornatus* breeding sites

Darker areas indicate probable semi-aquatic reed/grass presence. Potential breeding site for many freshwater and brackish water mosquito species.

Site 5

Site 7

0 1 2 3 4 Kilometers

Tables

Table 1: Andranangoo Creek West and Lethbridge Bay West supplementary trapping results 1st-2nd November 2005. Total number of female biting midges collected in Carbon Dioxide Baited EVS traps.

	Biting midge species											Total	% of Total
	<i>C. (Mar grp) marksi</i>	<i>C. (Mei) guttifer</i>	<i>C. (Orn grp) cordiger</i>	<i>C. (Orn grp) ornatus</i>	<i>C. (Orn grp) papuensis</i>	<i>C. (Orn grp) undescribed sp No 6</i>	<i>C. (Vic grp) bundyensis</i>	<i>C. (Vic grp) undescribed sp Vic 42</i>	<i>C. (Wil grp) austropalpalis</i>	<i>Culicoides unidentifiable</i>	<i>Nil Biting midges</i>		
Trap location													
Trap Site 1 Andranangoo Creek West. North edge of Andranangoo Creek West reed swamp, adjacent to NW arm of swamp.	0	23	0	14	0	3	0	0	3	2	0	45	43.7
Trap Site 3 Andranangoo Creek West. Approximately 50m north of construction camp, in Eucalypt woodland.	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Trap Site 5 Lethbridge Bay West. In paperbark forest northwest edge of proposed mining area, adjacent to northwest edge of extensive mudflat.	0	0	2	7	5	9	3	1	0	5	0	32	31.1
Trap Site 7 Lethbridge Bay West. In eucalypt open woodland near proposed construction camp.	1	0	0	4	0	13	2	4	0	2	0	26	25.2
Total	1	23	2	25	5	25	5	5	3	9	0	103	100
% of Total	1.0	22.3	1.9	24.3	4.9	24.3	4.9	4.9	2.9	8.7	0.0	100	

Table 2: Andranangoo Creek West and Lethbridge Bay West supplementary trapping results 13th-14th January 2006. Total number of female biting midges collected in Carbon Dioxide Baited EVS traps.									
Trap location	Biting midge species							Total	% of Total
	<i>C. (Orn grp) ornatus</i>	<i>C. (Orn grp) undescribed sp No 6</i>	<i>C. (Vic grp) pallidothorax</i>	<i>C. (Vic grp) undescribed sp Vic 42</i>	<i>Culicoides unidentifiable</i>	<i>Lasiohelius sp.</i>	Not collected biting midges		
Trap Site 1 Andranangoo Creek West. North edge of Andranangoo Creek West reed swamp, adjacent to NW arm of swamp.	15	0	3	4	0	0	0	22	44.0
Trap Site 3 Andranangoo Creek West. Approximately 50m north of construction camp, in Eucalypt woodland.	1	0	0	5	0	1	0	7	14.0
Trap Site 5 Lethbridge Bay West. In paperbark forest northwest edge of proposed mining area, adjacent to northwest edge of extensive mudflat.	0	0	0	0	0	0	1		
Trap Site 7 Lethbridge Bay West. In eucalypt open woodland near proposed construction camp.	9	5	1	3	2	1	0	21	42.0
Total	25	5	4	12	2	2		50	100
% of Total	50.0	10.0	8.0	24.0	4.0	4.0		100	

Table 3: Andranangoo Creek West and Lethbridge Bay West supplementary trapping results 12-13th May 2006. Total number of female biting midges collected in Carbon Dioxide Baited EVS traps.

	Biting midge species								Total	% of Total
	<i>C. (Mar grp) marksi</i>	<i>C. (Orn grp) ornatus</i>	<i>C. (Orn grp) undescribed sp No 6</i>	<i>C. (Vic grp) bundyensis</i>	<i>C. (Wil grp) austropalpalis</i>	<i>C. (Wil grp) narrabeenensis</i>	<i>Culicoides unidentifiable</i>	<i>Lasiohelius sp.</i>		
Trap location										
Trap Site 1 Andranangoo Creek West. North edge of Andranangoo Creek West reed swamp, adjacent to NW arm of swamp.	0	874	38	90	1	76	38	2	1119	39.4
Trap Site 3 Andranangoo Creek West. Approximately 50m north of construction camp, in Eucalypt woodland.	2	15	8	69	2	2	4	1	103	3.6
Trap Site 5 Lethbridge Bay West. In paperbark forest northwest edge of proposed mining area, adjacent to northwest edge of extensive mudflat.	0	102	6	132	0	36	36	6	318	11.2
Trap Site 7 Lethbridge Bay West. In eucalypt open woodland near proposed construction camp.	200	200	100	375	175	175	75	2	1302	45.8
Total	202	1191	152	666	178	289	153	11	2842	100
% of Total	7.1	41.9	5.3	23.4	6.3	10.2	5.4	0.4	100	

Table 4: Andranangoo Creek West and Lethbridge Bay West supplementary trapping results. Total number of all female biting midges collected in Carbon Dioxide baited EVS traps set one day before the full moon in November 2005, and January and May 2006.

Trap location	Biting midge species															Total	% of Total
	<i>C. (Mar grp) marksi</i>	<i>C. (Mei) guttifer</i>	<i>C. (Orn grp) cordiger</i>	<i>C. (Orn grp) ornatus</i>	<i>C. (Orn grp) papuensis</i>	<i>C. (Orn grp) undescribed sp No 6</i>	<i>C. (Vic grp) bundyensis</i>	<i>C. (Vic grp) pallidothorax</i>	<i>C. (Vic grp) undescribed sp Vic 42</i>	<i>C. (Wil grp) austropalpalis</i>	<i>C. (Wil grp) narrabeenensis</i>	<i>Culicoides unidentifiable</i>	<i>Lasiohelius sp.</i>	<i>Nil Biting midges</i>	<i>Not collected biting midges</i>		
Trap Site 1 Andranangoo Creek West. North edge of Andranangoo Creek West reed swamp, adjacent to NW arm of swamp.	0	23	0	903	0	41	90	3	4	4	76	40	2	0	0	1186	39.6
Trap Site 3 Andranangoo Creek West. Approximately 50m north of construction camp, in Eucalypt woodland.	2	0	0	16	0	8	69	0	5	2	2	4	2	0	0	110	3.7
Trap Site 5 Lethbridge Bay West. In paperbark forest northwest edge of proposed mining area, adjacent to northwest edge of extensive mudflat.	0	0	2	109	5	15	135	0	1	0	36	41	6	0	1	350	11.7
Trap Site 7 Lethbridge Bay West. In eucalypt open woodland near proposed construction camp.	201	0	0	213	0	118	377	1	7	175	175	79	3	0	0	1349	45.0
Total	203	23	2	1241	5	182	671	4	17	181	289	164	13	0		2995	100
% of Total	6.8	0.8	0.1	41.4	0.2	6.1	22.4	0.1	0.6	6.0	9.6	5.5	0.4	0.0		100	

Table 5: Andranangoo Creek West and Lethbridge Bay West supplementary trapping results 1st- 2nd November 2005. Total number of female mosquitoes collected in Carbon Dioxide Baited EVS traps.

	Mosquito species													
Trap location	<i>An. (Cel) farauti</i> s.l.	<i>An. (Cel) hilli</i>	<i>An. (Cel) species</i>	<i>Cq. (Coq) xanthogaster</i>	<i>Cx. (Cux) annulirostris</i>	<i>Cx. (Cux) sitiens</i>	<i>Cx. (Cux) species</i>	<i>Ma. (Mnd) uniformis</i>	mosquitoes unidentifiable (damaged)	<i>Ae. (Muc) alternans</i>	<i>Ae. (Och) vigilax</i>	<i>Ve. (Ver) funerea</i>	Total	% of Total
Trap Site 1 Andranangoo Creek West. North edge of Andranangoo Creek West reed swamp, adjacent to NW arm of swamp.	22	122	0	6	44	56	0	1	33	1	1952	33	2270	56.9
Trap Site 3 Andranangoo Creek West. Approximately 50m north of construction camp, in Eucalypt woodland.	0	1	0	0	2	0	0	0	0	0	13	0	16	0.4
Trap Site 5 Lethbridge Bay West. In paperbark forest northwest edge of proposed mining area, adjacent to northwest edge of extensive mudflat.	30	54	3	1	39	51	3	0	0	0	807	3	991	24.8
Trap Site 7 Lethbridge Bay West. In eucalypt open woodland near proposed construction camp.	13	30	0	2	20	16	0	0	0	0	634	0	715	17.9
Total	65	207	3	9	105	123	3	1	33	1	3406	36	3992	100
% of Total	1.63	5.19	0.08	0.23	2.63	3.08	0.08	0.03	0.83	0.03	85.3	0.9	100	

Table 6: Andranangoo Creek West and Lethbridge Bay West supplementary trapping results 13-14th January 2006. Total number of female mosquitoes collected in Carbon Dioxide Baited EVS traps.																				
Trap location	Mosquito Species																		Total	% of Total
	<i>An. (Cel) amictus</i>	<i>An. (Cel) farauti s.l.</i>	<i>An. (Cel) hilli</i>	<i>Cq. (Coq) xanthogaster</i>	<i>Cx. (Cux) annulirostris</i>	<i>Cx. (Cux) sitiens</i>	<i>Cx. (Lop) hilli</i>	<i>Fl. kochi</i>	<i>Ma. (Mnd) uniformis</i>	<i>mosquitoes unidentifiable (damaged)</i>	<i>Ae. (Muc) alternans</i>	<i>Ae. (Cha) elchoensis</i>	<i>Ae. (Fin) brittani</i>	<i>Ae. (Mac) species</i>	<i>Ae. (Mac) tremulus</i>	<i>Ae. (Och) vigilax</i>	<i>Ae. daliensis</i>	<i>Ve. (Ver) funerea</i>		
Trap Site 1 Andranangoo Creek West. North edge of Andranangoo Creek West reed swamp, adjacent to NW arm of swamp.	0	68	5	0	31	29	1	2	0	0	0	0	0	0	4	331	0	5	476	21.4
Trap Site 3 Andranangoo Creek West. Approximately 50m north of construction camp, in Eucalypt woodland.	0	10	0	3	15	12	0	1	3	0	0	1	0	4	0	275	0	0	324	14.6
Trap Site 5 Lethbridge Bay West. In paperbark forest northwest edge of proposed mining area, adjacent to northwest edge of extensive mudflat.	2	25	4	2	2	2	0	0	0	0	1	0	0	0	0	795	2	8	843	37.9
Trap Site 7 Lethbridge Bay West. In eucalypt open woodland near proposed construction camp.	0	52	0	3	16	2	1	7	0	2	0	0	0	0	1	499	0	0	583	26.2
Total	2	155	9	8	64	45	2	10	3	2	1	1	0	4	5	1900	2	13	2226	100
% of Total	0.1	7.0	0.4	0.4	2.9	2.0	0.1	0.4	0.1	0.1	0.0	0.0	0.0	0.2	0.2	85.4	0.1	0.6	100	

Table 7: Andranangoo Creek West and Lethbridge Bay West supplementary trapping results 12-13th May 2006. Total number of female mosquitoes collected in Carbon Dioxide Baited EVS traps.

	Mosquito Species																						
	<i>Ad. (Ady) catasticta</i>	<i>Ae. (Adm) alboscuteallatus</i>	<i>An. (Ano) bancroftii</i>	<i>An. (Ano) powelli</i>	<i>An. (Cel) farauti s.l.</i>	<i>An. (Cel) hilli</i>	<i>An. (Cel) meraukensis</i>	<i>An. (Cel) novaguinensis</i>	<i>Cq. (Coq) xanthogaster</i>	<i>Cx. (Cux) annulirostris</i>	<i>Cx. (Cux) palpalis</i>	<i>Cx. (Cux) squamosus</i>	<i>Cx. (Cux) Vishnui group</i>	<i>Ma. (Mnd) uniformis</i>	<i>Ae. (Fin) notoscriptus</i>	<i>Ae. (Mol) pecuniosus</i>	<i>Ae. (Och) normanensis</i>	<i>Ae. (Och) phaecasiatus</i>	<i>Ae. (Och) vigilax</i>	<i>Trp. (Trp) magnesianus</i>	<i>Ve. (Ver) reesi</i>	Total	% of Total
Trap Site 1 Andranangoo Creek West. North edge of Andranangoo Creek West reed swamp, adjacent to NW arm of swamp.	32	0	151	1	1273	0	22	0	43	54	0	11	0	1381	0	11	0	0	22	0	0	3001	76.5
Trap Site 3 Andranangoo Creek West. Approximately 50m north of construction camp, in Eucalypt woodland.	2	0	0	14	22	1	18	14	52	5	1	0	0	59	0	0	1	0	1	0	2	192	4.9
Trap Site 5 Lethbridge Bay West. In paperbark forest northwest edge of proposed mining area, adjacent to northwest edge of extensive mudflat.	0	1	33	0	66	3	1	0	28	26	0	0	2	10	1	0	3	2	1	1	0	178	4.5
Trap Site 7 Lethbridge Bay West. In eucalypt open woodland near proposed construction camp.	9	0	41	35	82	6	12	15	120	164	12	0	23	12	0	6	0	0	15	0	0	552	14.1
Total	43	1	225	50	1443	10	53	29	243	249	13	11	25	1462	1	17	4	2	39	1	2	3923	100
% of Total	1.1	0.0	5.7	1.3	36.8	0.3	1.4	0.7	6.2	6.3	0.3	0.3	0.6	37.3	0.0	0.4	0.1	0.1	1.0	0.0	0.1	100	

Table 8: Andranangoo Creek West and Lethbridge Bay West supplementary trapping results. Total number of all female mosquitoes collected in Carbon Dioxide baited EVS traps set one day before the full moon in November 2005, and January and May 2006.

	Mosquito species																																				
Trap location	<i>Ad. (Ady) catasicta</i>	<i>Ae. (Adm) alboscuelatus</i>	<i>An. (Ano) bancroftii</i>	<i>An. (Ano) powelli</i>	<i>An. (Cel) amictus</i>	<i>An. (Cel) farauti s.l.</i>	<i>An. (Cel) hilli</i>	<i>An. (Cel) meraukensis</i>	<i>An. (Cel) novaguinensis</i>	<i>An. (Cel) species</i>	<i>Cq. (Coq) xanthogaster</i>	<i>Cx. (Cux) annulirostris</i>	<i>Cx. (Cux) palpalis</i>	<i>Cx. (Cux) sitiens</i>	<i>Cx. (Cux) species</i>	<i>Cx. (Cux) squamosus</i>	<i>Cx. (Cux) Vishnui group</i>	<i>Cx. (Lop) hilli</i>	<i>Fl. kochi</i>	<i>Ma. (Mnd) uniformis</i>	<i>mosquitoes unidentifiable (damaged)</i>	<i>Ae. (Muc) alternans</i>	<i>Ae. (Cha) elchoensis</i>	<i>Ae. (Fin) brittnei</i>	<i>Ae. (Fin) notoscriptus</i>	<i>Ae. (Mac) species</i>	<i>Ae. (Mac) tremulus</i>	<i>Ae. (Mol) pecuniosus</i>	<i>Ae. (Och) normanensis</i>	<i>Ae. (Och) phaeccasiatus</i>	<i>Ae. (Och) vigilax</i>	<i>Ae. daliensis</i>	<i>Trp. (Trp) magnesianus</i>	<i>Ve. (Ver) funerea</i>	<i>Ve. (Ver) reesi</i>	Total	% of Total
Trap Site 1 Andranangoo Creek West. North edge of Andranangoo Creek West reed swamp, adjacent to NW arm of swamp.	32	0	151	1	0	1363	127	22	0	0	49	129	0	85	0	11	0	1	2	1382	33	1	0	0	0	0	4	11	0	0	2305	0	0	38	0	5747	56.7
Trap Site 3 Andranangoo Creek West. Approximately 50m north of construction camp, in Eucalypt woodland.	2	0	0	14	0	32	2	18	14	0	55	22	1	12	0	0	0	0	1	62	0	0	1	0	0	4	0	0	1	0	289	0	0	0	2	532	5.2
Trap Site 5 Lethbridge Bay West. In paperbark forest northwest edge of proposed mining area, adjacent to northwest edge of extensive mudflat.	0	1	33	0	2	121	61	1	0	3	31	67	0	53	3	0	2	0	0	10	0	1	0	0	1	0	0	0	3	2	1603	2	1	11	0	2012	19.8
Trap Site 7 Lethbridge Bay West. In eucalypt open woodland near proposed construction camp.	9	0	41	35	0	147	36	12	15	0	125	200	12	18	0	0	23	1	7	12	2	0	0	0	0	0	1	6	0	0	1148	0	0	0	0	1850	18.2
Total	43	1	225	50	2	1663	226	53	29	3	260	418	13	168	3	11	25	2	10	1466	35	2	1	0	1	4	5	17	4	2	5345	2	1	49	2	10141	100
% of Total	0.4	0.0	2.2	0.5	0.0	16.4	2.2	0.5	0.3	0.0	2.6	4.1	0.1	1.7	0.0	0.1	0.2	0.0	0.1	14.5	0.3	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	52.7	0.0	0.0	0.5	0.0	100		

Appendix 1: Summary of the biology of selected *Culicoides* species in the Top end of the Northern Territory *and* Seasonal prevalence of selected *Culicoides* species in the Top End of the NT.

TABLE 1

**SUMMARY OF THE BIOLOGY OF SELECTED *CULICOIDES* SPECIES
IN THE TOP END OF THE NORTHERN TERRITORY**

Peter Whelan, Medical Entomology Branch, Territory Health Services

Species	Larval Ecology	Adult Ecology
<i>C. ornatus</i>	Dry season – breeds between Mean Low Water Neap (MLWN) and MHWN tide mark extensive areas of mangroves with mud substrates. Breeds in highest numbers at creekbank habitats around Mean High Water Neap (MHWN) in association with <i>Avicennia</i> pneumatophores. Breeds in <i>Sonneratia</i> foreshore habitats associated with mud substrates. Wet season – breeds in transitional <i>Ceriops</i> zone just below Mean High Water Spring (MHWS) at back edge of creekbank forest, and <i>Rhizophora</i> transitional zone adjacent to <i>Sonneratia</i> foreshore habitats.	Bites people readily and a serious human pest. Bites other mammals; crepuscular; disperses in pest numbers to 2 km and up to 4 km. Emergence around neap tide time with peak dispersal over 3 days around full moon. Disperses readily to higher ground up to 1.5 km from mangroves.
<i>C. undescribed species (Ornatus grp) No. 6 (Dyce) (formerly C. sp. near hewitti)</i>	Upper estuary, freshwater influenced extensive mangrove areas. Breeds in highest numbers just below MHWS.	Crepuscular. Rarely bites people.
<i>C. marksi</i>	Breeds in the margins of freshwater lakes and streams.	Crepuscular to diurnal; feeds on cattle and occasionally bites people; a minor pest at times.
<i>C. narrabeenensis</i>	Breeds at edge of fresh water.	Rarely bites people.
<i>C. undescribed species (Victoriae grp) No. 42 (Dyce) (formerly C. ?pangkorensis)</i>	Upper estuary.	Occasionally bites people.
<i>C. pallidothorax</i>	Breeds near fresh water.	NT species, rarely bites people.
<i>C. flumineus</i>	Similar to <i>C. ornatus</i> but at a lower level on creekbanks of small upper tidal tributaries. Also breeds in crab burrows on creekbank.	Readily bites people but rarely encountered out of mangroves.
<i>C. undescribed sp. (near C. immaculatus)</i>	Possibly breeds below neap tide zone in mangrove creeks. Spring tide species.	Relatively common in lower reaches of mangrove creeks and bites viciously.
<i>C. immaculatus</i>	Sandy wave washed beach sand often with rocks, near neap high	A relatively rare to minor pest. Found near breeding sites only.

tide level. Neap tide species

<i>C. ?subimmaculatus</i> (northern form)	Maritime sands in wave sheltered areas often with small crabs between neap and spring tide zone.	Crepuscular. A minor to moderate pest. Bites man readily near breeding sites. Pest range generally up to 0.5 km.
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Adapted from information by Allan Dyce and pers com Martin Shivas 1998. Minor revision January 2004.

TABLE 2

**SEASONAL PREVALENCE OF SELECTED *CULICOIDES* SPECIES
IN THE TOP END OF THE NT**

Peter Whelan

Medical Entomology Branch, Territory Health Services

Species	Seasonal Prevalence
<i>C. ornatus</i>	The major human pest species within 2km of mangroves at coast. High localised populations all year round, with maximum numbers occurring in August to November and minimum in the wet season.
<i>C. undescribed species</i> (<i>Ornatus</i> grp) No. 6 (Dyce) (formerly <i>C. sp. near hewitti</i>)	A major species near extensive areas of mangroves at coast. High numbers in the late dry season and early wet season, and has low populations in the post wet season.
<i>C. marksi</i>	A major species in sub-coastal and inland areas, with only low populations at coast. Low populations in the late dry season and moderate populations in the early wet and post wet to mid dry seasons.
<i>C. narrabeenensis</i>	A minor species with peak numbers in the early to mid dry season.
<i>C. undescribed species</i> (<i>Victoriae</i> grp) No. 42 (Dyce) (formerly <i>C. ?pangkorensis</i>)	A minor species. Peak numbers in mid wet season.
<i>C. pallidothorax</i>	A minor species. Peak populations during the early to mid wet season.
<i>C. flumineus</i>	An important pest species with high numbers inside mangroves only. Peaks in late dry season, early wet season.
<i>C. undescribed sp. (near C. immaculatus)</i>	A serious pest in lower reaches of mangrove creeks
<i>C. immaculatus</i>	A minor to rare species near rock-sand or sandy beaches only. Peak numbers in mid to late dry and early wet season.
<i>C. ?subimmaculatus</i> (northern form)	An important pest species. Moderate numbers near favoured wave sheltered breeding sites only. Peak numbers in mid dry season tapering to late dry season.

Adapted from information by Allan Dyce and pers. comm. Martin Shivas 1998. Minor revision January 2004.

**Appendix 2 – Problems mosquito species in the Top end of the NT
– Pest and vector status, habitats and breeding sites.**



**Northern
Territory
Government**

Department of Health
and Community Services

**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

For more information contact:
Department of Health and Community Services
Medical Entomology Branch
PO Box 40596
Casuarina NT 0811

Telephone: (08) 8922 8333
Fax: (08) 8922 8820
E-mail: peter.whelan@nt.gov.au

PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT PEST AND VECTOR STATUS HABITATS AND BREEDING SITES

Peter Whelan
Senior Medical Entomologist
NT Department of Health and Community Services
1997

Minor update January 2004

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

SPECIES	PEST STATUS ¹	VECTOR STATUS
<i>An. annulipes</i> s.l. ²	Widespread pest, bites at night and will enter houses.	Potential malaria vector.
<i>An. bancroftii</i>	Major pest, widespread, bites anytime near breeding site, nightly or shaded areas elsewhere.	Potential malaria vector.
<i>An. farauti</i> s.l. ²	Local pest, bites at night. Uncommon, except near mostly sub-coastal and extensive freshwater or brackish swamps.	Major potential vector of malaria.
<i>An. hilli</i>	Coastal pest, bites at night, enters houses. Common near brackish water swamps.	Potential malaria vector.
<i>An. meraukensis</i>	Local pest, bites after dark. Very common near extensive freshwater swamp.	Not potential malaria vector.
<i>Cx. annulirostris</i>	Major pest, very common and widespread in both urban and rural areas. Bites mainly in evening and at night.	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.
<i>Cx. quinquefasciatus</i>	Major urban pest, bites at night, indoors, rests indoors, populations common with polluted water in dry season.	Potential arbovirus vector (MVEV). Vector of heartworm of dogs.
<i>Cx. sitiens</i>	Localized coastal pest, breeds in brackish or tidal waters, disperses widely, bites at night.	Probably no diseases. Possible RRV disease.
<i>Cq. xanthogaster</i>	Major localized pest near extensive reed swamps, disperses widely, bites at night, or in dense shade in day, attracted to lights.	No diseases. Filariasis in frill neck lizard
<i>Ma. uniformis</i>	Localized pest, bites at night near the breeding site, attracted to lights, does not disperse far from breeding sites.	No diseases.
<i>Fl. kochi</i>	Local pest at breeding site, does not disperse. Restricted to <i>Pandanus</i> thickets.	No diseases.
<i>Oc. normanensis</i>	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.	Major vector of Ross River and Barmah Forest viruses. Potential vector of MVEV. Potential vector of many other arboviruses.
<i>Oc. notoscriptus</i>	Local urban pest, receptacle or tree hole breeder, bites persistently, anytime in cool shade. Found naturally in forest areas.	Potential Ross River virus vector. Major vector of heartworm of dogs.
<i>Oc. tremulus</i>	Local urban pest, receptacle or tree hole breeder, bites at sundown and dawn. Often caught in forest areas.	No diseases.
<i>Oc. vigilax</i>	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.	Major vector of Ross River and Barmah Forest virus diseases and dog heartworm. Potential vector of many other arboviruses.
<i>Ve. funerea</i>	Local pest near breeding grounds, does not disperse. Common by day only locally inclosed forrest near tidal brackish swamps & Creeks.	Potential RRV and BFV arbovirus vector.
* Adapted and revised from P. Liehne et al. "Mosquitoes and biting midge investigation, Palmerston 1982 -85".		

**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**

SPECIES	IMMATURE STAGES	ADULT STAGES
<i>An. annulipes s.l.</i>	Eggs laid singly on water surface; any freshwater body but numerous near <i>Eleocharis</i> reed swamps; temporary or permanent; some receptacles; larvae float on water surface and feed on particles on top of water.	Feeds on a variety of mammals include 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.
<i>An. bancroftii</i>	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 <i>Eleocharis</i> reed swamps.	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.
<i>An. farauti s.l.</i> (Includes <i>An. farauti</i> , <i>An. hinesorum</i> and <i>An. torresiensis</i>)	Eggs laid singly on surface; larvae feed on water surface. <i>An. farauti</i> breeds in brackish water; <i>An. hinesorum</i> and <i>An. torresiensis</i> breed in freshwater swamps and pools. Larval habitat often sunlit.	Bites readily at night; feeds on humans, other mammals and birds. Will fly approximately 2 km from the breeding site.
<i>An. hilli</i>	Eggs laid singly on surface; larvae feed at surface; sunlit or shaded brackish to saline ground pools or swamps. Numerous in <i>Schoenoplectus</i> reed swamps near coast.	Bites humans, cattle and horses; mainly after sunset. Disperses up to 4 km from breeding site.
<i>An. meraukensis</i>	Eggs laid singly on surface of water; larvae feed at the surface; usually in freshwater <i>Eleocharis</i> reed swamps, sunlit or shaded.	Bites readily at dusk, feeds on humans and other mammals.
<i>Cx. annulirostris</i>	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.	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.
<i>Cx. quinquefasciatus</i>	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.	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.
<i>Cx. sitiens</i>	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.	Bites mammals and birds at night; pest near coast, will fly up to 5 km but common within 2 km of breeding site.
<i>Cq. xanthogaster</i>	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 <i>Eleocharis</i> and <i>Typha</i> reeds, water lilies and paperbark; larvae feed on suspended material in the water.	Adults are strong fliers 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.
<i>Ma. uniformis</i>	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 <i>Cq. xanthogaster</i> .	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.

SPECIES	IMMATURE STAGES	ADULT STAGES
<i>Oc. vigilax</i>	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 <i>Schoenoplectus littoralis</i> or landward ill draining mangrove areas; larvae browse on substrate.	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.
<i>Fl. kochi</i>	Eggs laid singly on the axils of <i>Pandanus</i> leaves. Larvae feed on detritus and debris in the water collected in the axil space.	Severe pests near the breeding sites. Do not disperse far from the breeding habitat.
<i>Oc. normanensis</i>	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.	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.
<i>Oc. notoscriptus</i>	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.	Feeds on humans and all mammals; bites day or evening in the cool shade. Does not disperse widely.
<i>Ve. funerea</i>	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.	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.
* 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* Peter Whelan Medical Entomology Branch, Department of Health and Community Services 1997	
SPECIES	SUMMARY OF BIOLOGY & SEASONAL PREVALENCE
<i>An. annulipes s.l.</i>	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.
<i>An. bancroftii</i>	Freshwater, paperbark and <i>Eleocharis</i> 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.
<i>An. farauti s.l.</i>	Brackish and freshwater species, in vegetated swamps or creeks. Low to moderate numbers in late wet and early post wet season.
<i>An. hilli</i>	Brackish/saltwater breeder, often associated with <i>Schoenoplectus</i> 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.
<i>An. meraukensis</i>	Open shallow freshwater <i>Eleocharis</i> reed swamps and creeks. Moderate to high numbers in the late and immediate post wet season.
<i>Ma. uniformis</i>	Same as <i>Cq. xanthogaster</i> but more associated with floating vegetation, (water lilies). Moderate to very high numbers near habitats in late wet, early dry season.
<i>Cx. annulirostris</i>	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.
<i>Cx. quinquefasciatus</i>	Domestic water sites, often with organic pollution. Moderate numbers in mid to late dry season, but can be present all year.
<i>Cx. sitiens</i>	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.
<i>Cq. xanthogaster</i>	Breeds in freshwater <i>Eleocharis</i> 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.
<i>Fl. kochi</i>	Breeds in <i>Pandanus</i> axils. Moderate numbers in wet season in <i>Pandanus</i> thickets.
<i>Oc. normanensis</i>	Floodwater, ground pool breeder in poorly draining floodways associated with creeks and rivers. Very high numbers during wet season, absent at other times.
<i>Oc. notoscriptus</i>	Tree hole or artificial receptacle breeder. Low numbers in wet season but persists in dry season with artificial breeding sites.
<i>Oc. tremulus</i>	Tree hole or receptacle breeder. Low numbers in wet season and early dry season.
<i>Oc. vigilax</i>	Breeds in tidal to brackish swamp or tidal pools in creeks. Extreme numbers in the very late dry and early wet season.
<i>Ve. funerea</i>	Brackish to tidal ground pools in tidal creeks and swamps, often in shade. Localised pest numbers in the pre wet and wet.
* 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

Species/ (Common Name)	Nuisance status	Disease Vector Status		Potential vectors in the NT	Peak Abundance
		Current	Potential		
<i>Ochlerotatus vigilax</i> (Salt marsh mosquito)	+++++	+++	++++	RRV BFV	September - January
<i>Ochlerotatus normanensis</i> (Floodwater mosquito)	+++++	+++	++++	RRV BFV	January - April
<i>Culex annulirostris</i> (Common banded mosquito)	+++++	+++++	+++++	MVEV, KUN RRV, BFV, JEV, others	January - August
<i>Culex gelidus</i> (The frosty mosquito)	+	+	+++	MVEV, KUNV, RRV BFV, JEV, others	January-April
<i>Culex palpalis</i> (Freshwater banded mosquito)	+++	++	+++	MVEV, KUNV RRV, BFV, JEV, others	January-August
<i>Anopheles bancroftii</i> (Black malaria mosquito)	+++	Nil	+	Malaria (possible)	February - July
<i>Coquillettidia xanthogaster</i> (The golden mosquito)	+++	Nil	Nil	None known	March - August
<i>Mansonia uniformis</i> (Waterlily mosquito)	+++	Nil	Nil	None known	March - June
<i>Anopheles farauti s.l.</i> (Australian malaria mosquito)	+	Nil	+++++	Malaria (probable)	March - June
<i>Culex quinquefasciatus</i> (Brown house mosquito)	+++	+	+	MVEV (possible)	January - Jun
<i>Ochlerotatus notoscriptus</i> (Receptacle mosquito)	+	+	++	RRV (probable)	Jan - June
<i>Verallina funerea</i> (Brackish water mosquito)	+++	+	++	RRV, BFV (probable)	Oct - Jan
LEGEND					
RRV - Ross River virus	MVEV - Murray Valley encephalitis virus JEV - Japanese encephalitis virus KUNV - Kunjin virus			+ Minor pest on Disease Potential	+++++ Major pest on Disease Potential
BFV - Barmah Forest 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

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

Pest Levels

* Indicative significant pest threshold levels (mosquitoes per CO₂ trap per night) at residence for relatively unprotected people at peak biting times.

Indicative significant pest threshold levels (mosquitoes per CO₂ 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.

Problem Mosquito Species In The Top End Of The NT Habitat and Flight Range Peter Whelan 1997 Medical Entomology Branch, Department of Health and Community Services			
Species/Common name	Habitat Description	Habitat Indicators	Flight Range & Pest Solutions
<i>Ochlerotatus vigilax</i> (Salt marsh mosquito)	Brackish reed swamps Upper mangrove margin and tidal creek extremities	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 <i>Schoenoplectus</i> reeds.	0 - 5 km major pest 5 - 50 km pest numbers 50 - over 200 km dispersal
<i>Ochlerotatus normanensis</i> (Floodwater mosquito)	Flooded freshwater sub-coastal or inland floodways and creeks	Broad, flat sub-coastal and inland drainage floors of minor and major creeks.	0 - 2 km major pest 2 - 5 km pest numbers
<i>Culex annulirostris</i> (Common banded mosquito)	Freshwater and coastal reed swamps. Streams, storm drains, and sewage effluents	Extensive reed swamps with <i>Eleocharis</i> or <i>Typha</i> reeds. Temporary flooded grasslands in sub-coastal and inland areas with organic matter. Sewage effluent and organic waste water with grass, <i>Lemna</i> (Duckweed), <i>Azolla</i> (water fern).	0 - 3 km major pest 2 - 10 km pest numbers 10 - 15 km dispersal
<i>Verrallina funerea</i> (brackish mosquito)	Upper reaches of mangroves with fresh water inflow. Rain filled coastal swamps	Brackish mangroves & mangrove fern. <i>Schoenoplectus</i> reed swamps. Shaded rainfilled coastal depressions & creeklines. Under beach hibiscus & <i>Casuarina</i> trees	0-500m minor pest Day pest in closed forest near breeding sites.
<i>Anopheles bancroftii</i> (Black malaria mosquito)	Freshwater and coastal reed swamps. Shaded streams and swamps	Extensive seasonally inundated <i>Melaleuca</i> paperbark swamps. <i>Eleocharis</i> and <i>Typha</i> reed swamps.	0 - 3 km major pest 3 - 5 km pest numbers
<i>Coquillettidia xanthogaster</i> (The golden mosquito)	Freshwater swamps with reeds Vegetated streams	Extensive <i>Eleocharis</i> and <i>Typha</i> reed swamps. Paperbark creek lines.	0 - 3 km major pest 3 - 5 km pest numbers
<i>Mansonia uniformis</i> (Waterlily mosquito)	Extensive freshwater reed swamp	Extensive <i>Eleocharis</i> and <i>Typha</i> reed swamps with water lilies.	0 - 2 km major pest 2 - 3 km dispersal
<i>Anopheles farauti s.l.</i> (Australian malaria mosquito)	Coastal and brackish reed swamps Freshwater swamps and vegetated streams	Brackish <i>Schoenoplectus</i> and <i>Eleocharis</i> reed swamps. Upper reaches of mangrove creeks with freshwater influence.	0 - 1.5 km minor pest 1.5 - 3 km dispersal
<i>Culex quinquefasciatus</i> (Brown house mosquito)	Storm drains, artificial receptacles Septic tanks Waste water ponds	Polluted ground or artificial receptacles. Filamentous green algae, <i>Lemna</i> (Duckweed), <i>Azolla</i> (water fern), or high organic water. Tyres, drums and other receptacles	0 - 500 m major pest 500 m - 1 km pest numbers
<i>Ochlerotatus notoscriptus</i> (Receptacle mosquito)	Tree holes or artificial receptacles	Trees with natural collections of water including <i>Eucalyptus</i> , <i>Ficus</i> , <i>Poinciana</i> and <i>Adansonia</i> . Tyres, drums, pot plant drip trays, roof gutters, rainwater tanks.	0 - 500 m minor pest 500 m - 1 km dispersal

Appendix 3 – Biting midges or “sandflies” in the NT.



**Northern
Territory
Government**

Department of Health
and Community Services

BITING MIDGES OR “SANDBLIES” IN THE NT

**PETER WHELAN
SENIOR MEDICAL ENTOMOLOGIST
DARWIN
NORTHERN TERRITORY
AUSTRALIA
July 2003**

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For more information contact:

Department of Health and Community Services
Medical Entomology Branch
PO Box 40596
Casuarina NT 0811

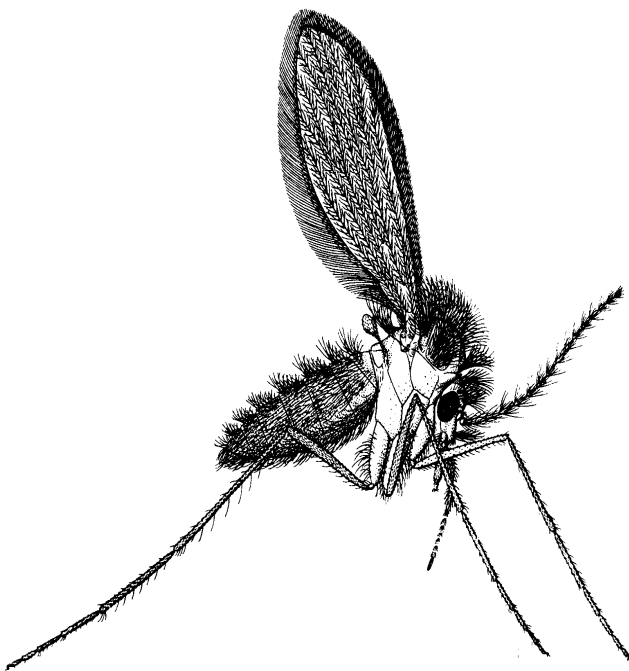
Telephone: 08 89228333
Fax: 08 89228820
Email: peter.whelan@nt.gov.au

Biting Midges or 'Sandflies' in the Northern Territory

*Peter Whelan, Senior Medical Entomologist,
DHCS
Darwin NT*

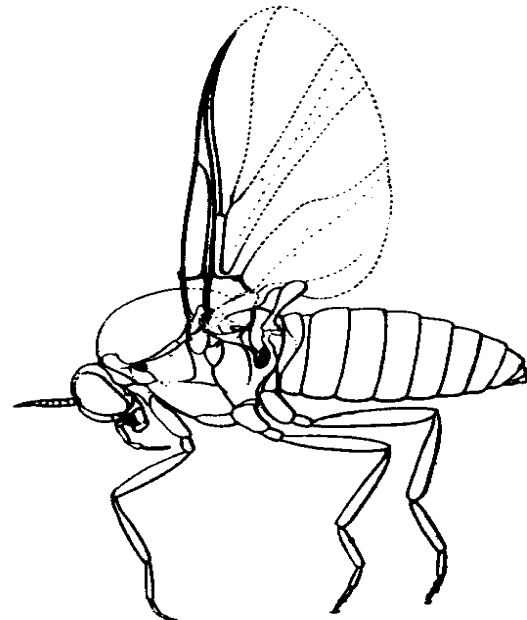
1.0 Introduction

Biting midges are small blood sucking flies in the family *Ceratopogonidae*. They are commonly referred to as "sandflies" in northern Australia. The term "sand fly" is a misused term for a number of families of small biting flies. This includes the true sandflies (Family *Psychodidae*) which are not pests of humans in Australia, as well as black flies (Family *Simuliidae*) which are serious pests in the inland areas of Qld and NSW following flooding, and the biting midges (Family *Ceratopogonidae*).¹



Phlebotomus – a female "Sand Fly"

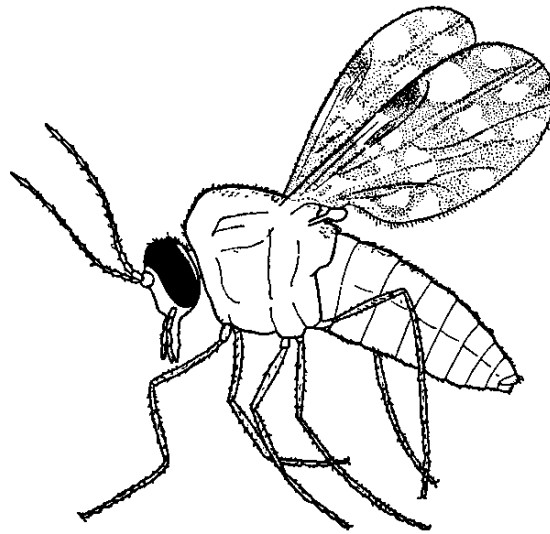
Insects of Medical Importance
British Museum 1956



Simulium – a female "Black Fly"

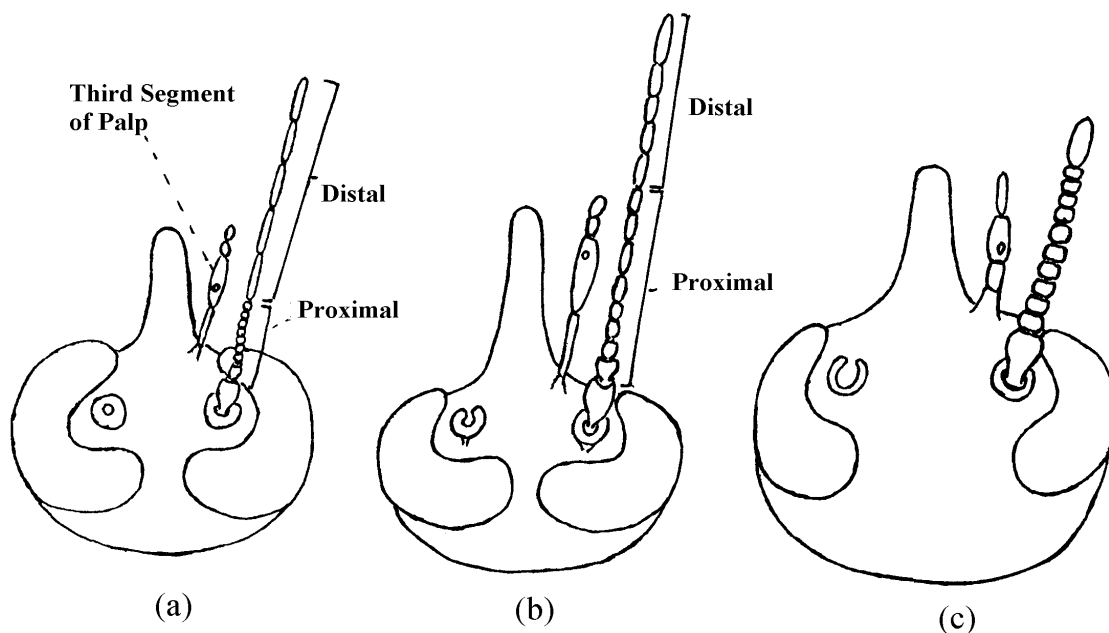
Insects of Medical Importance.
British Museum 1956

Biting midges are the major midge pest problem in Northern Australia.² A number of members of this family bite people in the Northern Territory. They include two species in the genus *Lasiohelea*, which are found biting in small numbers in shaded areas in or near dense forests during the day. A species of *Styloconops* is found in small numbers biting and swarming around the head on open sandy beaches during the day. The members of the *Culicoides* genus are more common, with many species and a wide range of breeding sites and biting habits.



Culicoides – a female “Biting Midge”

Entomology for Students of Medicine. Blackwell Scientific Ltd. 1962



Heads of *Ceratopogonidae* (Biting Midges) (a) *Lasiohelea* (b) *Culicoides* (c) *Styloconops*

Atlas of Common Queensland Mosquitoes. Queensland Institute of Medical Research, 1982

Thirty-three species of *Culicoides* have been recorded from the Darwin area.³ The *Culicoides* species include some species that don't bite vertebrates, some which preferentially bite cattle and other domestic animals, and the few species that are serious pests of people. The breeding sites include fresh water margins and cattle dung. Most of the serious human pest species breed in tidal and estuarine sites.

Culicoides midges are small, robust flies, approximately 1 mm in length with two wings usually showing a pattern of clear patches on a grey background. They have a short, forward directing proboscis or mouthparts for piercing skin and sucking blood.

Two species, *Culicoides flumineus* and *Culicoides* species near *subimmaculatus* can be severe human pests in mangrove areas across the Top End of the NT, but are rarely found outside mangrove forests.⁴

One species, *Culicoides ornatus*, sometimes referred to as the "mangrove midge", is found in association with mangroves across northern Australia, and is usually responsible for severe biting midge pest problems near the coast. This species is a major pest because it occurs in very high numbers and has a habit of invading nearby residential or recreational areas.

Culicoides ornatus is becoming an increasing problem across northern Australia due to urban development encroaching nearer to their major breeding places.^{5,6,7} They can impose serious restrictions on outdoor activities within flight range of their mangrove breeding sites due to the extremely annoying and painful bites, and to the discomforting after effects of the bites.

2.0 Bites of Biting Midges

It is only the female midges that bite. Biting midges do not transmit disease to humans in Australia. Their main human medical importance is as a biting pest.

Midges must take a blood meal for their eggs to mature. They do not, as is sometimes believed, urinate on people to cause discomfort. In the process of biting and sucking blood, they inject a salivary secretion that produces a skin reaction of varying intensity, depending on an individual's reaction. Bites usually produce a classic allergic response, with the first bite producing no noticeable effect, and the subsequent bites producing the reactions. If the exposure to midges is reasonably continuous, a process of desensitization may follow. People continuously exposed are usually tolerant to the bites, and generally have no reaction or show a mild reaction with a small red spot.⁸

The average reaction for newly exposed people is a red spot that develops a small dome shaped blister with a hole at the top. In people who are more sensitive to bites, the reaction may result in a red swelling over an area of a few centimetres. The bite area can be extremely itchy, and scratching is very difficult to avoid. Reactions may last 3 - 4 days with slowly decreasing irritation. Sometimes scratching breaks the skin and allows secondary bacterial infections that lead to unsightly sores and residual scarring.

3.0 Treatment of Bites

Mild reactions from bites require little treatment other than the application of soothing lotions. Proprietary products such as Eurax, Stingose, Medcream, Katers Lotion, Democaine and Paraderm crème can give relief from bites or prevent secondary infection. Useful non-proprietary products include tea tree oil, eucalyptus oil, aloe vera gel, or methylated spirits. Painful reactions to bites can be appreciably reduced by the intermittent application of ice packs to the bite site.

More severe reactions may need medical advice and systemic treatment using antihistamine products such as Phenergan, Telfast or Vallergran. Check with your doctor or pharmacist for available products and safety information.

4.0 Breeding Sites of *Culicoides ornatus*

Culicoides ornatus is by far the most common biting midge pest around the coast of the Northern Territory.³

This midge breeds in the highest numbers in the dry season in the mangrove mud in the creek banks of upper tidal tributaries around the mean high water neap tide mark. This corresponds to an area reached by tides from 4.8 to 6.0 m in Darwin Harbor.^{4,9} The prime breeding sites are in a narrow zone in the upper section of the creek bank associated with the occurrence of pneumatophores of the mangrove species *Avicennia marina* on narrow creek banks. The prime dry season breeding site has an upper limit where the *Avicennia* reduces in height and predominance, and a lower limit where the creek opens out from the overhanging *Avicennia* canopy.⁴ Broad mangrove areas with many tidal tributaries will have a considerable area of breeding sites.

Other breeding sites of low to medium productivity occur at the front edge of the mangrove forest in the *Sonneratia* or woodland mangrove zone facing open water. These breeding sites are usually associated with mud substrates and not with sandy substrates. Narrow beach fringing mangrove areas are usually not appreciable sources of *Culicoides ornatus*, particularly in areas with sandy substrates.⁴

Another site exploited only in the wet season is in the *Ceriops* transition zone at the back of the creek bank forest. This is just below MHWS (Mean High Water Spring or average high tide mark) or 6.6m ACD (Admiralty Chart Datum) in Darwin harbor. This is where the mixed *Ceriops* starts in a transition from the taller creek bank mangroves to the smaller mangroves in drier, less frequently flooded areas only reached by tides from 6.5 to 6.8m.

The larvae are small active worm-like creatures that are confined to the surface mud. The larvae take in excess of 6 weeks to mature, when they change into a relatively inactive, air-breathing pupa. The pupa stage lasts only two to three days and the adults emerge around the time of neap tides.⁹

5.0 The Flight Activity of *Culicoides ornatus*

The numbers of adults emerging from pupa cases is related to the lunar cycle, with sudden rises in numbers inside their mangrove breeding sites of the order of 16 times the number occurring on the previous day. The peak in emergence occurs in the two days around the neap tide, although emergence of adults can continue for up to 4 days after the neap tide.⁴

The adults mate soon after emergence. The males are short lived while the females stay in the mangroves to develop and lay their first batch of eggs. The females then start to disperse from the mangroves in an active flight inland in search of blood meals. The dispersal starts about 2 days before the spring tide, and reaches a peak around the day of the spring tide. They show a marked abundance around spring tides with full moons, but are also numerous around spring tides of the new moon.³

The adults seek shelter in winds above 8 km/hour, so that there is little tendency for them to be borne long distances by strong winds. Light breezes from their breeding areas will however aid their dispersal flight. They are active fliers and despite their small size, are relatively hardy insects.

Mass movements of adults can occur to 0.5 to 1.5 km from the mangrove margin of their major breeding sites, although they will move greater distances up creeks and rivers with dense tree cover which form avenues of humidity for dispersal. The dispersal is a purposeful one, with the midges actively flying away from the mangroves. Often higher numbers can be found up to 1.0 km from the mangroves compared to numbers in the mangroves or at the mangrove margin. Elevated hills or escarpments within 1.5 km of prolific biting midge breeding sites often exhibit higher biting midge numbers compared with lower adjacent areas. Minor pest numbers can be detected up to 3 km from the nearest mangrove margin.

Most *C. ornatus* bite in the morning and evening. There is a peak in biting activity in the one hour either side of sunset, with a smaller peak in the one-hour after sunrise of about half the sunset peak. However there is a low level of activity throughout the night.

6.0 Seasonal Abundance of *Culicoides ornatus*

The annual peak of *Culicoides ornatus* adults in the NT is in the August to October period in the late dry season, with lowest numbers in January and February during the wet season. Populations start to build up from the end of the wet season to the late dry season with a slight decrease in the coldest months of June and July. Populations start to decline rapidly after the first heavy rains occur. However pest numbers can still be present during the seasonal lows in the mid dry season and the mid wet season.

There are three different breeding sites in the mangroves, with varying seasonal productivity from the different breeding sites. Mangroves with small tidal tributaries that contain the prime creek bank breeding sites are dry season breeding sites. The greatest productivity from these creeks occurs in the August to October period. They are not significant sources of midges in the wet season.⁴ The back of small mangrove creeks in the *Ceriops* transition zones has moderate productivity in the wet season.^{4,9} Areas with extensive *Sonneratia* zones will have moderate productivity at least in the dry season⁴ and probably all year around.

Highest numbers of *Culicoides ornatus* occur for the four days around the full moon, with high numbers to a lesser extent, four days around the new moon.

7.0 Protection from Bites of *Culicoides ornatus*

7.1 Avoidance

Culicoides ornatus bite primarily in the early morning or evening around sunrise and sunset. Attacks can occur in the daytime in shaded areas adjacent to the mangroves near major mangrove breeding areas or in dense creek vegetation that is continuous with the mangrove breeding places. They will continue to bite throughout a still, humid day and warm humid night, particularly in sheltered areas outside the mangroves but close to their breeding areas. Often there is only a little biting activity in the mangroves during the day during and just after the spring tide, as all midges have usually dispersed landward.

Landward areas that are close to and within one kilometre of broad areas of mangroves with many tidal creek tributaries, especially near densely vegetated creeks that run into the mangroves, should be avoided. This particularly applies to the two days either side of the spring tides in the August to November period. Spring tides on full moons have roughly twice as many biting midges as spring tides on new moons.³

Minimum pest problems occur in the June-July period during the mid dry season or in January and February in the middle of the wet season. During any month the least pest problems occur in the two to three days either side of the neap tide, particularly neap tides following a new moon. A calendar marked with the 4 days around full moons and new moons, with highlights of seasonal peaks of abundance, can serve as a good midge avoidance reminder.

Biting midges are active under calm conditions and are generally inhibited by wind. Wind protected areas adjacent to and within 1.5km of large expanses of mangroves should be avoided around the spring tide period. People in open areas exposed to winds will experience less pest problems compared to other areas.

Elevated houses and high rise buildings have less pest problems than ground dwellings. Although midges probably fly over dense tree canopies and can fly in appreciable numbers at least 3 metres above the landscape surface, they are generally more numerous lower to the ground surface.¹¹

The worst pest problems around Darwin include areas include landward areas adjacent to the mangroves and tidal areas of Sadgroves and Reichardt Creeks, Hudson Creek, Elizabeth River, and Buffalo Creek.

The north shore of Frances Bay near Sadgroves Creek in the Charles Darwin National Park is a particularly troublesome area. This is due to the dendrite pattern of numerous narrow mangrove creeks and an extensive *Sonneratia* zone nearby. Urban areas of Stuart Park, the Narrows, and near Winnellie, which are closest to the Sadgroves creek mangroves, can experience seasonal moderate to minor pest problems. There are some minor pest problems near the lower reaches of Ludmilla creek and Alawa near Rapid Creek. Darwin city itself is relatively free from midges due to the relative lack of mangroves, the exposed cliffs, and the fact that the prevailing SE and NW winds do not blow from mangrove areas.

7.2 Clothing and Netting

Full-length trousers, socks and shoes, and long sleeved shirts will usually provide considerable protection from midge attack. Pale clothing is generally less attractive than dark clothing. Any exposed part of the body will still be subject to midge bites, with most bites occurring on the legs. Protective clothing should be supplemented with the application of repellants on exposed skin.

Clothing impregnated with permethrin or bifenthrin insecticide offers considerable protection for people continually exposed to biting midges. Impregnation involves soaking the clothing in a prescribed volume and concentration of certain formulations of the insecticide. Protective clothing such as overalls and mosquito nets impregnated with permethrin or bifenthrin will remain effective through one or two washes at the most, and will need reapplication. The insecticides in these treatments can kill the insects after they land on them, but they can also have the effect of interfering with the normal biting behaviour. Impregnated clothes with the additional use of insect repellents can provide extremely good protection.

Normal insect nets and screens are usually not adequate to restrict entry to midges unless the mesh is very fine. Tents screens in particular should have mesh diameter approximately half that of normal mosquito netting. Clothing, screens, netting or tents can be impregnated with permethrin or sprayed with permethrin, bifenthrin or repellents containing Deet to increase their efficiency.

Houses should have outward opening doors and insect screens to prevent entry when opening doors during midge activity.

7.3 Repellents

Most repellents have limitations because of their short duration of effectiveness (about 2-4 hours) and their irritability to mucous membranes around the eyes and mouth. Care is needed with young children to avoid the spread of repellent to their eyes or mouth. Repellents are also removed by perspiration.

Repellents that contain Deet (diethyl toluamide) or Picaridin as the active constituent offer considerable protection. Mixtures of natural oils or oils with natural ingredients such as herbs or antiseptics are not as effective as repellents containing Deet or Picaridin. In general effective repellents require above 10% Deet and 9% Picaridin. Repellents in lotions are more effective than alcohol based spray-ons, while gels are the most effective formulations. Repellents can also be applied to mosquito netting or insect screens, although a sample application on a small piece of netting is wise as some repellents affect synthetics. Repellents containing relatively high amounts of Deet can melt some plastics, although those containing Picaridin don't have the same effect.

Other methods of repelling biting midges include the use of coils, repellent oil lamps, and electric vapor pads impregnated with insecticide. These work satisfactorily in closed situations such as rooms, or sheltered patio and veranda situations out of the wind, where a cloud of vapour or smoke can build up. However they cannot provide satisfactory protection in windy and exposed situations.

Smoke from a fire with green leaves will give some protection in emergency situations. Burning aromatic and oil producing foliage of plants such as *Hyptis* (horehound), *Calytrix* (turkey bush), *Melaleuca* species (paperbark) and *Eucalyptus* species (gum trees) can give appreciable protection.

Rubbing the skin with the leaves of some of these plants can also provide some protection, but this is not as good as recommended repellents.

The so-called "electronic mosquito repellers" that emits a frequency that is supposed to repel biting midges by imitating the noise of males do not work and offer no protection against biting insect attack.

There is an urban myth that taking Vitamin B1 or thiamin can act as a repellent. There is no scientific evidence that Vitamin B1 acts as a repellent, or helps to reduce the reaction to insect bites by developing some immunity to the bites.¹³ Other topical applications such as a DettolTM and baby oil mixture do offer some physical barrier to biting midges, but are not as effective as Deet or Picaridin based repellents. The best protection from biting insects remains the avoidance of the problem areas at times of abundance and the use of protective clothing in combination with efficient repellents.

7.4 *Use of Lights*

Biting midges can be attracted to lights. Houses in biting midge problem areas should have dull outside lighting, with little internal light visible from outside. Lightproof curtains that can be drawn at night offer a good alternative. Outside lights should be away from insect screens, as the midges attracted to the light can then penetrate the screens. Outside lights should be yellow (or red, which is even better) to reduce their attractiveness to biting insects. Attractive lights such as large incandescent bulbs or white or ultra violet fluorescent tubes positioned a distance away from a house or building can deflect biting midges to some extent. However rows of streetlights positioned between mangroves and residential areas are not effective barriers to midge dispersal inland.¹¹

7.5 *The reduction of vegetation*

The reduction of vegetation around houses or recreation areas can reduce problems by removing shelter for the midges. A buffer of clear open space between the mangroves and residential areas can reduce biting midge numbers in a residential area, as long as the buffer is wide and subject to winds. However clear open buffers by themselves offer little protection unless they are at least 1 km wide. Mowing a wide margin around houses to eliminate dense grass can help reduce the available areas where midges can harbor.

7.6 *The use of attractant traps*

There are a number of insect attracting traps on the market. They generally use light or carbon dioxide as an attractant and either trap the insect in a container, electrocute, or drown the insects. Some are more useful than others but can not be relied to give considerable protection from bites for unprotected people in close proximity to the traps. In most cases they attract biting insects to the general vicinity and these are then diverted to people, who are more attractive targets. Some traps can help to reduce the overall population, as long as there are enough traps, the biting insect population is relatively small, and the area is isolated from re-invasion from other areas. However most trapping techniques can not cope with the huge populations of midges at one time, and those not trapped still result in a pest problem.

8.0 *Evaluation of Biting Midge Problems*

The Medical Entomology Branch of the Department of Health and Community Services has conducted numerous investigations into biting midge problems in the Top End of the NT.^{2,3,5} Potential problems have been investigated by trapping midges overnight using special carbon dioxide (CO₂) baited traps. The number of midges collected can be counted or estimated by weight or volume and identified to species under a microscope in the laboratory.

The number of bites by biting midges that constitute a pest problem will largely depend on an individual. It has been suggested that over 60 bites per hour for most experienced biting midge workers are the thresholds of acceptability. For people unaccustomed to biting midge bites, even 1 to 5 bites per hour may be considered unbearable.

There is an approximate relationship between the number of midges collected in a CO₂ trap and the number of bites that can be expected at the peak biting period. For an unprotected person, the number of bites in an hour at the peak biting time is approximately one quarter of the number collected in a CO₂ trap over one night at the same position. Thus CO₂ collections of over 240 per carbon dioxide trap per night are likely to represent a pest problem (equal to over 60 bites per hour) to unprotected people with prior experience of biting midges. Collections of over 1000 per trap per night represent over 250 bites in an hour and would constitute a major pest problem. Trap collections of over 5,000 per trap would constitute a severe pest problem.³

The numbers of *C. ornatus* collected by CO₂ traps in different locations can indicate the magnitude of the human pest problem in each location. Trapping on a constant day in relation to the tide cycle over every month in a year can give an indication of the seasonal population fluctuations. Trapping at different distances from the mangroves and in different vegetation types can give an indication of the dispersal of midges into various areas.

9.0 Control of *Culicoides ornatus*

9.1 Insecticide fogging for Adult Midges

Insecticide fogging is the application of aerosol size particles directed against active flying insects. Insecticide fogging operations in residential areas by vehicle or hand held equipment are usually not very effective measures to eliminate pest problems, due to the rapid re-infestation of midges from nearby breeding and harborage areas. Sometimes re-infestation occurs very soon after the fog has cleared, although up to 12 hours protection can be achieved in some localized situations.

For effective midge control, the entire midge breeding and harboring area near residential development needs to be fogged each day over the 3-4 day period of peak emergence. This has to be timed to coincide with the time just after the midges have emerged and before they begin to disperse out of their breeding areas. This area would also have to be relatively isolated from other such areas to prevent re-invasion. Fogging also has to be carried out during the peak activity period in the evening and early morning.

For vehicle ground based operations, the fog has to be able to drift into the target area on favorable winds of the right velocity and in the right direction. This often reduces the opportunity for effective fogging. Fogs do not usually penetrate more than 50m into dense forested areas such as mangroves, monsoon forests and other thick vegetation.

One of the major problems is determining the level of control required. A reduction of *C. ornatus* numbers by 99% may be required to reduce a large pest problem to an appreciable level. This may be impossible to achieve for various operational purposes, and if there were still any remaining pest problem, the control would not be cost effective.

In the Darwin situation, the mangrove breeding and harboring areas are generally inaccessible, too wide, or too extensive for ground based application methods to effectively reduce midge numbers, although some temporary relief would be possible in some areas.

Aerial application of insecticides aimed at adult midges in breeding and harborage areas has given the best results in overseas investigations, but in some instances there has been immediate re-infestation. It is a difficult practice, as the breeding grounds have to be closely delineated and fogging must be based

on an accurate forecast of adult emergence times. The fogging has to be with sufficient regularity to kill all the emerging dispersing females over the night and fog drift to nearby residential areas has to be avoided. Fogging is not carried out regularly for midge control in Australia and requires more local research. Fogging involves large continuing costs, which is often beyond the resources of many local authorities. Insecticide resistance and the killing of other insects pose additional potential problems.

9.2 *Barrier spraying*

The application of insecticides to create an artificial barrier or an insect killing zone around houses where biting insect harbor before biting offers some promise as a new control method. The application of residual insecticides to exterior walls, screens, patio plants, nearby hedging plants or lawns and other close vegetation may kill midges attracted to houses or people.¹⁴ Insecticides that can be used include permethrin, deltamethrin and bifenthrin. Bifenthrin has the advantage over other similar insecticides, as it appears to have less of a repellent or agitation effect on insects, is less irritant to people, is ultra violet resistant, and binds very well to surfaces to give a good residual effect.¹⁴ As with all synthetic pyrethroids, it must only be applied as per the label and kept out of fish habitats.

9.3 *Insecticide Control of Larval Habitats*

Breeding site treatment by applying insecticides to kill larvae before emergence of adults is a possible control method but there have been very few examples of successful larval treatment in mangrove areas. Larval habitat treatment involves considerable costs and organization, which is impractical in extensive breeding areas such as those surrounding Darwin. Insecticides would need to have good residual qualities and be able to penetrate dense mangrove tree cover and mud in a tidal situation. Most insecticides with these qualities would generally kill non-target insects. The problem of accurately delineating all the significant breeding sites and the seasonal fluctuation of breeding sites pose additional problems.

9.4 *Elimination of Breeding Habitats*

Reclamation of mangroves has been successful in eliminating biting midge breeding sites in various localized situations. This usually requires large amounts of fill material which is neither cheap or readily available. For *Culicoides ornatus*, the reclamation needs to extend from near the average high tide level to below the outer mangrove forest. This may involve significant engineering considerations posed by deep mud and erosion of the filled area.

Reclamation would not be practicable in most of the Darwin area because of the extensive areas involved. The destruction of large areas of mangroves would be environmentally undesirable and unacceptable to public opinion. This potential solution would only be practicable in localized areas if the breeding site was small, in close proximity to residential development, was regarded as an area of reduced environmental importance, and the filling could create a stable shore environment.

There should be conclusive evidence that the site to be reclaimed is a significant source of biting midges and that the midges are significant pests to nearby residential development. Mangroves can be an indicator of biting midge breeding sites, but the presence of mangroves does not confirm any site as the breeding place. Other specific factors such as substrate types are involved in productive breeding sites.

9.5 *Buffer zones*

There is some evidence that creating a buffer zone between urban residential development and mangrove areas can reduce the dispersal of biting midges into residential areas. Clearing of vegetation and mowing to allow wind disruption, or extensive streetlights or roads with active traffic in the buffer zone may enhance the buffer to some extent.³ However extensive testing of a modified buffer with lights and

different vegetation types in Darwin have shown that unmodified buffers and lights by themselves are not effective barriers to *C. ornatus* dispersal from mangroves to urban areas. The effectiveness of buffers is generally related to the width of the buffer and the presence of blood sources or other attractions such as light in the buffer zone. However semi-urban residential or industrial development between mangroves and urban areas can reduce midge dispersal inland. In general, unmodified buffers need to be in the order of 1.5km, and modified buffers in the order of one kilometre to offer significant reduction in numbers.

10.0 Planning Guidelines To Prevent Biting Insect Problems

The Medical Entomology Branch is involved in the planning process to reduce the effects of biting insects. Guidelines have been prepared for preventing biting insect problems in new urban and semi rural residential developments, industrial, and other developments.

In 1974 the planning for the new satellite town of Palmerston near Darwin included a buffer of at least 1-km from the mangrove boundary to urban residential development.¹² Palmerston is one of the few urban areas in Australia that has been specifically designed to minimize biting insect problems.

Good urban planning is required to;

- reduce the risk of biting insect pests
- recognize and avoid areas of biting insect breeding or harborage
- avoid costly and environmentally undesirable rectification methods
- avoid costly and ongoing biting insect control programs

The Medical Entomology Branch gives advice on what may constitute a potentially significant biting insect breeding site. In some instances detailed entomological investigations are necessary to gather sufficient information before the detailed planning stage. The avoidance of biting insect problems can be achieved in the initial planning process by consideration of development location, easements, buffer zones, and sub division design.

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Appendix 4 – Personal protection from mosquitoes and biting midges in the NT.



**Northern
Territory
Government**

Department of Health
and Community Services

PERSONAL PROTECTION FROM MOSQUITOES & BITING MIDGES IN THE NT

**PETER WHELAN
SENIOR MEDICAL ENTOMOLOGIST
DARWIN
NORTHERN TERRITORY
AUSTRALIA**

April 2004*

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For more information contact:

Department of Health and Community Services
Medical Entomology Branch
PO Box 40596
Casuarina NT 0811

Telephone: 08 89228333
Fax: 08 89228820
Email: peter.whelan@nt.gov.au

PERSONAL PROTECTION FROM MOSQUITOES & BITING MIDGES

**P. I. Whelan,
Department of Health and Community Services
April 2004**

Adapted from paper by P. Whelan in “Australian Mosquito Control Manual” by a panel of authors, Editors C. Morris and P. Dale. Australian Mosquito Control Association, 1998, ISBN 0-646-35310-1.

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, Muskol, 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 can not 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, Medicrome, 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 usually give immediate relief for painful and itchy bites and swelling or blisters from 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 Vallergran. 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, warnulpa, 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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**Northern
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Department of Health
and Community Services

Biting Insect Assessment

**Andranangoo Creek West and Lethbridge Bay
West mining prospects, Tiwi Islands**

29 September -1st October 2005

25 October 2005

**Study undertaken on behalf of URS Australia PTY LTD
for
Matilda Minerals Ltd**

Allan Warchot & Peter Whelan

For further information contact:

Medical Entomology Branch
Centre for Disease Control
Department of Health and Community Services
PO Box 40596
Casuarina NT 0811

Telephone: (08) 8922 8337
Fax: (08) 8922 8820
E-mail: medicalentomologyrdh@nt.gov.au

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1. Introduction

1.1 Background

Matilda Minerals Limited (Matilda) proposes to develop sand mining operations at Andranangoo Creek West (Andranangoo) and Lethbridge Bay West (Lethbridge), Melville Island, Tiwi Islands, Northern Territory. The proposed operation will extract high grade heavy minerals (HM), specifically zircon and rutile, for export to China. It is estimated that a total of 99,000 t of zircon and rutile will be exported during the anticipated sand mining operation over three and half years. A proposal to mine both sites was submitted to the NT Government in the form of a Notice of Intent Document (URS, 2005).

The NT Government determined the project is to undergo formal environmental assessment in the form of an Environmental Impact Assessment (EIS). Part of the EIS process is to conduct a biting insect assessment of the general project areas to determine any public health risks to workers and the potential for mining activities to alter the natural environment and create further biting insect breeding sites. The Medical Entomology Branch was commissioned by URS Australia on behalf of Matilda Minerals to undertake a biting insect assessment at both proposed sandmining sites.

The Medical Entomology Branch was commissioned to;

1. Examine aerial photography to determine potential biting insect breeding sites.
2. Conduct trapping in late September 2005 to determine potential peak late dry season numbers of the salt marsh mosquito and assess the potential abundance of other mosquito species.
3. Conduct brief investigations of natural biting insect breeding sites occurring in and adjacent to the project sites, to determine the potential source of any biting insects at the project sites.
4. Conduct peak season trapping one day before the full moon in November 2005 to determine potential peak seasonal biting midge numbers, trapping one day before the full moon in January 2006 to assess mid wet season abundance of freshwater breeding mosquitoes, and trapping one day before the full moon in May 2006 to assess post wet season peaks in various freshwater and brackish water mosquito species.
5. Conduct an assessment of the project sites during trapping in late September to determine the potential for the creation of new mosquito breeding sites as a result of mining activities.
6. Provide guidance on how to prevent mining activities from creating new mosquito breeding sites.
7. Provide information on how to reduce biting insect populations and prevent mosquito borne disease transmission at the development sites.

1.2 Investigation

Late September biting insect trapping was conducted on the night of the 29th at the Andranangoo Creek West prospect, and on the night of the 30th at the Lethbridge Bay West prospect. As part of the biting insect assessment, brief investigations were also conducted at the natural breeding sites surrounding the mining prospects, and brief investigations were also carried out in the actual prospect areas. The following report details the findings of the adult biting insect investigation carried out from the 29th of September to the 1st of October 2005. Results from the peak season trapping will be addressed in a supplementary report once trapping in May 2006 has been completed.

1.3 Acknowledgements

The Medical Entomology Branch would like to thank Julie Marris and James Collins of URS Australia Pty Ltd for arranging the flights for the September 29 to October 1 field visit, as well as supplying MEB with rectified aerial photographs of the project sites, to assist in the preparation of figures.

The Medical Entomology Branch would like to thank Dennis McCamish of Matilda Minerals, who was the site manager at the construction camp. Dennis assisted MEB officers in on-site navigation by

providing information on access tracks and providing a 4WD vehicle, and organised accommodation and meals.

The field survey and trapping was conducted by Allan Warchot and Huy Nguyen. Mosquitoes were identified by Huy Nguyen and Michael Browne. Biting midges were identified by Nina Kurucz and Allan Warchot. Figures were prepared by Jane Carter of MEB, tables were prepared by Allan Warchot. The report was written by Allan Warchot, with guidance and review from Peter Whelan, Director MEB.

2. Project Aims

2.1 Aims

The aim of the biting insect study was to outline existing and potential mosquito and biting midge pest problems at the Andranangoo Creek West and Lethbridge Bay West prospects, due to the absence of information on biting insect species diversity and abundance at or nearby to the prospect areas. Additional aims were to evaluate the mining plans and survey the project areas, to determine the possibility of mining activities creating new mosquito breeding sites. A brief field survey was planned to evaluate current mosquito and biting midge numbers and species diversity, and evaluate the prospect areas for current mosquito breeding sites. The information from the trapping was to be assessed for likely seasonal abundance at the prospect sites, taking into consideration available biting insect information from the MEB database and previous field investigations, and information regarding seasonal abundance of various important pest species. Further biting insect trapping was proposed for November 2005, January 2006 and May 2006, to further assess biting insect numbers at the prospect sites.

An initial report is to be prepared outlining the results of the initial field survey and trapping, as well as providing an assessment of current and potential biting insect problems, and a discussion on mining activities and management considerations. The initial report is to be used to provide information for the Environmental Impact Statement. A supplementary report will outline and discuss the findings of the November 2005, January 2006 and May 2006 biting insect trapping.

2.2 Significance and scope of the project

A biting insect evaluation is required under the planning provisions by the NT Government. It is a requirement to consider the impact of development on biting insect populations, and the impacts of biting insects on the workforce.

Biting midges can be considerable pests within a few kilometres of the coast in the NT (Whelan 1991). These pests can disrupt the work force by causing direct effects due to their painful bites, and indirect effects due to secondary infection and loss of a sense of well being. As the study sites are located adjacent to tidal mangrove creek areas, it was considered a possibility that pest biting midges would be present at the development sites, in particular the mangrove biting midge *Culicoides ornatus*.

Culicoides ornatus reaches monthly peaks in population around the full moon. Peak numbers generally occur from three days before the full moon to one day before the full moon, with seasonal peaks expected in the months of August to November. Peak season trapping is proposed to occur one day before the full moon in November 2005 to sample peak season numbers of *C. ornatus*. The results of this survey are to be discussed in a separate supplementary report.

Mosquitoes are a serious potential public health issue in the NT, both as pest insects and as vectors of a number of human diseases including the potentially fatal Murray Valley encephalitis virus, and a number of other diseases caused by Kunjin Virus, Ross River virus and Barmah Forest virus. The Andranangoo Creek West and Lethbridge Bay West prospects are located adjacent to extensive tidal and freshwater influenced swamps, which could be expected to provide breeding sites for a number of mosquito species such as the salt marsh mosquito *Ochlerotatus vigilax*, the common banded mosquito *Culex annulirostris* and the North Australian malaria mosquito *Anopheles farauti* s.l.

The salt marsh mosquito *Oc. vigilax* peaks in numbers from 10 to 15 days following monthly high tides or over 25mm of rain from September to January. The timing of initial trapping at the Andranangoo Creek West and Lethbridge Bay West prospects was designed to fall within this period after the September 2005 monthly high tides. The common banded mosquito *Culex annulirostris* is most abundant in the months of January to August, generally with a mid wet season peak in January, and post wet season peaks in April and May in those areas nearby to extensive swamps. Trapping in

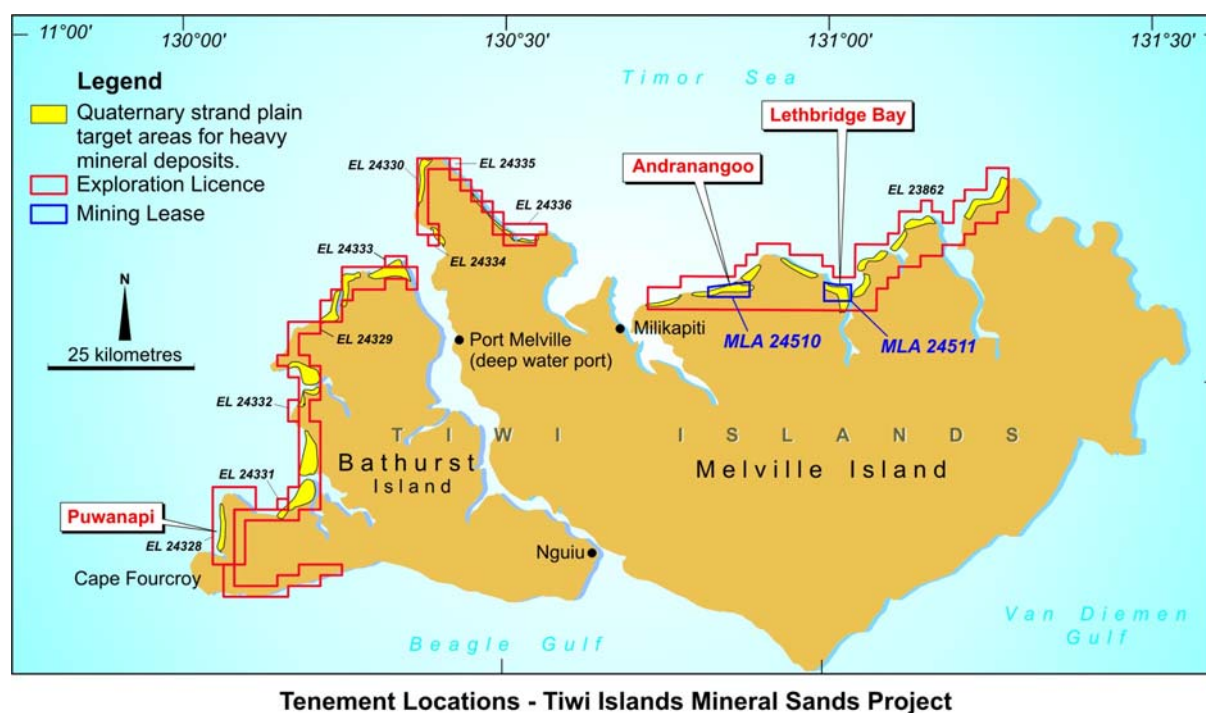
January 2006 and May 2006 has been planned to sample peak numbers of this species. The North Australian malaria mosquito peaks from April to June, with trapping in May 2006 designed to locate peak season numbers of this species. The results of the January 2006 and May 2006 trapping will be discussed in a separate supplementary report.

An evaluation of the prospect areas, the mining method, together with knowledge of the potential habitats created by mining were used to evaluate potential mosquito breeding sites. Preventative measures or management procedures have been recommended to prevent the development from creating new mosquito breeding sites, and reduce biting insect pest problems.

2.3 Study site

Both study sites are located in relatively remote areas of Melville Island, which is part of the Tiwi Islands located 60km north of Darwin. The Andranangoo Creek West prospect is located adjacent to an extensive brackish water and freshwater swamp to the east, and a tidal creek mangrove area to the west. The Lethbridge Bay West prospect is located adjacent to an extensive tidal mudflat to the west, and a tidal creek mangrove area to the east. The study areas are shown in detail Figures 1-4, with a general outline of the study areas shown in Figure 5 below.

Figure 5



3. Methods

Adult biting insect sampling

Four adult trap sites were chosen at each mining prospect, which was designed to locate problem areas and likely breeding sites. The location of each trap site was saved using a Garmin hand held GPS unit and marked with flagging tape, to aid in the future location of the trap site, and to allow trap sites to be plotted on a rectified aerial photograph. The trap locations are shown below.



Trap Site 1 – Andranangoo Creek West. North edge of Andranangoo Creek West reed swamp, adjacent to NW arm of swamp. In Paperbark margin at edge of swamp.



Trap Site 2 – Andranangoo Creek West. Near western limit of proposed mining area, in Eucalypt woodland. Mangrove swamp in background.



Trap Site 3 – Andranangoo Creek West. Approximately 50m north of construction camp, in Eucalypt woodland.



Trap Site 4 – Andranangoo Creek West. 3km south of construction camp, in Eucalypt woodland. Note the recently burnt area.



Trap Site 5 – Lethbridge Bay West. In Melaleuca/coastal vine forest northwest edge of proposed mining area, adjacent to northwest edge of extensive mudflat. The mudflat can be seen in the background.



Trap Site 6 – Lethbridge Bay West. In Melaleuca forest adjacent to the eastern end of the proposed mining area.



Trap Site 7 – Lethbridge Bay West. In eucalypt open woodland near proposed construction camp.



Trap Site 8 – Lethbridge Bay West. In eucalypt open woodland 3km south of proposed construction camp.

Due to time constraints, four of the trap collections were taken live to the MEB laboratory, killed by freezing and sieved to separate the midges from mosquitoes. The other four trap collections were killed by freezing at the Andranangoo Creek West construction camp and sieved to separate the midges from the mosquitoes. The midges were stored in 70% alcohol in individual vials for each collection. All trap collections were taken to the MEB Laboratory in Darwin for identification.

The biting midges from each collection were randomly sub-sampled (50 individuals per sub-sample) when collections were over 50 individuals and identified with the aid of light microscopes using taxonomic references and wing photos (Dyce and Wellings 1998, Wirth and Hubert 1989). If the collection was less than 1000 individuals, the remaining bulk was examined for any additional species not detected in the original sub-sample of 50. If the collection was more than 1000 individuals, a separate sub-sample of approximately 600 individuals was examined for any additional species not detected in the original sub-sample of 50. Total numbers were estimated for each catch using a standard volume/number comparison method. All species and totals for each individual collection were then entered into a database for future evaluation.

Mosquitoes were stored in a petri dish or plastic container in the MEB Laboratory freezer. Seven of the eight mosquito collections were over 300 individuals, for which a sub-sample of 300 was taken for identification. The sample and sub-sample weights were used to calculate total numbers. The bulk of the collections were checked for any species not detected in the sub-sample. All species and totals for each individual collection were then entered into a database for future evaluation.

Larval mosquito sampling

Potential mosquito breeding sites were inspected and sampled using a standard 270ml volume ladle, painted white on the inside to aid in the visual location of larvae. Actual and potential mosquito breeding sites were marked using a hand held Garmin GPS unit. Larval mosquitoes were killed immediately after sampling with 70% alcohol, to prevent the mosquito larvae from advancing through their larval stages and misrepresenting the results of the larval survey. Mosquito larvae were taken back to the MEB Laboratory in Darwin and identified with the aid of light microscopes and various taxonomic keys.

4. Results

4.1 Field survey 29th September 2005 – 30th September 2005

Brief larval mosquito sampling was undertaken at both prospect areas, to locate major actual and potential mosquito breeding sites. The prospect areas were also surveyed to determine the likelihood of mining activities creating new mosquito breeding sites. The results of the larval sampling are presented in Table 5, with sampling points at Andranangoo Creek West shown in Figure 3, and sampling points for Lethbridge Bay West shown in Figure 4. Photos are shown in Appendix 1. The results of the larval sampling are discussed below.

Andranangoo Creek West 29th September 2005

Larval Site 1 – Larval mosquito sampling was undertaken in the NW section of the main body of the extensive reed swamp associated with Andranangoo Creek, adjacent to the prospect area. Most of the swamp was still significantly flooded, although much of the swamp appeared relatively shallow. This was evident by the abundance of emergent vegetation, with virtually the entire swamp containing some form of emergent vegetation, such as *Eleocharis* and *Schoenoplectus* reeds, as well as grasses. The edge of the water was approximately 10m from the paperbark fringe, indicating that in dry years the swamp is likely to retreat further than what was observed. The specific conductivity of the site was 2.5 mS/cm, indicating freshwater.

Larval mosquito sampling was restricted to the edge of the swamp, with minor mosquito breeding located in small cut off pools and vegetated margins. The species found breeding in densities of 0.2 larvae per ladle dip were *Culex annulirostris* and *Cx. (Lop) species 155*. An abundance of aquatic predators of mosquito larvae were present in the sparsely vegetated areas, such as water beetles and fish.

Larval Site 2 – Larval mosquito sampling was also undertaken at the southern end of the peninsular that runs across the northern end of the reed swamp. Water in this section of the swamp was deeper than Larval Site 1, with the water still flooded up to the paperbark fringe. Thick stands of *Eleocharis* reeds were present in large sections of this part of the swamp, with some isolated patches of *Schoenoplectus* reeds and large grassy areas. Some deeper pools vegetated with water lilies were also present, with an abundance of aquatic predators such as water beetles and fish. No mosquito larvae were detected. The specific conductivity of the site was 1.9 mS/cm, indicating freshwater.

Larval Site 3 – This site was at the entrance to a small arm on the northern edge of Andranangoo Creek West reed swamp, and was characterised by very large, dense areas of partially flooded *Eleocharis* reeds on the upstream side of the entrance, and flooded *Eleocharis* and *Schoenoplectus* reed and grassy areas on the downstream side. High numbers of adult salt marsh mosquitoes were biting while walking through the dry reed areas, indicating this site was probably a breeding area for the salt marsh mosquito during the monthly high tides 10 and 11 days previous. No mosquito larvae were located. The specific conductivity of the water at this site was 1.9 ms/cm, indicating freshwater.

Larval Site 4 – This site was the upper extremities of the small arm of the Andranangoo Creek West reed swamp, and was characterised by mainly bare, partially flooded mudflat, with some *Eleocharis* reeds in the NW corner. A small ephemeral stream led into the SW corner of the mudflat. Mosquito larvae were located at the edges of the partially flooded mudflat in concentrations of 1 larvae per ladle dip, with the species located being *Anopheles hilli* and *Culex sitiens*. The specific conductivity of the site was 22.2 ms/cm, indicating brackish water. This site was a probable salt marsh mosquito breeding site during the previous tides.

Larval Site 5 – This site was the southern edge of an extensive *Melaleuca* swamp, which will most likely be flooded to some extent during the wet season. This site is a potential mosquito breeding site during the wet season.

Larval Site 6 – This site was an interdune area behind the main beach dune, adjacent to the western side of the prospect area, and was dry at the time of the survey. Vegetation consisted of Coastal Vine forest. It appears unlikely that significant surface water ponding will occur for extended periods at this site, if at all. This area is typical of other coastal vine forest areas in the prospect area.

Larval Site 7 – This site was a dune area consisting of *Melaleuca* vegetation, adjacent to the western side of the prospect area. The presence of *Melaleuca* vegetation indicates the water table will probably be at the surface in the wet season, although surface water ponding probably does not occur to any great extent. This site is typical of the other *Melaleuca* forests in the prospect area.

Larval Site 8 – This site was the upper reaches of a *Melaleuca* flowline that grades gently towards the Larval Site 5 Paperbark Swamp. The site was dry at the time of survey. This site is likely to be flooded to some extent after heavy monsoon rainfall.

Larval Site 9 & 10 – These sites were excavated pits in the prospect area, both of which were below the water table. The water in the Larval Site 9 test pit was 0.1ms/cm, and the water in the Larval Site 10 pit was 0.5 ms/cm, indicating freshwater. No breeding was located.

Lethbridge Bay West 30th September 2005

Larval Site 11 – This site was an isolated pool in the northern section of an extensive tidal mudflat. No mosquito breeding was located. There were large numbers of adult *Oc. vigilax* present while walking on the mudflat, presumably they were resting/laying eggs in the cracks in the mud and began biting when our presence was detected. The southern reaches of the mudflat appeared extensively flooded, although was not surveyed. According to aerial photography (Figure 2), there appears to be some extensive reed areas at the top end of the swamp where seasonal stream flows occur. Due to the presence of large numbers of *Oc. vigilax* adults, it can be presumed that the mudflat is a very significant breeding site for this species.

Larval Site 12 – This site was a *Melaleuca* and Coastal Vine forest between the large mudflat and the coast. This site is representative of most of the *Melaleuca* dominated sections of prospect area, and it appears that surface water ponding will probably be negligible in these areas in the prospect area, due to the absence of extensive low lying areas and creeklines.

Larval Site 13 – This site was a coastal vine forest behind the main beach dune, with some scattered *Melaleuca* trees. The site is representative of most of the coastal vine forest sections of the prospect area, and appears to be well drained, due to the absence of any extensive low lying areas.

4.2 Biting midge trapping

The summary of the adult mosquito trapping results for the September 29th – October 1st trapping at Andranangoo Creek West and Lethbridge Bay West are shown in Tables 1 & 2 respectively. Trap locations are shown in Figures 1 & 2.

Andranangoo Creek West

Species present

A total of five (5) species of biting midge were collected during trapping at the Andranangoo Creek West mining prospect area on the night of the 29th September 2005. The most common species of biting midge trapped was *Culicoides marksii*, accounting for 57% of all midges, followed by

Culicoides undescribed species No. 6 (30%), *Culicoides ornatus* (3.41%) and *Culicoides austropalpalis* (1 %), with a single *Lasiohelius* sp. specimen also collected (Table 1).

Spatial abundance

Trap Site 3 collected the majority of biting midges, accounting for 80% of all biting midges collected. Trap Site 2 was the next most abundant trap site, accounting for 18% of all biting midges collected, with Trap Site 1 recording 2% of total midges collected, and Trap Site 4 accounting for 0.27% of total midges collected (Table 1). It should be noted that there were recent extensive fires in the general area surrounding Trap Site 4, with the residual smoke likely to have contributed significantly to the very low numbers collected in this trap.

Lethbridge Bay West

Species present

A total of seven (7) species of biting midge were collected during trapping at the Lethbridge Bay West mining prospect area on the night of the 30th September 2005. The most common species collected was *C. austropalpalis*, accounting for 58% of all biting midges trapped, followed by *C. undescribed species no. 6* (23%), *C. marksi* (4%), *C. ornatus* (1.37%), *C. narrabeenensis* (1.10%) and *C. histrio* and *C. bundyensis*, for which single specimens were recovered (Table 2).

Spatial abundance

Trap Site 6 collected the most biting midges, accounting for 46% of all biting midges trapped. Trap Site 7 was the next most productive trap, accounting for 40% of total biting midges trapped, followed by Trap Site 8 (12%) and Trap Site 5 (3%) (Table 2).

4.3 Mosquito trapping

The summary of the adult mosquito trapping results for the September 29th – October 1st trapping at Andranangoo Creek West and Lethbridge Bay West are shown in Tables 3 & 4 respectively. Trap locations are shown in Figures 1 & 2. The spatial abundance of the salt marsh mosquito *Ochlerotatus vigilax*, the common banded mosquito *Culex annulirostris*, the North Australia Malaria mosquito *Anopheles farauti* s.l. and the golden mosquito *Coquillettidia xanthogaster* are shown in Figures 1 & 2.

Andranangoo Creek West

Species present

A total of thirteen (13) species of mosquitoes were collected during trapping on the night of the 29th September 2005 at the Andranangoo Creek West mining prospect area. The most common mosquito species trapped was the salt marsh mosquito *Ochlerotatus vigilax*, accounting for 59% of all mosquitoes trapped. This was followed by *Culex annulirostris* (24%), *Coquillettidia xanthogaster* (6%), *Anopheles bancroftii* (4%), *Culex sitiens* (3%) and *Anopheles farauti* s.l. (1%) (Table 3). All other mosquito species were trapped in very low numbers.

Spatial abundance

Trap Site 1 was the most productive trap site, accounting for 66% of all mosquitoes trapped. This was followed by Trap Site 2 (23%), Trap Site 3 (12%) and Trap Site 4 (0.3%). It should be noted that there were recent extensive fires in the general area surrounding Trap Site 4, with the residual smoke the likely cause of the very low numbers collected in this trap (Table 3).

Trap Site 1 collected the most *Oc. vigilax*, with a total of 1685 females. This was followed by Trap Site 2 (344), Trap Site 3 (279) and Trap Site 4 (9) (Table 3, Figure 1).

Trap Site 1 collected the most *Cx. annulirostris*, with a total of 526 females. This was followed by Trap Site 2 (300) and Trap Site 3 (114), with no *Cx. annulirostris* specimens collected at Trap Site 4 (Table 3, Figure 1).

Trap Site 2 collected the most *Cq. xanthogaster* (198), followed by Trap Site 3 (28), Trap Site 1 (14) and Trap Site 4 (2) (Table 3, Figure 1).

Trap Site 1 collected the most *An. farauti s.l.* (28), followed by Trap Site 3 (14) and Trap Site 2 (7), with no specimens collected at Trap Site 4 (Table 3, Figure 1).

Anopheles bancroftii were only collected at Trap Site 1, with 168 adult females collected (Table 3, Figure 1)

Lethbridge Bay West

Species present

A total of nine (9) species of mosquitoes were collected during trapping on the night of the 30th September 2005 at the Lethbridge Bay West mining prospect area. The most common species trapped was the salt marsh mosquito *Oc. vigilax*, accounting for 81% of all mosquitoes trapped. This was followed by the common banded mosquito *Cx. annulirostris* (13%), *Cx. xanthogaster* (5%), with all other mosquito species trapped in very low numbers (Table 4).

Spatial abundance

Mosquitoes were relatively evenly distributed amongst the four trap sites at the Lethbridge Bay West prospect area, with Trap Site 7 accounting for 30% of total mosquitoes trapped, Trap Site 8 accounting for 26% of total mosquitoes trapped, followed by Trap Site 5 (23%) and Trap Site 6 (21%) (Table 4).

Ochlerotatus vigilax was most abundant at Trap Site 7, with 2125 adult females collected at this trap site (Table 4, Figure 2). Trap Site 5 collected the second highest total of *Oc. vigilax*, with 1529 adult females collected, followed by Trap Site 8 (1498) and Trap Site 6 (1298) (Table 4, Figure 2).

Culex annulirostris was most abundant at Trap Site 8, with 311 adult females collected at this trap site (Table 4, Figure 2). This was followed by Trap Site 6 (285), Trap Site 5 (228) and Trap Site 7 (179) (Tables 4, Figure 2).

Coquillettidia xanthogaster was most abundant at Trap Site 8, with 196 adult females collected at this trap site, followed by Trap Site 7 (77), Trap Site 6 (76) and Trap site 5 (57) (Table 4, Figure 2).

5. Discussion

5.1 Biting midges

Andranangoo Creek West

Species present

There were five species of biting midge collected during trapping at the Andranangoo Creek West prospect area. The most important species trapped was *C. ornate*. This species is the major human pest biting midge species around coastal mangrove areas in northern Australia. Other biting midge species collected that are of minor pest significance were *Culicoides marksi* and *Lasiohelius* sp. All other species collected do not bite humans to any appreciable degree so are of no pest importance to the development.

Probable breeding sites

The actual breeding sites for *C. ornatus* affecting the Andranangoo Creek West prospect area have not been located. However the breeding sites can be inferred from studies conducted in other areas of Darwin Harbour (Shivas et al 1997, Shivas 1999, Whelan 2003). Potential breeding sites are highlighted in Figure 1.

Investigations of breeding sites in Darwin Harbour have located the breeding sites of *C. ornatus* by adult emergence trapping (Shivas et. al. 1997, Shivas 1999). The midge breeds in the dry season in the mangrove mud in the creek banks of upper tidal tributaries between Mean Low Water Neap (MLWN) and Mean High Water Neap (MHWN). Larval sampling has revealed significant breeding at tidal elevations of 4.7m ACD to 5.5m ACD at creekbank habitats (Shivas 1999). The prime breeding sites are in a narrow zone in the upper section of narrow creek banks associated with the occurrence of pneumatophores of the mangrove species *Avicennia marina*. The prime dry season breeding site has an upper limit where the *Avicennia* reduces in height and predominance, and a lower limit where the creek opens out from the overhanging *Avicennia* canopy (Shivas 1999). Breeding also occurs in a broad band centred around the edge of the vegetation line on the upper part of the creekbank i.e just above MHWN (Shivas 1999, Shivas 2001).

Other breeding sites of low to medium productivity occur at the front edge of the mangrove forest in the *Sonneratia* mangrove zone facing open water. These breeding sites are usually associated with mud substrates and not with sandy substrates. Narrow beach fringing mangrove areas are usually not appreciable sources of *C. ornatus*, particularly in areas with sandy substrates (Shivas 1999). Wet season emergence in foreshore breeding habitat shifts from the *Sonneratia* mangrove zone into the adjacent *Rhizophora* zone (Shivas 1999, Shivas & Whelan 2001).

During the wet season, emergence on the creek bank decreases to insignificant levels in direct response to rainfall (Shivas et. al. 1997). Significant emergence in the wet season shifts to the *Ceriops* transition zone at the back edge of the creek bank forest. This is just below MHS (Mean High Water Spring or average high tide mark) or 6.9m ACD in Darwin Harbour. This is where the mixed *Ceriops* starts in a transition from the taller creek bank mangroves to the smaller mangroves in drier, less frequently flooded areas only reached by tides from 6.5 to 6.8m.

The *C. ornatus* breeding sites affecting the development area are likely to be associated with the small tidal creek located adjacent to the western limit of the prospect area, and the Andranangoo Creek tidal creek mangrove areas located adjacent to the eastern limit of the prospect area. There is an absence of extensive *Sonneratia* foreshore mangrove areas adjacent to the prospect area, so it is unlikely that foreshore mangrove areas will be extensive sources of *C. ornatus* to the Andranangoo Creek West prospect area. The upper tidal creek breeding sites appear limited in potential, due to the absence of

numerous small tidal tributaries that generally indicate significant breeding sites. Trapping in November 2005 will show if significant breeding sites exist adjacent to the prospect area.

Culicoides marksi breed at the edges of freshwater lakes and streams (Whelan 1998), although this species is thought to also breed in brackish coastal situations (Reye 1992). The large freshwater and brackish water reed swamp at the eastern end of the prospect area is the most likely source of this species to the prospect area.

The breeding sites for most Australian *Lasiohelia* sp. are unknown, although some species are thought to breed in damp, surface-terrestrial environments, which can include patches of tropical rainforest, and general vegetation ranging from wet-sclerophyll forest to open grassland (Debenham 1983). *Lasiohelia* larvae have previously been collected on habitats such as mosses, algae on rocks, soil and wet wood (Debenham 1983). In the NT, *Lasiohelia* Sp. have been recorded from monsoon vine forests (Whelan et al 1997c) The development site contains areas of monsoon vine forest, which probably contain small breeding sites for some *Lasiohelia* species.

Spatial abundance and dispersal

Culicoides ornatus are generally found in high numbers 1 to 2km inland from the mangrove margin, with greatest numbers within 1 to 1.5km of the mangrove margin (Shivas and Whelan 2001). Low levels of *C. ornatus* can be encountered at least 3.5km from the nearest mangroves (Shivas and Whelan 2001). *Culicoides ornatus* numbers are elevated around the full and new moon periods, with full moon abundance generally around twice as large as new moon abundance (Shivas 1999, Shivas & Whelan 2001).

In some areas of Darwin Harbour, two peaks in *C. ornatus* numbers occurs over a 4 day period during the full and new moons, the first peak resulting from females leaving the mangrove foreshore (*Sonneratia*) breeding sites, and the second peak occurring four days later resulting from females leaving the upper tidal creek breeding sites (Shivas and Whelan 2001). The presence of two waves of dispersing females results in heightened midge levels for at least 6 days in each fortnight (Shivas and Whelan 2001).

The highest number of *C. ornatus* was recovered from Trap Site 2, which was located adjacent to the small tidal creek near the western limit of the prospect area. Other trap sites recorded very low numbers of this species. Trapping was conducted five days before the new moon, and as peak abundance generally occurs from three days to one day before the full or new moon, it indicates that peak new moon numbers were missed. The limited numbers inland of the tidal creek areas is a result of trapping being conducted before peak abundance and dispersal was expected to occur. Trapping one day before the full moon in November will provide a true indication of the spatial abundance and dispersal characteristics of *C. ornatus* in the prospect area.

Lasiohelia sp. was only recorded as a single specimen at Trap Site 1. Little information is known about the spatial abundance and dispersal characteristics of *Lasiohelia* species in Australia, although Reye (1992) states that the pest range of *Lasiohelia townsvillensis* appears to be around 50 metres unless the breeding area is large and productive.

Culicoides marksi was recorded in relatively high numbers at Trap Site 3, with low numbers elsewhere. Little information is known about the dispersal characteristics of this species, although the presence of relatively high numbers of this species at Trap Site 3 suggests *C. marksi* can disperse over 1km from their breeding sites.

Seasonal abundance

Culicoides ornatus are generally most abundant during the dry season, with numbers increasing through the dry season to the peak August to November period, and lowest numbers occurring towards the end of the wet season (Shivas & Whelan 2001). A peak in dispersal also occurs in the early dry

season (April and May) (Shivas and Whelan 2001). The population build-up during the dry season could be a result of upper tidal creek larval habitats shifting from the late wet season transitional zone to the more productive (approximately 5 times) dry season creekbank habitats (Shivas and Whelan 2001). The trend of increasing midge numbers through the dry season could also occur as a result of a natural population build-up while conditions are favourable (Shivas and Whelan 2001). The seasonal abundance of *C. ornatus* at the Andranangoo Creek West prospect area is likely to follow this usual trend.

Culicoides marksii has been described by Whelan (1998) as being most abundant in the early wet and post wet to mid dry seasons, with low populations in the late dry season. Trapping was conducted in the late dry season, which means numbers of this species in the prospect area are likely to be higher during the peak season months in the early wet and post wet to mid dry seasons.

Lasiohelia sp. was only located as a single specimen at Trap Site 3. *Lasiohelia* sp. was most abundant from January to March inclusive during the baseline trapping program at Wickham Point (Warchot and Whelan 2004), and were most abundant from January to May inclusive during the baseline trapping program at Durack (Fairway Waters) (Whelan et al 1998). This indicates that *Lasiohelia* sp. in the Darwin region generally occur in the mid to late wet seasons, and it is these months that *Lasiohelia* sp. are most likely to be present in the prospect area.

Lethbridge Bay West

Species present

There were seven species of adult biting midge collected during trapping at the Lethbridge Bay West prospect area, with the most important species being *C. ornatus*. The other species collected of minor importance was *C. marksii*. All other biting midge species collected do not usually bite humans so are of little pest importance to the development. Due to the presence of *Lasiohelia* sp. at the Andranangoo Creek West prospect area, it is likely that this species will also be present at the Lethbridge Bay West prospect area, as there are similarities in the nearby habitats.

Probable breeding sites

The probable breeding sites for *C. ornatus* at the Lethbridge Bay West prospect area are likely to be associated with the small tidal creek located to the east of the prospect area. There is an absence of nearby extensive areas of *Sonneratia* foreshore mangroves, although there appears to be narrow areas of foreshore mangroves to the east of the prospect area. The narrow area of foreshore mangrove appears to be located on sandy substrates, which will limit the potential for *C. ornatus* breeding. Potential breeding sites are highlighted in Figure 2.

The breeding sites for *C. marksii* at the Lethbridge Bay West prospect area are likely to be associated with the margins of the upper reaches of the large tidal swamp, where seasonal stream flows occur, as there appears to be semi-aquatic vegetation associated with the bottom end of the streams, which could provide habitat for *C. marksii*.

Spatial abundance and dispersal

The highest number of *C. ornatus* was collected at Trap Site 6, located near the eastern end of the prospect area. Trapping was conducted four days before the new moon, indicating peak new moon numbers were missed. Trapping one day before the full moon in November will provide a clearer indication of the spatial abundance and dispersal characteristics of *C. ornatus* in the prospect area.

Culicoides marksii were recorded at Trap Sites 7 & 8 only, indicating these trap sites were probably located closer to the breeding sites for this species, i.e. the top end of the adjacent swamp, or were located in preferred harbourage areas.

Seasonal abundance

Please refer to Section 5.1, Andranangoo Creek West Seasonal abundance, for a discussion on likely seasonal abundance of important biting midge species at the Lethbridge Bay West prospect area.

5.1.1 Pest problems and public health

Culicoides ornatus pest problems at the proposed mining areas will be of a lesser magnitude compared to those pest problems experienced in some urban areas of Darwin and Palmerston. The prospect areas are not located near large tidal creeks with numerous tidal tributaries or large areas of *Sonneratia* foreshore mangroves, which are the major source of high numbers of *C. ornatus*. The small tidal creeks adjacent to the prospect areas are possibly sources of low to moderate pest numbers of *C. ornatus* in the dry season. Trapping one day before the full moon in November 2005 will provide a true indication of likely pest problems.

The number of bites by *Culicoides* species that will constitute a pest problem will largely depend on the person being bitten. It has been suggested that over 60 bites per hour for most experienced biting midge workers is unacceptable, while for people unaccustomed to biting midge bites, one to five bites per hour may be unbearable (Whelan et al 1997a).

Investigations near Darwin have suggested an approximate relationship between the numbers of biting midges collected in a carbon dioxide trap and the number of bites that can be expected at the peak biting period (Whelan et. al. 1997a). The number of bites in an hour on an exposed leg at the peak biting time around sunset is approximately a quarter of the number collected in a CO₂ trap over one night at the same position (Whelan et. al. 1997a). For example if there were 240 *C. ornatus* in a CO₂ trap this would equate to 60 bites per hour.

The trap results did not reveal peak numbers of *C. ornatus*, due to the timing of the trapping. The minor numbers trapped indicate that there are breeding sites for this species adjacent to the prospect areas, so it is possible that at least nuisance numbers of *C. ornatus* will frequent the prospect areas, and possibly low to moderate pest problems will be experienced. This species will be most notable during the dry season months of April to November, with highest numbers in August to November.

The pest problem, if any, will affect outdoor workers. Outdoor activity during full and new moon periods in the two hours around sunset and sunrise in the dry season months of August to November may warrant personal protection measures.

Culicoides marksii were recorded in relatively high numbers at the Andranangoo Creek West prospect area, and are likely to be present in higher numbers during peak abundance months. This species is also likely to be present in high numbers at the Lethbridge Bay West prospect area during peak abundance months. This species mainly bites animals (eg cattle), and occasionally humans (Appendix 2), although it has not been the cause of any public complaints made to the Medical Entomology Branch (MEB database information). At most, it is only likely to cause an occasional nuisance problem around sunset and sunrise in the prospect areas.

Lasiohelius sp. has not been implicated as the cause of any public complaints in the Darwin region, and does not appear to be an abundant midge species in the Top End of the NT when compared to other midge species such as *C. ornatus* and *C. marksii* (MEB database information). However, Whelan et al (1997c) did notice this species causing minor pest problems during the daytime in a monsoon vine forest at Wickham Point, Darwin, so it is possible that this species may cause minor nuisance/pest problems at the prospect areas in shaded areas during the daytime when numbers are elevated.

Biting midge bites can be a significant pest problem and can cause associated health problems. The bites are painful and large numbers of bites can cause a generalized reaction in non-immune people. Many people, particularly newly arrived or newly exposed people, suffer from bite reactions that can lead to intense itching, scratching, skin lesions, secondary infection and scarring.

5.1.2 Biting midge control

The prime breeding habitat of *C. ornatus* are upper tidal creek habitats and at the seaward fringe of extensive mangrove areas, and will generally be at the margin and under a canopy of mangrove vegetation in mangrove creeks. Insecticide treatment of biting midge larvae in these habitats is unproven, highly impractical and likely to be environmentally unacceptable.

To eliminate most *C. ornatus* breeding sites it would be necessary to remove or permanently flood the neap tide habitats of upper tidal creek areas, the transitional *Ceriops* zone, and the *Sonneratia* foreshore and adjacent *Rhizophora* zone within 1.5km of the development area. This would be environmentally unacceptable.

If pest problems occur, 'fogging' or the application of aerosol insecticides against adult biting midges can offer some scope for the reduction of biting midge populations. However aerosol application of insecticides for adult biting midge control poses serious practical problems to achieve an effective measure of control. These include timing of control, the necessary environmental and weather conditions, access requirements, the non-specificity of most adulticides, and the failure of aerosols to penetrate thick vegetation.

Although unlikely, if there is a need to reduce biting midge pest problems, a new residual insecticide product aimed at adult biting midge and mosquito barrier control (Bistar 80SC, active ingredient 0.1% bifenthrin) has been proven very successful in reducing adult biting midges around residences for up to six weeks in Hervey Bay QLD (Standfast et al 2003, Appendix 4). It is likely to reduce adult biting midge numbers in prepared or landscaped areas and if required, could be used as part of a strategy for biting midge protection. If adult biting midge control is required, shade cloth fencing erected around the construction camp and treated with bifenthrin will enhance the effectiveness of any barrier treatment. Other areas that could be treated include under demountables, external floorboards, walls, insect screens and any dense vegetation surrounding the construction camps. Landscaped hedges can act as trap zone, and when treated with barrier insecticides can act to reduce adult biting insect populations.

Additional measures can be taken to reduce biting midge numbers if required. The use of UV or white lights in non personnel areas can act as a diversion for biting midges, although the use of lights alone is not likely to provide a useful or effective buffer (Shivas & Whelan 2001).

5.1.3 Limitations

Trapping was not conducted around the time of the full moon, therefore seasonal abundance of the main human pest biting midge *C. ornatus* could not be accurately assessed. Trapping one day before the full moon in November will provide a better indication of likely peak abundance of *C. ornatus*. It is possible though that trapping in November will miss peak numbers, as in some years peak numbers of *C. ornatus* can vary greatly from month to month during the peak season. The best method to assess peak seasonal numbers is to trap over a three day period around the full moon during the peak season months of August to November.

5.2 Mosquitoes

Andranangoo Creek West

Species present

A total of 13 species of mosquitoes were collected during trapping at the Andranangoo Creek West prospect area on the night of the 29th September, 2005. The species collected include most of the common or most relevant pest and potential disease vectors in the Top End of the NT (Whelan 1997, Appendix 3). The most important mosquito species collected in terms of vector potential were *Ochlerotatus vigilax*, *Culex annulirostris* and *Anopheles farauti* s.l. The major pest mosquitoes

collected were *Oc. vigilax*, *Culex annulirostris*, *Coquillettidia xanthogaster* and *Anopheles bancroftii*. The important mosquito species are discussed below.

Ochlerotatus vigilax

Breeding sites

The salt marsh mosquito *Ochlerotatus vigilax* generally breeds in depressions, swamps and creeklines within or directly adjacent to the upper high tide zone (Whelan 1997). This species is most commonly found breeding in brackish and saline water. Females of this species lay their eggs in the drying mud, with the eggs hatching after subsequent inundation with tidal water or rainwater, with peak breeding generally occurring in the months of September to January inclusive. The field survey in late September 2005 was conducted at a time when *Oc. vigilax* were not expected to be present as larvae, as sampling took place when there were no recent significant tide or rainfall events. Brief larval surveys were conducted to determine likely breeding sites for *Oc. vigilax*, with aerial photography also examined to determine potential breeding sites.

By far the largest likely breeding sites for *Oc. vigilax* nearby to the Andranangoo Creek West prospect area is the adjacent extensive reed swamp. At the time of survey, most of the northern edge of the swamp was still extensively flooded with freshwater, with some dry areas in the small NW arm of the swamp. Other parts of the swamp were not surveyed, but were probably similar in nature to the northern edge of the swamp. *Ochlerotatus vigilax* breeding will be restricted to those brackish areas of the swamp that are dry and then become flooded with water after significant high tides or rainfall. For example, the upper reaches of the narrow NW arm of the swamp had brackish water in a cut off pool on the mudflat (Larval Site 4), indicating a potential *Oc. vigilax* breeding site.

The presence of brackish water at Larval Site 4 was unusual, as the salinity of the water on the mudflat was 22.2 mS/cm, compared to a salinity reading of 1.9mS/cm at Larval Site 3, which was located downstream of Larval site 4. It may be a result of the underlying water table in this section of the swamp being saline, or the fact that incoming tides channel along the northern edge of the swamp

However, *Ochlerotatus vigilax* has occasionally been recorded breeding in freshwater (Lee et al 1984), so it is possible that the freshwater edges of the reed swamp may also be sources of the salt marsh mosquito, after significant high tides or rainfall lead to flooding of the previously dry/damp edges. Breeding in the swamp will be more apparent in drier years, as tides in drier years will lead to more favourable brackish water conditions, and drier years will lead to more of the swamp drying out, therefore leading to more available breeding habitat.

Other breeding sites for *Oc. vigilax* that are likely to affect the prospect area are the other saline coastal flats associated with Andranangoo Creek, as well as any poorly draining upper tidal areas associated with the small tidal creek to the west of the prospect area.

Seasonal abundance

Ochlerotatus vigilax is generally present in the dry season and early to mid wet season months, with this species absent during late wet season months. Peak numbers generally occur in the late dry season and early to mid wet season months of September to January inclusive. At the Andranangoo Creek reed swamp, significant breeding probably begins from September and continues into January. This is as the reed swamp appears to remain considerably flooded for most of the year, indicating significant breeding habitat probably does not become available until the late dry season. Heavy rain in January is likely to flood the swamp to its extremes, thereby removing potential breeding sites for this species until the next dry season. Therefore, highest numbers are likely to occur from September to January inclusive at the Andranangoo Creek West prospect area, with dispersal from other breeding sites also likely to contribute to peak numbers in September to January inclusive.

There may be small localised breeding sites associated with the upper tidal reaches of the small mangrove creek to the west of the prospect area. These breeding sites may lead to elevated numbers of *Oc. vigilax* in the early to mid dry season months, and add to elevated numbers in the peak months of

September to January, although any breeding site for this species in this area will not be to the same extent as breeding sites associated with the Andranangoo Creek West reed swamp.

Adult salt marsh mosquitoes are likely to appear from 9 days after the monthly high tides or significant rainfall in the months of September to January. Pest problems are likely to be present for up to 2 weeks during the months of November to January, due to the high humidity in these months increasing the longevity of *Oc. vigilax* females. Isolated rainfall events during October to early January can also lead to multiple hatches during these months, leading to extended periods of elevated numbers.

Dispersal

The dispersal of *Oc. vigilax* from a breeding area is related to the distribution, area and productivity of their breeding sites. If there are only a few small breeding sites, or the breeding sites are of low productivity, dispersal will be mainly restricted to areas nearby to the breeding site. If there are very large breeding areas of high productivity, dispersal will be widespread and pest problems will be noticed in areas that are located large distances away from the breeding sites. For example, in some years *Oc. vigilax* reaches moderate to high pest levels in Jabiru, which is located at least 50km from any tidal area (MEB database information).

The productivity of breeding sites nearby to the Andranangoo Creek West prospect area is sufficient to lead to very high numbers of this species in the prospect area. Although the trap results only revealed very high numbers adjacent to the reed swamp, it was highly likely that in the days after trapping this species had dispersed in very high numbers throughout the prospect area. This was noticed at the construction camp, with numbers of *Oc. vigilax* the night after trapping being considerably higher than what was noticed at the camp during the trap night.

Pest numbers

Public complaints regarding *Oc. vigilax* and corresponding collections in CO₂ baited EVS traps placed between the residential area and the swamp near the suburbs bordering the Leanyer Swamp in Darwin has indicated that pest numbers occur at levels in excess of 50 *Oc. vigilax* per CO₂ baited EVS trap per trap night (DHCS and Darwin City Council 1989, P. Whelan unpublished data).

A CO₂ trap collected of 50 *Oc. vigilax* per night is approximately equal to a biting rate of 50 mosquitoes per hour at the peak biting period for an unprotected person (DHCS & Darwin City Council 1989, P. Whelan unpublished data). This species bites during the day and night, with the peak biting period being around sunset. This species is regarded as the most important pest mosquito in the Darwin area because of its aggressive biting habits, its ability to bite during the day as well as the night, and its sudden emergence in plague proportions.

Trap collections at the Andranangoo Creek West prospect area revealed moderate to very high numbers, indicating this species will cause considerable pest problems at the Andranangoo Creek West prospect area. All outdoor workers will be affected, and exposed workers at the construction camp will also be affected.

Disease significance

Ochlerotatus vigilax is a vector of Ross River virus (RRV) disease 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) disease (Merianos et al. 1992, Whelan et al 1993). The greatest potential virus transmission period of these viruses in the Top End of the NT is in November to February, when *Oc. vigilax* occurs in relatively high numbers, and the humid conditions in these months increases the longevity of mosquitoes, increasing the chance of an individual *Oc. vigilax* from obtaining a virus from a vertebrate host and passing it on to a human. Vertebrate hosts for RRV are macropods, while the main vertebrate hosts for BFV is unclear, although there is evidence that macropods could be hosts for the virus (Van Buynder et al 1995).

If the mine site relies on seasonal workers, it may include new arrivals who may be non-immune to these arboviral diseases. These workers will be most at risk of contracting RRV or BFV.

Culex annulirostris

Breeding sites

The common banded mosquito *Culex annulirostris* generally breeds in temporary and permanent freshwater swamps and pools with emergent vegetation such as semi-aquatic reeds, temporary flooded grasslands, polluted stormwater drains, vegetated effluent ponds, and vegetated margins of creeklines and floodways (Whelan 1997, Appendix 3).

This species was located breeding at Larval Site 1, which was located at the NW edge of the main body of the Andranangoo Creek reed swamp. Almost the entire swamp is a potential *Cx. annulirostris* breeding site, with the majority of breeding likely to be associated with the dense stands of *Eleocharis* reeds that are widespread throughout the swamp. The reed swamp will be a year round source of *Cx. annulirostris*. The *Melaleuca* swamp in the prospect area is also a potential source of this species, particularly if there are grassed margins.

Seasonal abundance

This species will be present all year at the prospect area, with peak numbers likely to occur in the mid wet season, and the post wet to mid dry season. Peak numbers in the mid wet season will be a result of previously dry areas of the reed swamp becoming significantly flooded after heavy monsoon rainfall, allowing *Cx. annulirostris* breeding until fish and other aquatic predators of mosquito larvae colonise the newly flooded areas. Peak numbers in the mid wet season is also likely to be contributed to by breeding in the *Melaleuca* swamp when it first becomes inundated with water.

Peak numbers in the post wet and mid dry seasons will be a result of breeding occurring in the drying edges of the reed swamp, particularly in dense, thick stands of *Eleocharis* reeds, which will become lodged when water levels recede, creating isolated pools with restricted access for aquatic predators of mosquito larvae. Low levels of breeding will be occurring in the reed swamp during other periods of the year, maintaining an all year presence for this species.

Dispersal

Culex annulirostris can disperse up to 10km from highly productive sources (Russell 1986), although highest numbers are generally found within 3km of extensive breeding sites (Whelan 1997, Appendix 3). Trap results revealed that this species had dispersed throughout the development area, with highest numbers adjacent to the Andranangoo Creek reed swamp. As the entire prospect area is within 3km of the reed swamp, there will be widespread dispersal of *Cx. annulirostris* throughout the prospect area all year.

Pest numbers

Culex annulirostris reach pest levels when there are more than 100 per CO₂ trap per night, for those traps set away from residential areas (Whelan 1997). This number was exceeded at Trap Sites 1 (526), 2 (300) & 3 (114), indicating low to moderate pest levels throughout the prospect area. This species is not as significant as a pest compared to *Oc. vigilax*, due to its habit of biting only after sundown, and being less persistent in the presence of lights, personal protective clothing and repellents (Whelan et al 2001). This species will reach high pest levels in the mid wet season, and post wet season and mid dry season. It is likely that this species will be present in pest levels for most, if not all months of the year.

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 presence of this species all year will significantly increase the risk of arbovirus transmission, as this species will be present during the peak risk months for the various arboviruses (see Appendix 6). Any exposed worker after sundown will be at risk of arbovirus infection.

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*, which is a brackish water breeder, and the freshwater breeders *Anopheles hinesorum* and *Anopheles torresiensis*. 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 *An. farauti* s.l. breeding sites affecting the prospect area will be the adjacent Andranangoo Creek reed swamp, in particular the *Schoenoplectus* and *Eleocharis* vegetated areas.

Seasonal abundance

Anopheles farauti s.l. are generally most abundant in the late wet season and early dry season months of March to June (Whelan 1997, Appendix 3). In these months semi-aquatic vegetation growth is at its maximum, and receding water levels combine to create suitable areas for peak breeding. The same trend in peak numbers is likely to be similar at the Andranangoo Creek West prospect area, although it is likely that this species will also be present for most, if not all months of the year.

Dispersal

Anopheles farauti s.l. can disperse up to 3km, although they are most common within 1.5km of breeding sites (Whelan 1997, Appendix 3). Therefore the majority of *An. farauti* s.l. at the prospect area will be noticed within 1.5km of the reed swamp, which will include the construction camp.

Pest numbers

Pest numbers of this species in a CO₂ trap is generally regarded to be 50 per trap per trap night (Whelan 1997, Appendix 3). However, this species is a more timid biter compared to *Oc. vigilax*, therefore will be of lower pest significance. *Anopheles farauti* s.l. females only bite after sundown. Pest numbers were not recorded during the trapping, but it is likely that moderate to high pest numbers will be present in the peak season months of March to June.

Disease significance

This species is the major potential vector of malaria in the Top End of Australia, and will pose a potential risk of transmitting malaria if a person with the infectious stages of malaria is bitten by an *An. farauti* s.l. female in the prospect area. The risk threshold for malaria transmission from this species per trap is generally regarded to be 10 females per trap per trap night. This number was exceeded at Trap Sites 1 & 3, which were within 1.5km of the reed swamp, and as trapping was conducted in late September, which is generally a month of minimal abundance, it is likely that there will be a potential risk of malaria transmission for most, if not all months of the year in the Andranangoo Creek West prospect area within 1.5km of the reed swamp.

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

*Other significant mosquitoes**Coquillettidia xanthogaster*

The golden mosquito *Coquillettidia xanthogaster* was recorded in minor pest numbers at Trap Site 2. Breeding sites for this species are generally brackish and freshwater swamps and Paperbark swamps with semi-aquatic reeds, water lilies and emergent grasses, indicating the Andranangoo Creek reed swamp will be the major source of this species to the prospect area. The *Melaleuca* swamp in the prospect area is not likely to be a significant source of this species, as it is likely to dry relatively quickly when wet season rainfall ceases. Peak numbers generally occur in the months of March to August, and as the Andranangoo Creek reed swamp is very large, it is likely that high pest problems of this species will be encountered in the prospect area. This species disperses widely, up to 3-5km from breeding sites, and bites mainly at dusk, but also in shaded areas during the day (Whelan 1997, Appendix 3). This species does not transmit human disease in Australia.

Anopheles bancroftii

The black malaria mosquito *Anopheles bancroftii* was recorded in low pest numbers at Trap Site 1. The main breeding sites for this species are *Eleocharis* reed swamps and Paperbark (*Melaleuca*) swamps. The Andranangoo Creek reed swamp will be a significant source of this species, while the Paperbark swamp in the prospect area is not likely to be a significant source of this species as it is likely to dry relatively quickly when wet season rainfall ceases. Peak abundance from this species generally occurs from February to July, indicating this species will most likely be present in high pest numbers at the prospect area during peak season months. This species can be major pest up to 3km from their breeding sites, and bites during the day in shaded areas and at night (Whelan 1997, Appendix 3). This species is a potential vector of malaria, although due to its short life span it is not considered a significant potential vector (Russell 1987).

Culex sitiens

The saltwater *Culex* mosquito *Culex sitiens* was recorded in low pest numbers at Trap Site 1. This species breeds in brackish water, in similar breeding sites as *Oc. vigilax*, and was recorded breeding in the small NW arm of the Andranangoo Creek reed swamp. *Culex sitiens* is most common within 2km of breeding sites, and bites at night. This species is a possible vector of RRV (Lee et al 1989). Peak numbers generally occur in the late dry and early wet season, and late wet season, indicating higher numbers are likely to be present during peak season months.

Mansonia uniformis

Very low numbers of the water hyacinth mosquito *Mansonia uniformis* were recorded at Trap Sites 1 & 3. This species breeds in similar habitats as *Cq. xanthogaster*, and reaches peak numbers in March to June (Whelan 1997, Appendix 3). During peak season months, it is likely that this species will be present in low to moderate pest numbers at the prospect areas within 2km of the Andranangoo Creek reed swamp. Adults bite during the day in shaded areas and at night, and are considered a pest mosquito species only as it does not transmit human disease in Australia.

Verrallina funerea

This species was not recorded during trapping. They generally breed in shaded areas with some salt influence. This species does not fly far from their breeding sites, but are vicious biters and will bite all day in shaded areas near their breeding sites. It is possible that this species will be breeding in the *Melaleuca* swamp in the prospect area during the mid wet season, when the site becomes inundated with water. Any section of coastal vine forest that floods will be a source of *Ve. funerea*. If pest problems occur, they will be restricted to areas in and adjacent to the breeding site. *Verallina funerea* is a potential vector of RRV and BFV (Whelan 1997, Appendix 3).

Lethbridge Bay West*Ochlerotatus vigilax*

This species was recorded in very high pest numbers at all four trap sites, indicating a widespread severe pest problem. The main breeding site affecting the prospect area will be the adjacent extensive tidal and freshwater influenced swamp, which includes a considerable area of mudflat and probably some large reed areas at the top end of the swamp, where seasonal stream flows occur. The risk of RRV and BFV transmission at the Lethbridge Bay West prospect area will be considerable. The greatest pest problems will occur from September to January.. Smaller breeding sites are also likely to be associated with the upper tidal areas of the mangrove creek to the east of the prospect area.

Culex annulirostris

This species was present in low pest numbers at all trap sites, indicating freshwater/brackish water flooding was still present in the adjacent swamp, most likely at the top end of the swamp near the freshwater inflow areas. This species is likely to be present in high pest numbers in the mid wet season, post wet season and mid dry season, with low pest numbers for most of the remaining months of the year. This species will pose a high potential for virus transmission at the Lethbridge Bay West prospect area.

Anopheles farauti s.l.

This species was recorded in relatively low numbers, although the presence of 12 adult females at Trap Site 8 indicates that there are breeding sites for this species adjacent to the prospect area. Breeding sites for *An. farauti. s.l.* adjacent to the prospect area are likely to be associated with the top end of the extensive swamp, where there are likely to be semi-aquatic reeds. It is likely that this species will be present in at least low to moderate pest numbers in the peak season months of March to June, which will be the months of greatest risk for potential malaria transmission. This species also appears to be present in significant numbers for extended periods of the year, due to the 12 females being collected at Trap Site 8.

Coquillettidia xanthogaster

This species was recorded in low pest numbers at all trap sites, with by far the highest numbers recorded at Trap Site 8. The breeding sites for this species affecting the development area will be those sections of the extensive swamp vegetated with semi-aquatic vegetation. There are likely to be high pest problems from this mosquito species throughout the development area during the peak season months of March to August, with low pest numbers for most of the remaining months of the year.

Anopheles bancroftii

This species was not recorded during trapping at the Lethbridge Bay West prospect area. Due to the presence of species such as *Cq. xanthogaster*, it is likely that this species will be present in the prospect area during the peak season months of February to July. Pest problems in these months are likely to be moderate to high. Breeding sites will be those sections of the extensive swamp vegetated with semi-aquatic vegetation.

Culex sitiens

Culex sitiens were recorded in low numbers at all trap sites. Due to the presence of an extensive tidal mudflat, it is likely that this species will be present in minor to moderate pest numbers in the late dry and early wet season, and late wet season. This species will pose a potential RRV transmission risk when numbers are elevated.

Mansonia uniformis

This species was not recorded during trapping at the Lethbridge Bay West prospect area. Due to the presence of *Cx. xanthogaster*, it is possible that this species will be present in the prospect area during the peak season months of March to June, possibly in low to moderate pest numbers.

Verrallina funerea

This species is likely to be present at the Lethbridge Bay West prospect area if areas of the Coastal Vine forest and Melaleuca forest flood during the wet season, although it appears unlikely that significant areas of the prospect area will flood during the wet season.

5.2.1 Exotic mosquitoes

Due to the mined product being shipped directly overseas via Snake Bay Port (Dennis McCamish pers. comm.), there is the possibility of exotic dengue carrying mosquitoes being introduced into Snake Bay. However, the arriving export ships should be inspected by Australian Quarantine and Inspection Service officers, therefore minimising the potential for exotic mosquito incursion.

5.2.2 Mosquito breeding and development aspects

The potential for increased mosquito breeding at the mining sites will arise from mining activities that penetrate the ground water table, and the ground water is left to pond within the excavation for periods greater than five consecutive days. The proposed mining method (a form of slot mining) is to include a continuous rehabilitation program occurring close behind the mining face (URS, 2005), so it is unlikely that conditions will be suitable for mosquito breeding in excavated areas. Matilda Minerals have also mentioned that excavations will not be made lower than the groundwater table (Dennis McCamish pers. comm.), which will also limit the potential for surface water ponding and mosquito breeding in excavations during the dry season. However, the suitable rehabilitation of mined areas would be required to prevent the creation of new mosquito breeding sites that could be a detriment to the future use of the surrounding areas.

Andranangoo Creek West

Excavations adjacent to the extensive reed swamp have the potential to create further extensive breeding sites for *Oc. vigilax*, *An. farauti* s.l., *Cx annulirostris*, *An. bancroftii*, *Cx. sitiens*, *Cq. xanthogaster* and *Ma. uniformis*. It is important that mining does not create further mosquito breeding sites, especially as the community of Milikapiti is within flight range of *Oc. vigilax* from the prospect area. Excavations adjacent to the reed swamp should be rectified in a manner that ensures the rehabilitated area has the same topographical level post mining as pre-mining. Rehabilitation works should take into account the likelihood of the backfilled sand consolidating and sinking slightly, potentially creating a low lying area that could become a mosquito breeding site. This situation could be avoided by backfilling the excavations so that the rehabilitated surface is slightly higher than the natural surface level, so that when consolidation and compaction occurs the rehabilitated surface is the same as the natural surface of adjacent undisturbed areas.

It is mentioned in the Notice of Intent Document (URS, 2005) that mining will avoid the *Melaleuca* swamp and associated drainage line where possible, and rehabilitation would be undertaken in a way that reinstates the previous natural pattern of drainage. This rehabilitation work should also include backfilling mined areas as described in the paragraph above, to prevent the expansion of the swamp or creation of new poorly draining areas.

Other areas that are mined should also be rehabilitated in a manner that prevents the creation of low lying areas that could pond water and become mosquito breeding sites, and prevent the creation of areas with impeded drainage.

Lethbridge Bay West

The potential for the creation of new mosquito breeding sites will arise from mining activities that occur adjacent to the large tidal mudflat. Any excavations that occur adjacent to the mudflat should be rehabilitated in a manner that re-instates the existing ground level pre-development, to prevent the creation of new areas where tide and rainwater can pond and breed mosquitoes. Other mined areas in the Lethbridge Bay West prospect should also be rehabilitated in a manner that prevents the creation of low lying areas that can pond water, and prevents the creation of areas with impeded surface water

flows, especially as the community of Milikapiti is within flight range of *Oc. vigilax* from the prospect area.

5.2.3 Mosquito control

Due to the short life span of both mine sites, larval mosquito control would not be warranted or feasible for both prospect areas. The larval control of both swamps will be time consuming and costly, due to the extensive nature of both swamps. Most mosquito problems, with the exception of *Oc. vigilax* and *Ve. funerea*, will occur from sundown to sunrise. Other potential daytime pest problems will be only be of nuisance value. Personal protection and avoidance should be the main actions taken to reduce mosquito problems (Appendix 4).

However, due to the seasonal very high numbers of virus carrying mosquitoes, some form of adult mosquito control is recommended around the construction camps. Currently the most effective way of controlling adult mosquitoes is to use barrier insecticides, with bifenthrin a proven insecticide for adult mosquito barrier control (Appendix 5). The insecticide can be applied to external walls, floorboards, under demountables, insect screens and vegetation surrounding the construction camp. To increase the effectiveness of any barrier insecticide application, dark shade netting erected around the construction camp treated with bifenthrin will further reduce adult mosquito populations at the construction camp. Barrier control of mosquitoes will reduce the potential for mosquito borne disease transmission, and reduce the numbers of bites that can lead to secondary infection from scratching.

Adult mosquito control by fogging may also be required if there are cases of mosquito borne disease and subsequent entomological investigations indicate a further disease transmission risk. Adult mosquito control by ground based operations would only be successful if the mosquitoes were breeding or harbouring in accessible areas relatively close to where they were causing the problem. In this case, the areas to be targeted for fogging will be the extensive swamps located adjacent to both prospect areas, and the areas surrounding the construction camps.

5.2.4 Limitations

The results of the initial field investigation and trapping does not give a good indication of likely seasonal numbers and diversity of most mosquitoes at the prospect areas. The field investigation did however give an indication of very high salt marsh mosquito numbers at both prospect areas. To provide a better indication of seasonal abundance and diversity of other mosquitoes, monthly trapping around the time of the full moon over 12 months would be required. The future trapping in January and May 2006 is likely to provide a good compromise indication of seasonal abundance and diversity of most other mosquitoes, but there is a possibility that peak numbers of some mosquito species may occur in other months. With the exception of *Oc. vigilax*, the potential seasonal abundance of mosquito species mentioned in this report are estimations based on available MEB database information from other areas, therefore may not be an accurate indication of seasonal mosquito problems at both prospect sites.

5. Conclusions

The major findings of the initial trapping and field investigation are;

5.1 Biting midges

- Trapping on the night of the 29th and 30th September 2005 for salt marsh mosquitoes was not conducted around the full moon, therefore pest problems from the main human pest biting midge species *Culicoides ornatus* could not be accurately assessed. Trapping one day before the full moon in November 2005 is likely to give a better indication of potential biting midge pest problems at both prospect areas.
- It is possible that nuisance, and possibly minor to moderate pest problems will be caused by the mangrove biting midge *C. ornatus* at both prospect areas. If pest problems are present, they will originate from the mangrove creeks that are adjacent to both prospect areas.
- Very minor to minor nuisance problems may be caused by the biting midge *Culicoides marksii* at the Andranangoo Creek West prospect area, and possibly at the Lethbridge Bay West prospect area. Breeding sites for this species at the Andranangoo Creek West prospect area will be the Andranangoo Creek reed swamp, while breeding sites for *C. marksii* at the Lethbridge Bay West prospect area will be the upper reaches of the tidal swamp, where seasonal streams flow into the swamp.
- *Lasiohelia* sp. midges may cause minor nuisance/pest problems at both prospect areas. The source of this species is likely to be the monsoon vine forests in the prospect areas.
- The insecticide control of larval biting midges is not practical, and will not be necessary or warranted.
- If necessary, the reduction of seasonal adult biting midge numbers in the development site can be achieved by using bifenthrin insecticide barrier treatments.
- The development will not remove any biting midge breeding site.
- The elimination of biting midge breeding sites will not be required for both mining prospect areas.
- The Northern Territory Government will not be responsible for any biting midge control or biting insect monitoring in the vicinity of the mining development.
- If and when biting midge pest problems occur at either prospect areas, the work force and visitors should be warned of the potential problem and be advised on personal protection measures.

5.2 Mosquitoes

- With the exception of the salt marsh mosquito *Ochlerotatus vigilax*, the initial investigation and trapping did indicate large numbers of most mosquito species. Trapping in January and May 2006 is likely to give a better indication of peak abundance of most other mosquito species.
- The salt marsh mosquito *Ochlerotatus vigilax* will pose a severe pest problem at both the Andranangoo Creek West and Lethbridge Bay West prospect areas. Severe pest problems will be present at both prospect areas during the months of September to January inclusive. Pest problems can be present for up to 2-3 weeks during these months, with pest problems likely to be noticed in shaded areas during the day, and from sunset to sunrise. Pest problems will be present throughout both prospect areas.

- *Ochlerotatus vigilax* will pose a considerable risk for the seasonal transmission of Ross River virus (RRV) and Barmah Forest virus (BFV) at both prospect sites, with November to February being main risk months for transmission of these viruses from *Oc. vigilax*.
- The most productive *Oc. vigilax* breeding site affecting the Andranangoo Creek West prospect area will be the extensive Andranangoo Creek West reed swamp, with possible dispersal from other tidal swamps associated with Andranangoo Creek. The most productive *Oc. vigilax* breeding site affecting the Lethbridge Bay West prospect area will be the adjacent extensive tidal swamp. Other smaller *Oc. vigilax* sites are likely to be associated with the small tidal creeks adjacent to both prospect areas.
- The common banded mosquito *Culex annulirostris* will most likely be present in high pest numbers at both the Andranangoo Creek West and Lethbridge Bay West prospect sites during the mid wet, post wet and early dry season, and minor pest numbers for most of the remaining months of the year. Pest problems will be noticed after sundown.
- *Culex annulirostris* will pose a seasonally high risk of RRV and BFV transmission at both prospect areas, with December to June being main risk months for virus transmission from this species. This species will also pose a potential seasonal risk for Kunjin virus and Murray Valley encephalitis transmission at both prospect areas, with January to July being the main risk period for Murray Valley encephalitis virus transmission, and December to July being the main risk period for Kunjin virus transmission.
- The most productive *Cx. annulirostris* breeding sites affecting the Andranangoo Creek West prospect area will be the extensive Andranangoo Creek West reed swamp, with the *Melaleuca* swamp in the prospect area being a possible source. The most productive *Cx. annulirostris* breeding sites affecting the Lethbridge Bay West prospect area are likely to be the upper reaches of the adjacent extensive tidal swamp, where seasonal freshwater inflows occur, as there are likely to be semi-aquatic reeds in that section of the swamp.
- The North Australian malaria mosquito *Anopheles farauti* s.l. is likely to be present in moderate to high pest numbers in areas of the Andranangoo Creek West prospect area within 1.5km of the Andranangoo Creek West reed swamp. This species is likely to be present in at least low to moderate pest numbers at the Lethbridge Bay West prospect area within 1.5km of the adjacent extensive tidal swamp. This species is likely to be present in pest numbers during at least the months of March to June, and is likely to be present for most other months of the year. Pest problems will be noticed after sundown.
- *Anopheles farauti* s.l. will pose a high risk of potential malaria transmission at both prospect areas in at least the months of March to June, with a potential risk of malaria transmission likely to occur for extended periods of the year at both prospect sites. The risk of potential malaria transmission will occur if a person infected overseas with malaria is exposed to mosquito bites from this species.
- The most productive breeding sites for *An. farauti* s.l. affecting the Andranangoo Creek West prospect area will be the extensive Andranangoo Creek reed swamp. Breeding sites for *An. farauti* s.l. affecting the Lethbridge Bay West prospect area will be the upper reaches of the adjacent extensive tidal swamp, where there are likely to be semi-aquatic reeds.
- The saltwater *Culex* mosquito *Culex sitiens* is likely to be present in low to moderate pest numbers at both prospect areas, particularly in the late dry and early wet season. This species will pose a low to moderate potential RRV transmission risk in December and January, when numbers are

elevated. Breeding sites will be associated with the tidal influenced sections of the large swamps located adjacent to both prospect areas. Pest problems will be noticed after sundown.

- The brackish water forest mosquito *Verrallina funerea* may potentially pose a pest problem during the mid wet season at the Andranangoo Creek West prospect area. It will originate from the *Melaleuca* swamp located in the prospect area, and from any Coastal Vine forest that may flood. This species may also pose a potential pest problem at the Lethbridge Bay West prospect area, when *Melaleuca* and Coastal Vine forest areas flood during the wet season. When present, this species will pose a potential RRV and BFV transmission risk. Pest problems will only be in areas within 500m of productive breeding sites or dense closed forest.
- Other mosquito species of pest importance only will be present in pest numbers at both prospect areas. The golden mosquito *Coquillettidia xanthogaster* is likely to be present in high pest numbers during the peak months of March to August, and low pest numbers of most of the other months of the year. The black malaria mosquito *Anopheles bancroftii* is likely to be present in high pest numbers at both prospect areas during the peak months of February to July, and low pest problems for most months at the Andranangoo Creek West prospect area. The water hyacinth mosquito *Mansonia uniformis* may be present in low to moderate pest numbers at both prospect sites during the peak months of March to June. Breeding sites for these species will be the vegetated areas of the extensive swamps adjacent to the prospect area.
- Development activities have the potential to create new mosquito breeding sites, especially in those areas where mining will occur adjacent to swamps and drainage lines, such as the Andranangoo Creek reed swamp, the Andranangoo Creek West prospect area *Melaleuca* swamp and associated drainage lines, and the extensive tidal swamp adjacent to the Lethbridge Bay West prospect.

6. Recommendations

6.1 Biting midges

- If required, barrier insecticide treatments can be used to lower biting midge populations around the construction camp. Areas that can be treated include under demountables, external floorboards, walls, insect screens and any dense vegetation surrounding the construction camps. Shade cloth fencing erected around the construction camp and treated with bifenthrin will also enhance the effectiveness of any barrier treatment. Shrub type vegetation treated with barrier insecticides can also be used around the construction camps.

6.2 Mosquitoes

- All workers should be advised of the high mosquito problems that will occur at both prospect sites, and the high potential for mosquito borne disease transmission at both prospect areas when mosquito numbers are high. Workers should be supplied with a copy of the Medical Entomology Branch handout “Personal protection from mosquitoes and biting midges in the NT”.
- Adult mosquito control using barrier insecticides such as bifenthrin is highly recommended. Areas that can be treated include under demountables, external floorboards, walls, insect screens and any dense vegetation surrounding the construction camps. Shade cloth fencing erected around the construction camp and treated with bifenthrin will also enhance the effectiveness of any barrier treatment. Shrub type vegetation treated with barrier insecticides can also be used around the construction camps.
- Any worker returning or sourced from overseas who suddenly experience an onset of fever should be considered as possibly having malaria and be kept indoors away from mosquito bites, until cleared of having malaria or cleared of the infectious stages of malaria by a health care practitioner.
- Rehabilitation of the mining areas should be conducted in a manner that prevents the creation of new mosquito breeding sites which could affect the future use of the land, or disperse to existing or future development areas.

6. Bibliography

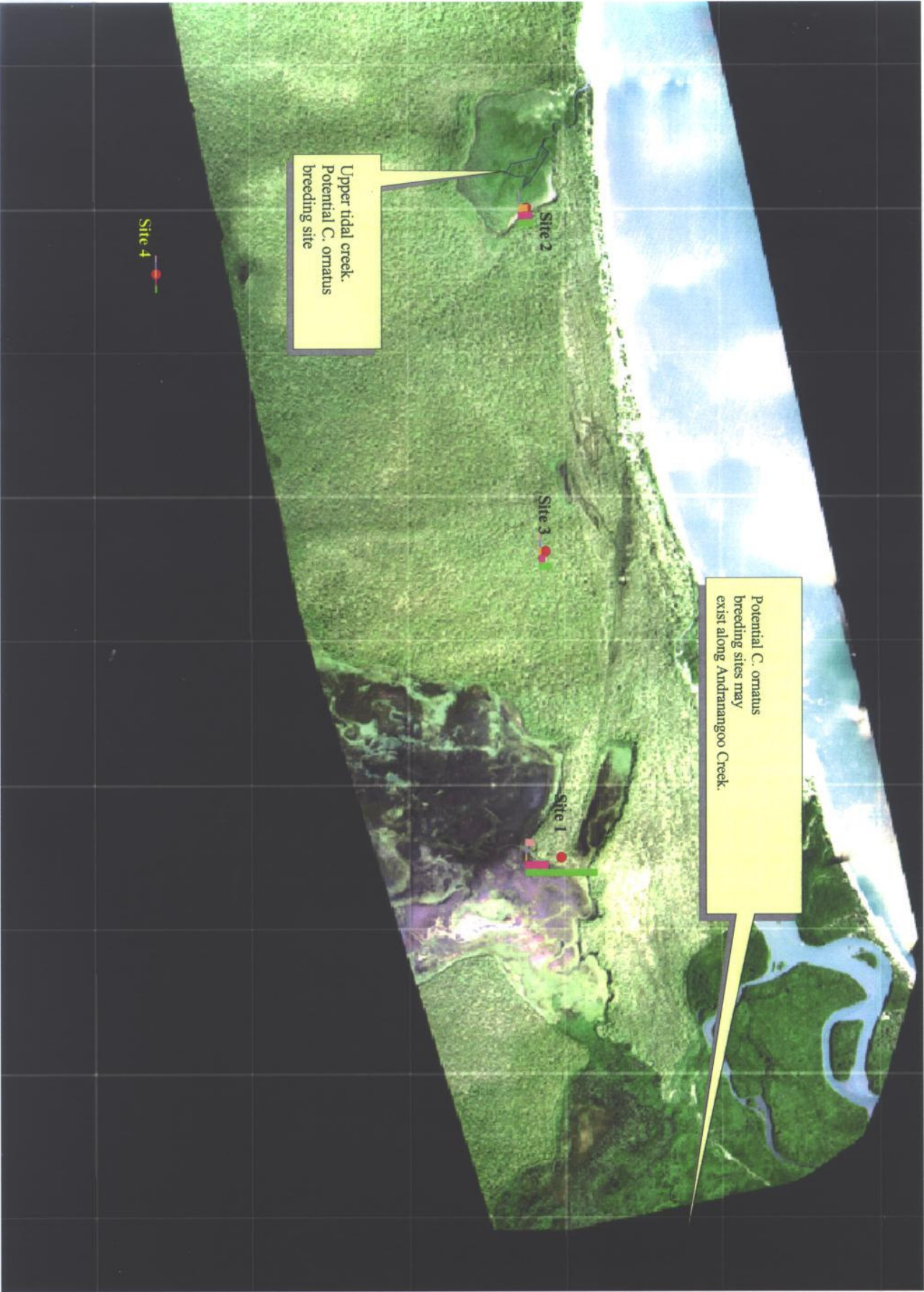
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Figures

Figure 1 - Tiwi Islands - CO2 adult mosquito trap results, Andranangoo Creek West, 29-30 September 2005. Spatial abundance of selected mosquito species, potential *Culicoides ornatus* breeding sites.



LEGEND

- Tiwi_islands_2005_mosquito.shp
- An. bancroftii
- An. farauti
- Cq. xanthogaster
- Cx. annulirostris
- Oc. vigilax

1cm = 1296 mosquitoes

Potential *C. ornatus* breeding sites.

Figure 2 - Tiwi Islands - CO2 adult mosquito trap results, Lethbridge Bay West, 30 September to 1 October 2005. Spatial abundance of selected mosquito species, potential *Culicoides ornatus* breeding sites.

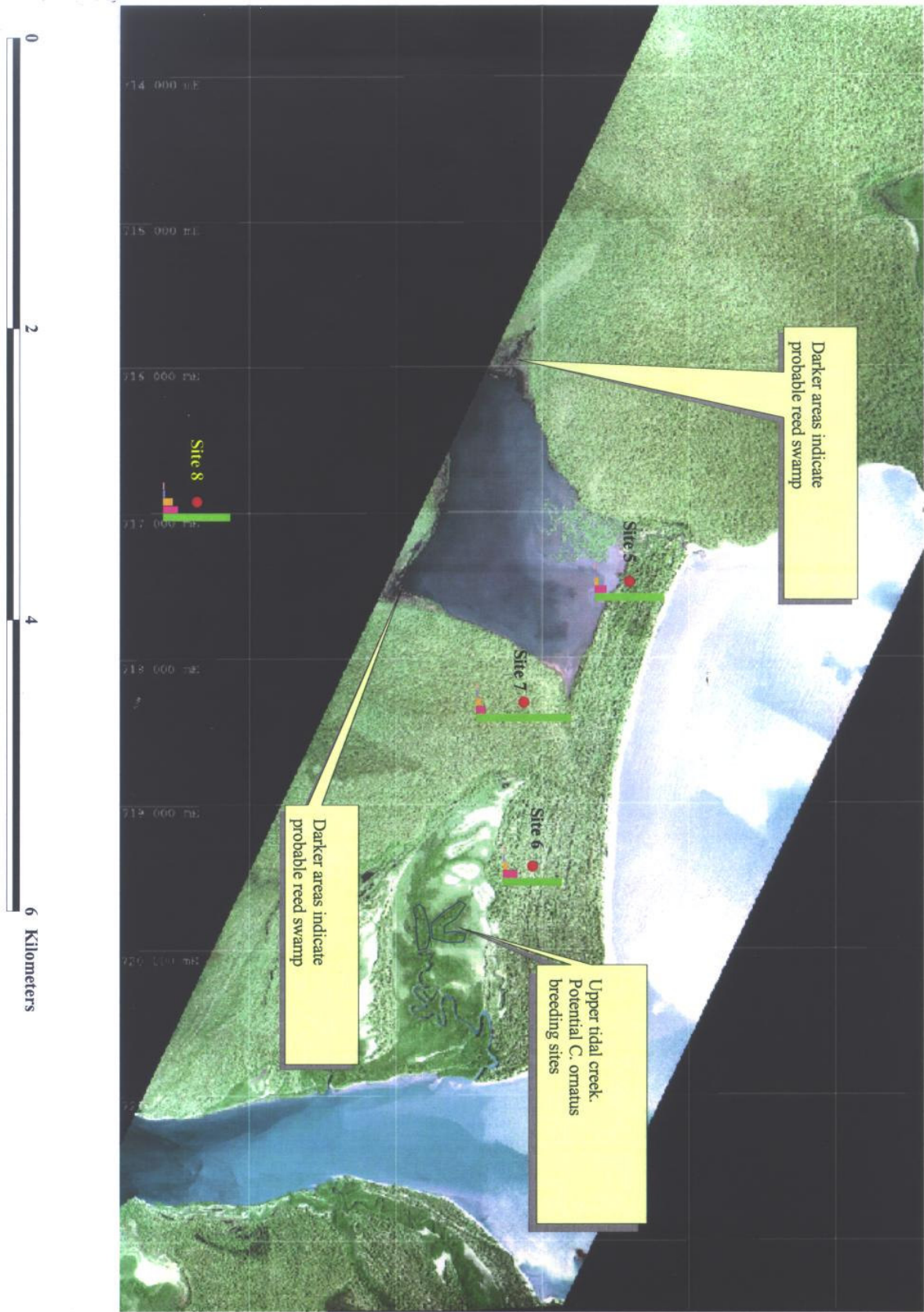


Figure 3 - Andranangoo Creek West larval mosquito sampling points 29 September 2005

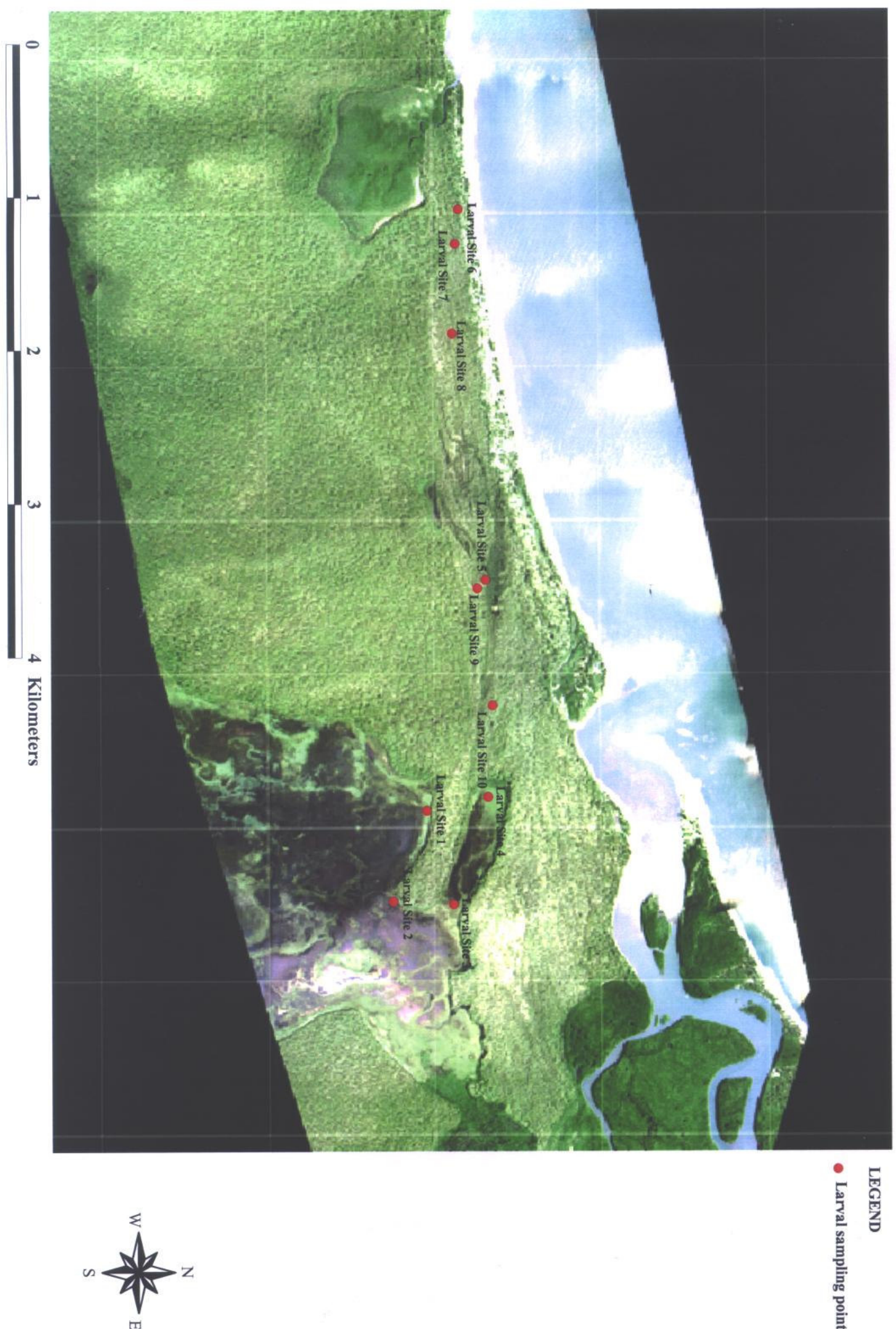
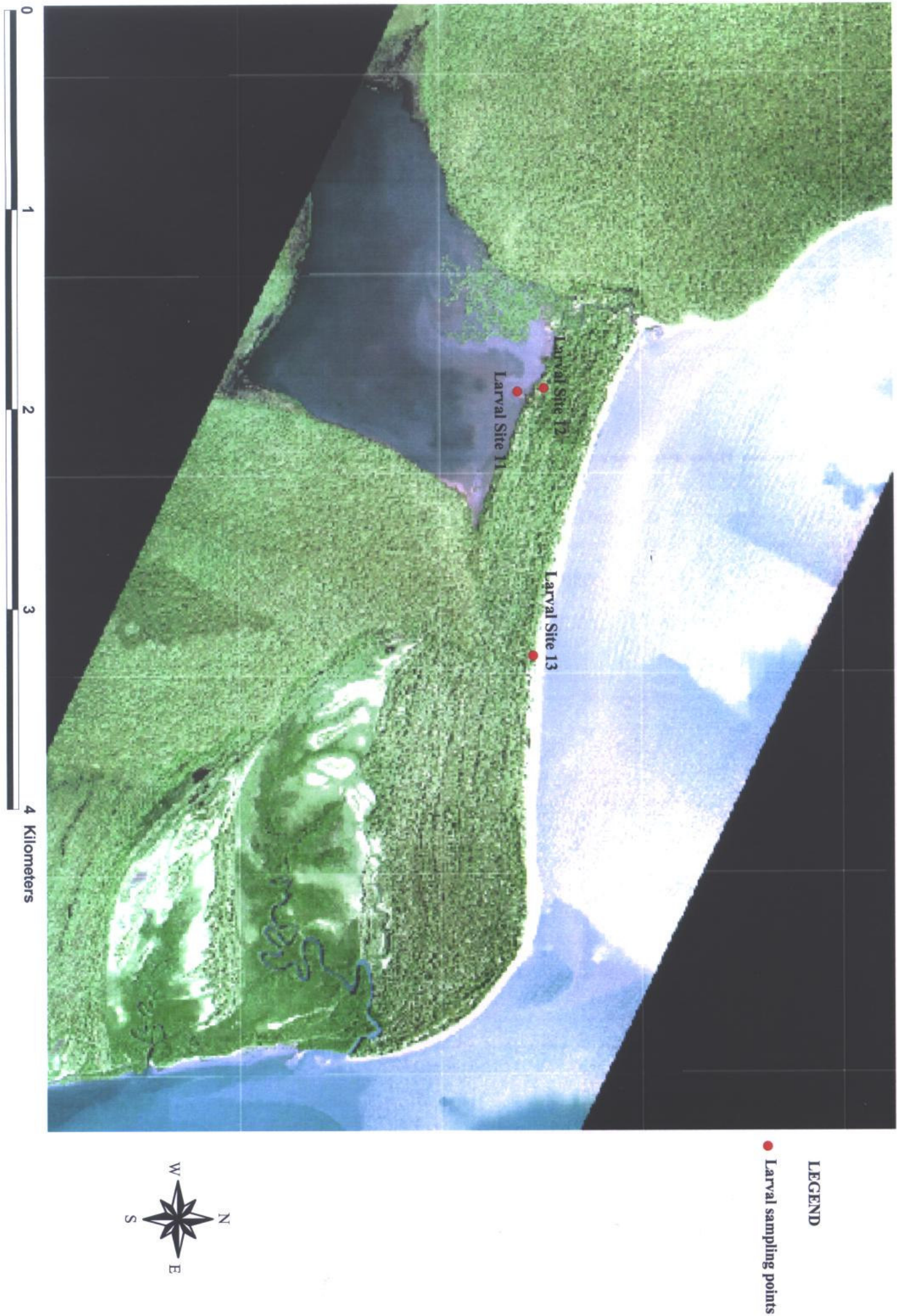


Figure 4 - Lethbridge Bay West larval mosquito sampling points, 30 September 2005.



Tables

Table 1 - Tiwi Islands - CO2 adult biting midge monitoring trap results , Andranangoo Creek West, 29-30 September 2005								
	Biting midge species							
Trap location	<i>C. (Mar grp) marksii</i>	<i>C. (Orn grp) ornatus</i>	<i>C. (Orn grp) undescribed sp No 6</i>	<i>C. (Wil grp) austropalpalis</i>	<i>Culicoides unidentifiable</i>	<i>Lasiohelius sp.</i>	Total	% of total
Trap Site 1 Andranangoo Creek West. North edge of Andranangoo Creek West reed swamp, adjacent to NW arm of swamp.	1	5	1	9	7	0	23	2.1
Trap Site 2 Andranangoo Creek West. Near western limit of proposed mining area, in Eucalypt woodland.	32	32	68	0	68	0	200	17.9
Trap Site 3 Andranangoo Creek West. Approximately 50m north of construction camp, in Eucalypt woodland.	594	1	270	5	18	1	889	79.7
Trap Site 4 Andranangoo Creek West. 3km south of construction camp, in Eucalypt woodland	3	0	0	0	0	0	3	0.3
Total	630	38	339	14	93	1	1115	100
% of total	56.5	3.4	30.4	1.3	8.3	0.1	100	

Table 2 - Tiwi Islands - CO2 adult biting midge monitoring trap results, Lethbridge Bay West, 30 September - 1 October 2005										
	Biting midge species									
Trap location	<i>C. (Mar grp) marksi</i>	<i>C. (Mei) histrio</i>	<i>C. (Orn grp) ornatus</i>	<i>C. (Orn grp) undescribed sp No 6</i>	<i>C. (Vic grp) bundyensis</i>	<i>C. (Wil grp) austropalpalis</i>	<i>C. (Wil grp) narrabeenensis</i>	<i>Culicoides unidentifiable</i>	Total	% of total
Trap Site 5 Lethbridge Bay West. In paperbark forest northwest edge of proposed mining area, adjacent to northwest edge of extensive mudflat.	0	1	0	18	0	10	1	1	31	2.8
Trap Site 6 Lethbridge Bay West. In paperbark forest adjacent to the eastern end of proposed mining area.	0	0	10	150	0	300	10	30	500	45.8
Trap Site 7 Lethbridge Bay West. In eucalypt open woodland near proposed construction camp.	16	0	1	64	0	288	0	64	433	39.7
Trap Site 8 Lethbridge Bay West. In eucalypt open woodland 3km south of proposed construction camp.	23	0	4	19	1	39	1	40	127	11.6
Total	39	1	15	251	1	637	12	135	1091	100.00
% of total	3.6	0.1	1.4	23.0	0.1	58.4	1.1	12.4	100	

Table 3 - Tiwi Islands - CO₂ adult mosquito monitoring trap results, Andranangoo Creek West, 29-30 September 2005

	Mosquito species																
Trap location	<i>Ad. (Adv) catasticta</i>	<i>An. (Ano) bancroftii</i>	<i>An. (Cel) annulipes s.l.</i>	<i>An. (Cel) farauti s.l.</i>	<i>An. (Cel) hilli</i>	<i>Cq. (Cog) xanthogaster</i>	<i>Cx. (Cux) annulirostris</i>	<i>Cx. (Cux) palpalis</i>	<i>Cx. (Cux) sitiens</i>	<i>Cx. (Cux) Vishnui group</i>	<i>Oc. (Och) vigilax</i>	<i>Ma. (Mnd) uniformis</i>	<i>mosquitoes unidentifiable (damaged)</i>	<i>An. (Cel) meraukensis</i>	Total	% of total	
Trap Site 1 Andranangoo Creek West. North edge of Andranangoo Creek West reed swamp, adjacent to NW arm of swamp.	0	168	0	28	0	14	526	0	112	0	1685	14	0	7	2554	65.5	
Trap Site 2 Andranangoo Creek West. Near western limit of proposed mining area, in Eucalypt woodland.	3	0	7	7	0	198	300	3	14	3	344	0	0	0	879	22.6	
Trap Site 3 Andranangoo Creek West. Approximately 50m north of construction camp, in Eucalypt woodland.	1	0	5	14	5	28	114	0	4	0	279	2	1	0	453	11.6	
Trap Site 4 Andranangoo Creek West. 3km south of construction camp, in Eucalypt woodland	0	0	0	0	0	2	0	0	0	0	9	0	0	0	11	0.3	
Total	4	168	12	49	5	242	940	3	130	3	2317	16	1	7	3897	100	
% of total	0.1	4.3	0.3	1.3	0.1	6.2	24.1	0.1	3.3	0.1	59.5	0.4	0.0	0.2	100		

Table 4 - Tiwi Islands - CO2 adult mosquito monitoring trap results, Lethbridge Bay West, 30 September - 1 October 2005

	Mosquito species											
Trap location	<i>Ad. (Ady) catasticta</i>	<i>An. (Cel) farauti s.l.</i>	<i>An. (Cel) hilli</i>	<i>Cq. (Coq) xanthogaster</i>	<i>Cx. (Cux) annulirostris</i>	<i>Cx. (Cux) sitiens</i>	<i>Cx. (Cux) Vishnui group</i>	<i>Oc. (Och) vigilax</i>	<i>mosquitoes unidentifiable (damaged)</i>	<i>An. (Cel) species</i>	Total	% of total
Trap Site 5 Lethbridge Bay West. In paperbark forest northwest edge of proposed mining area, adjacent to northwest edge of extensive mudflat.	0	0	0	57	228	32	13	1529	0	0	1859	23.3
Trap Site 6 Lethbridge Bay West. In paperbark forest adjacent to the eastern end of proposed mining area.	5	0	0	76	285	10	0	1298	0	15	1689	21.2
Trap Site 7 Lethbridge Bay West. In eucalypt open woodland near proposed construction camp.	2	1	6	77	179	6	0	2125	0	0	2396	30.0
Trap Site 8 Lethbridge Bay West. In eucalypt open woodland 3km south of proposed construction camp.	6	12	0	196	311	6	0	1498	6	0	2035	25.5
Total	13	13	6	406	1003	54	13	6450	6	15	7979	100
% of total	0.2	0.2	0.1	5.1	12.6	0.7	0.2	80.8	0.1	0.2	100	

Table 5 - Larval sampling results from the Andranangoo Creek West and Lethbridge Bay West prospect sites and adjacent swamps, 29-30 September 2005.

Record no	Date collected	Photo number	Trap Location	Specific conductivity (mS/cm)	Water presence	Estimated water area (m ²)	Breeding	Breeding area sampled (m ²)	Average no per dip	Species
LN01378	29-Sep-2005	1-6	Larval Site 1 - Andranangoo Creek West, NW edge of main body of large reed swamp	2.5	Flooded	800000	Yes	5	0.2	<i>Cx. (Lop) species 155</i>
LN01378	29-Sep-2005	1-6	Larval Site 1 - Andranangoo Creek West, NW edge of main body of large reed swamp	2.5	Flooded	800000	Yes	5	0.2	<i>Cx. (Cux) annulirostris</i>
LN01379	29-Sep-2005	7-8	Larval Site 2 - Andranangoo Creek West, north edge of extensive reed swamp	1.9	Flooded	800000	No	0	0	<i>Nil mosquitoes</i>
LN01380	29-Sep-2005	9-11	Larval Site 3 - Andranangoo Creek West, at entrance to small arm of swamp, NW edge of extensive reed swamp	1.9	Flooded	800000	No	0	0	<i>Nil mosquitoes</i>
LN01381	29-Sep-2005	12-14	Larval Site 4 - Andranangoo Creek West, top of small NW arm of large reed swamp	22.2	Pooling	800000	Yes	5	1	<i>Cx. (Cux) sitiens</i>
LN01381	29-Sep-2005	12-14	Larval Site 4 - Andranangoo Creek West, top of small NW arm of large reed swamp	22.2	Pooling	800000	Yes	5	1	<i>An. (Cel) hilli</i>
LN01382	29-Sep-2005	15	Larval Site 5 - Andranangoo Creek West, paperbark swamp in centre of prospect area	0	Dry	0	No	0	0	<i>Nil mosquitoes</i>
LN01383	29-Sep-2005	16-19	Larval Site 6 - Andranangoo Creek West, interdune area adjacent to western limit of propsect area	0	Dry	0	No	0	0	<i>Nil mosquitoes</i>
LN01384	29-Sep-2005	20-21	Larval Site 7 - Andranangoo Creek West, interdune area near western limit of prospect area	0	Dry	0	No	0	0	<i>Nil mosquitoes</i>
LN01385	29-Sep-2005	22-23	Larval Site 8 - Andranangoo Creek West, paperbark creekline in NW edge of prospect area	0	Dry	0	No	0	0	<i>Nil mosquitoes</i>
LN01386	29-Sep-2005	24-25	Larval Site 9 - Andranangoo Creek West, test pit in dune area	0.1	Pooling	15	No	0	0	<i>Nil mosquitoes</i>
LN01387	29-Sep-2005	26	Larval Site 10 - Andranangoo Creek West, test pit	0.5	Pooling	12	No	0	0	<i>Nil mosquitoes</i>
LN01388	30-Sep-2005	27-30	Larval Site 11 - Lethbridge Bay West, north edge of extensive mudflat	n/c	Pooling	10	No	0	0	<i>Nil mosquitoes</i>
LN01389	30-Sep-2005	31-33	Larval Site 12 - Lethbridge Bay West, interdune area between tidal mudflat and beach	0	Dry	0	No	0	0	<i>Nil mosquitoes</i>
LN01390	30-Sep-2005	34-35	Larval Site 13 - Lethbridge Bay West, interdune area behind main beach dune	0	Dry	0	No	0	0	<i>Nil mosquitoes</i>

Appendix 1



Larval Site 1 – north edge of Andranangoo Creek reed swamp. Looking SSE. Dark areas in swamp are *Eleocharis* reeds, light areas are grass.



Larval Site 1 – north edge of Andranangoo Creek reed swamp. Looking SW.



Larval Site 1 – north edge of Andranangoo Creek reed swamp. Reeds in foreground are *Schoenoplectus* sp. Looking east.



Larval Site 1 – north edge of Andranangoo Creek reed swamp. Looking SE.



Larval Site 1 – north edge of Andranangoo Creek reed swamp. Looking south.



Larval Site 1 – north edge of Andranangoo Creek reed swamp. Looking inland from swamp margin.



Larval Site 2 – north edge of Andranangoo Creek reed swamp, at south end of peninsular. Extensive areas of *Eleocharis* reeds. Looking SE.



Larval Site 2 – north edge of Andranangoo Creek reed swamp, at south end of peninsular. *Schoenoplectus* reeds in foreground, some deep pools in background. Looking NE.



Larval Site 3 – north edge of Andranangoo Creek reed swamp, at start of small arm of swamp. Extensive drying areas of *Eleocharis* reeds. Looking west.



Larval Site 3 – north edge of Andranangoo Creek reed swamp, at start of small arm of swamp. Looking east. Extensive *Eleocharis* reeds, *Schoenoplectus* reeds at edge of swamp at top left hand side of picture.



Larval Site 3 – north edge of Andranangoo Creek reed swamp, at start of small arm of swamp. Looking NE. *Eleocharis* reeds in foreground, *Schoenoplectus* reeds at edge of swamp.



Larval Site 4 – north edge of Andranangoo Creek reed swamp, at top of small arm of swamp. Extensive mudflat. *Eleocharis* reeds in background behind MEB officer Huy Nguyen. Looking EEN.



Larval Site 4 – north edge of Andranangoo Creek reed swamp, at top of small arm of swamp. Lower reaches of creek near swamp margin, looking upstream (west).



Larval Site 4 – north edge of Andranangoo Creek reed swamp, at top of small arm of swamp. Looking north towards mudflat.



Larval Site 5 – *Melaleuca* swamp in Andranangoo Creek West prospect area. Looking north.



Larval Site 6 – adjacent to west edge of Andranangoo Creek West prospect area. High frontal beach dune looking north.



Larval Site 6 – adjacent to west edge of Andranangoo Creek West prospect area. High frontal beach dune looking south into Coastal Vine forest.



Larval Site 6 – adjacent to west edge of Andranangoo Creek West prospect area. Coastal Vine forest behind main beach dune, looking NE.



Larval Site 6 – adjacent to west edge of Andranangoo Creek West prospect area. Looking south from Coastal Vine forest behind frontal beach dune.



Larval Site 7 – adjacent to west edge of Andranangoo Creek West prospect area. *Melaleuca* interdune area. Looking north.



Larval Site 7 – adjacent to west edge of Andranangoo Creek West prospect area. *Melaleuca* interdune area. Looking south.



Larval Site 8 – *Melaleuca* creekline in NW edge of Andranangoo Creek West prospect area. Looking south..



Larval Site 8 – Looking north from edge of *Melaleuca* creekline in NW edge of Andranangoo Creek West prospect area.



Larval Site 9 – Test pit in Andranangoo Creek West prospect area. Note the pit had been excavated to below the ground water table. Looking north.



Larval Site 9 – Entrance to test pit in Andranangoo Creek West prospect area. Looking south.



Larval Site 10 – Test pit in Andranangoo Creek West prospect area. Note the pit had been excavated to below the ground water table. Looking north.



Larval Site 11 – Lethbridge Bay West extensive mudflat. Looking SE.



Larval Site 11 – Lethbridge Bay West extensive mudflat. Looking west.



Larval Site 11 – Lethbridge Bay West extensive mudflat. Looking SW. Small tidal pool in middle of picture. Extensive water ponding can be seen in background of picture.



Larval Site 11 – Lethbridge Bay West extensive mudflat. Looking south. Small tidal pool in middle of picture. Extensive water ponding can be seen in background of picture.



Larval Site 12 – Lethbridge Bay West prospect area, *Melaleuca* interdune area between swamp and beach. Looking north.



Larval Site 12 – Lethbridge Bay West prospect area, *Melaleuca* interdune area between swamp and beach. Looking south.



Larval Site 12 – Lethbridge Bay West prospect area, *Melaleuca* interdune area between swamp and beach. Looking SE.



Larval Site 13 – Lethbridge Bay West prospect area, Coastal Vine forest behind main beach dune. Looking south.



Larval Site 13 – Lethbridge Bay West prospect area, edge Coastal Vine forest behind main beach dune, looking north.

Appendix 2

TABLE 1

**SUMMARY OF THE BIOLOGY OF SELECTED *CULICOIDES* SPECIES
IN THE TOP END OF THE NORTHERN TERRITORY**
Peter Whelan, Medical Entomology Branch, Territory Health Services

Species	Larval Ecology	Adult Ecology
<i>C. ornatus</i>	Dry season – breeds between Mean Low Water Neap (MLWN) and MHWN tide mark extensive areas of mangroves with mud substrates. Breeds in highest numbers at creekbank habitats around Mean High Water Neap (MHWN) in association with <i>Avicennia</i> pneumatophores. Breeds in <i>Sonneratia</i> foreshore habitats associated with mud substrates. Wet season – breeds in transitional <i>Ceriops</i> zone just below Mean High Water Spring (MHWS) at back edge of creekbank forest, and <i>Rhizophora</i> transitional zone adjacent to <i>Sonneratia</i> foreshore habitats.	Bites people readily and a serious human pest. Bites other mammals; crepuscular; disperses in pest numbers to 2 km and up to 4 km. Emergence around neap tide time with peak dispersal over 3 days around full moon. Disperses readily to higher ground up to 1.5 km from mangroves.
<i>C. undescribed species (Ornatus grp) No. 6 (Dyce) (formerly C. sp. near hewitti)</i>	Upper estuary, freshwater influenced extensive mangrove areas. Breeds in highest numbers just below MHWS.	Crepuscular. Rarely bites people.
<i>C. marksi</i>	Breeds in the margins of freshwater lakes and streams.	Crepuscular to diurnal; feeds on cattle and occasionally bites people; a minor pest at times.
<i>C. narrabeenensis</i>	Breeds at edge of fresh water.	Rarely bites people.
<i>C. undescribed species (Victoriae grp) No. 42 (Dyce) (formerly C. ?pangkorensis)</i>	Upper estuary.	Occasionally bites people.
<i>C. pallidothorax</i>	Breeds near fresh water.	NT species, rarely bites people.
<i>C. flumineus</i>	Similar to <i>C. ornatus</i> but at a lower level on creekbanks of small upper tidal tributaries. Also breeds in crab burrows on creekbank.	Readily bites people but rarely encountered out of mangroves.
<i>C. undescribed sp. (near C. immaculatus)</i>	Possibly breeds below neap tide zone in mangrove creeks. Spring tide species.	Relatively common in lower reaches of mangrove creeks and bites viciously.
<i>C. immaculatus</i>	Sandy wave washed beach sand	A relatively rare to minor pest .

	often with rocks, near neap high tide level. Neap tide species	Found near breeding sites only.
<i>C. ?subimmaculatus</i> (northern form)	Maritime sands in wave sheltered areas often with small crabs between neap and spring tide zone.	Crepuscular. A minor to moderate pest. Bites man readily near breeding sites. Pest range generally up to 0.5 km.

Adapted from information by Allan Dyce and pers com Martin Shivas 1998. Minor revision January 2004.

TABLE 2

**SEASONAL PREVALENCE OF SELECTED *CULICOIDES* SPECIES
IN THE TOP END OF THE NT**

Peter Whelan

Medical Entomology Branch, Territory Health Services

Species	Seasonal Prevalence
<i>C. ornatus</i>	The major human pest species within 2km of mangroves at coast. High localised populations all year round, with maximum numbers occurring in August to November and minimum in the wet season.
<i>C. undescribed species</i> (<i>Ornatus</i> grp) No. 6 (Dyce) (formerly <i>C. sp. near hewitti</i>)	A major species near extensive areas of mangroves at coast. High numbers in the late dry season and early wet season, and has low populations in the post wet season.
<i>C. marksi</i>	A major species in sub-coastal and inland areas, with only low populations at coast. Low populations in the late dry season and moderate populations in the early wet and post wet to mid dry seasons.
<i>C. narrabeenensis</i>	A minor species with peak numbers in the early to mid dry season.
<i>C. undescribed species</i> (<i>Victoriae</i> grp) No. 42 (Dyce) (formerly <i>C. ?pangkorensis</i>)	A minor species. Peak numbers in mid wet season.
<i>C. pallidothorax</i>	A minor species. Peak populations during the early to mid wet season.
<i>C. flumineus</i>	An important pest species with high numbers inside mangroves only. Peaks in late dry season, early wet season.
<i>C. undescribed sp. (near C. immaculatus)</i>	A serious pest in lower reaches of mangrove creeks
<i>C. immaculatus</i>	A minor to rare species near rock-sand or sandy beaches only. Peak numbers in mid to late dry and early wet season.
<i>C. ?subimmaculatus</i> (<i>northern form</i>)	An important pest species. Moderate numbers near favoured wave sheltered breeding sites only. Peak numbers in mid dry season tapering to late dry season.

Adapted from information by Allan Dyce and pers. comm. Martin Shivas 1998. Minor revision January 2004.

Appendix 3



NORTHERN TERRITORY GOVERNMENT

DEPARTMENT
OF HEALTH
AND COMMUNITY
SERVICES

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

Updated January 2004

For more information contact:
Department of Health and Community Services
Medical Entomology Branch
PO Box 40596
Casuarina NT 0811

Telephone: (08) 8922 8333
Fax: (08) 8922 8820
E-mail: peter.whelan@nt.gov.au

PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT PEST AND VECTOR STATUS HABITATS AND BREEDING SITES

Peter Whelan
Senior Medical Entomologist
NT Department of Health and Community Services
1997

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

SPECIES	PEST STATUS ¹	VECTOR STATUS
<i>An. annulipes s.l.</i> ²	Widespread pest, bites at night and will enter houses.	Potential malaria vector.
<i>An. bancroftii</i>	Major pest, widespread, bites anytime near breeding site, nightly or shaded areas elsewhere.	Potential malaria vector.
<i>An. farauti s.l.</i> ²	Local pest, bites at night. Uncommon, except near mostly sub-coastal and extensive freshwater or brackish swamps.	Major potential vector of malaria.
<i>An. hilli</i>	Coastal pest, bites at night, enters houses. Common near brackish water swamps.	Potential malaria vector.
<i>An. meraukensis</i>	Local pest, bites after dark. Very common near extensive freshwater swamp.	Not potential malaria vector.
<i>Cx. annulirostris</i>	Major pest, very common and widespread in both urban and rural areas. Bites mainly in evening and at night.	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.
<i>Cx. quinquefasciatus</i>	Major urban pest, bites at night, indoors, rests indoors, populations common with polluted water in dry season.	Potential arbovirus vector (MVEV). Vector of heartworm of dogs.
<i>Cx. sitiens</i>	Localized coastal pest, breeds in brackish or tidal waters, disperses widely, bites at night.	Probably no diseases. Possible RRV disease.
<i>Cq. xanthogaster</i>	Major localized pest near extensive reed swamps, disperses widely, bites at night, or in dense shade in day, attracted to lights.	No diseases. Filariasis in frill neck lizard
<i>Ma. uniformis</i>	Localized pest, bites at night near the breeding site, attracted to lights, does not disperse far from breeding sites.	No diseases.
<i>Fl. kochi</i>	Local pest at breeding site, does not disperse. Restricted to <i>Pandanus</i> thickets.	No diseases.
<i>Oc. normanensis</i>	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.	Major vector of Ross River and Barmah Forest viruses. Potential vector of MVEV. Potential vector of many other arboviruses.
<i>Oc. notoscriptus</i>	Local urban pest, container or tree hole breeder, bites persistently, anytime in cool shade. Found naturally in forest areas.	Potential Ross River virus vector. Major vector of heartworm of dogs.
<i>Oc. tremulus</i>	Local urban pest, container or tree hole breeder, bites at sundown and dawn. Often caught in forest areas.	No diseases.
<i>Oc. vigilax</i>	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.	Major vector of Ross River and Barmah Forest virus diseases and dog heartworm. Potential vector of many other arboviruses.
<i>Ve. funerea</i>	Local pest near breeding grounds, does not disperse. Common by day only locally inclosed forrest near tidal brackish swamps & Creeks.	Potential RRV and BFV arbovirus vector.
* Adapted and revised from P. Liehne et al. "Mosquitoes and biting midge investigation, Palmerston 1982 -85".		

**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**

SPECIES	IMMATURE STAGES	ADULT STAGES
<i>An. annulipes s.l.</i>	Eggs laid singly on water surface; any freshwater body but numerous near <i>Eleocharis</i> reed swamps; temporary or permanent; some containers; larvae float on water surface and feed on particles on top of water.	Feeds on a variety of mammals include 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.
<i>An. bancroftii</i>	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 <i>Eleocharis</i> reed swamps.	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.
<i>An. farauti s.l.</i> (Includes <i>An. farauti</i> , <i>An. hinesorum</i> and <i>An. torresiensis</i>)	Eggs laid singly on surface; larvae feed on water surface. <i>An. farauti</i> breeds in brackish water; <i>An. hinesorum</i> and <i>An. torresiensis</i> breed in freshwater swamps and pools. Larval habitat often sunlit.	Bites readily at night; feeds on humans, other mammals and birds. Will fly approximately 2 km from the breeding site.
<i>An. hilli</i>	Eggs laid singly on surface; larvae feed at surface; sunlit or shaded brackish to saline ground pools or swamps. Numerous in <i>Schoenoplectus</i> reed swamps near coast.	Bites humans, cattle and horses; mainly after sunset. Disperses up to 4 km from breeding site.
<i>An. meraukensis</i>	Eggs laid singly on surface of water; larvae feed at the surface; usually in freshwater <i>Eleocharis</i> reed swamps, sunlit or shaded.	Bites readily at dusk, feeds on humans and other mammals.
<i>Cx. annulirostris</i>	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 containers and breed readily in semi polluted water in storm drains or sewage effluent with vegetation.	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.
<i>Cx. quinquefasciatus</i>	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.	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.
<i>Cx. sitiens</i>	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.	Bites mammals and birds at night; pest near coast, will fly up to 5 km but common within 2 km of breeding site.
<i>Cq. xanthogaster</i>	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 <i>Eleocharis</i> and <i>Typha</i> reeds, water lilies and paperbark; larvae feed on suspended material in the water.	Adults are strong fliers 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.
<i>Ma. uniformis</i>	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 <i>Cq. xanthogaster</i> .	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.

SPECIES	IMMATURE STAGES	ADULT STAGES
<i>Oc. vigilax</i>	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 <i>Schoenoplectus littoralis</i> or landward ill draining mangrove areas; larvae browse on substrate.	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.
<i>Fl. kochi</i>	Eggs laid singly on the axils of <i>Pandanus</i> leaves. Larvae feed on detritus and debris in the water collected in the axil space.	Severe pests near the breeding sites. Do not disperse far from the breeding habitat.
<i>Oc. normanensis</i>	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.	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.
<i>Oc. notoscriptus</i>	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 container habitats.	Feeds on humans and all mammals; bites day or evening in the cool shade. Does not disperse widely.
<i>Ve. funerea</i>	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.	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.
* 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* Peter Whelan Medical Entomology Branch, Department of Health and Community Services 1997	
SPECIES	SUMMARY OF BIOLOGY & SEASONAL PREVALENCE
<i>An. annulipes s.l.</i>	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.
<i>An. bancroftii</i>	Freshwater, paperbark and <i>Eleocharis</i> 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.
<i>An. farauti s.l.</i>	Brackish and freshwater species, in vegetated swamps or creeks. Low to moderate numbers in late wet and early post wet season.
<i>An. hilli</i>	Brackish/saltwater breeder, often associated with <i>Schoenoplectus</i> 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.
<i>An. meraukensis</i>	Open shallow freshwater <i>Eleocharis</i> reed swamps and creeks. Moderate to high numbers in the late and immediate post wet season.
<i>Ma. uniformis</i>	Same as <i>Cq. xanthogaster</i> but more associated with floating vegetation, (water lilies). Moderate to very high numbers near habitats in late wet, early dry season.
<i>Cx. annulirostris</i>	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.
<i>Cx. quinquefasciatus</i>	Domestic water sites, often with organic pollution. Moderate numbers in mid to late dry season, but can be present all year.
<i>Cx. sitiens</i>	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.
<i>Cq. xanthogaster</i>	Breeds in freshwater <i>Eleocharis</i> 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.
<i>Fl. kochi</i>	Breeds in <i>Pandanus</i> axils. Moderate numbers in wet season in <i>Pandanus</i> thickets.
<i>Oc. normanensis</i>	Floodwater, ground pool breeder in poorly draining floodways associated with creeks and rivers. Very high numbers during wet season, absent at other times.
<i>Oc. notoscriptus</i>	Tree hole or artificial container breeder. Low numbers in wet season but persists in dry season with artificial breeding sites.
<i>Oc. tremulus</i>	Tree hole or container breeder. Low numbers in wet season and early dry season.
<i>Oc. vigilax</i>	Breeds in tidal to brackish swamp or tidal pools in creeks. Extreme numbers in the very late dry and early wet season.
<i>Ve. funerea</i>	Brackish to tidal ground pools in tidal creeks and swamps, often in shade. Localised pest numbers in the pre wet and wet.
* 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

Species/	Nuisance status	Disease Vector Status		Potential vectors in the NT	Peak Abundance
(Common Name)		Current	Potential		
<i>Ochlerotatus vigilax</i> (Salt marsh mosquito)	+++++	+++	++++	RRV BFV	September - January
<i>Ochlerotatus normanensis</i> (Floodwater mosquito)	+++++	+++	++++	RRV BFV	January - April
<i>Culex annulirostris</i> (Common banded mosquito)	+++++	+++++	+++++	MVEV, KUN RRV, BFV, JEV, others	January - August
<i>Culex gelidus</i> (The frosty mosquito)	+	+	+++	MVEV, KUNV, RRV BFV, JEV, others	January-April
<i>Culex palpalis</i> (Freshwater banded mosquito)	+++	++	+++	MVEV, KUNV RRV, BFV, JEV, others	January-August
<i>Anopheles bancroftii</i> (Black malaria mosquito)	+++	Nil	+	Malaria (possible)	February - July
<i>Coquillettidia xanthogaster</i> (The golden mosquito)	+++	Nil	Nil	None known	March - August
<i>Mansonia uniformis</i> (Waterlily mosquito)	+++	Nil	Nil	None known	March - June
<i>Anopheles farauti s.l.</i> (Australian malaria mosquito)	+	Nil	+++++	Malaria (probable)	March - June
<i>Culex quinquefasciatus</i> (Brown house mosquito)	+++	+	+	MVEV (possible)	January - Jun
<i>Ochlerotatus notoscriptus</i> (Container mosquito)	+	+	++	RRV (probable)	Jan - June
<i>Verallina funerea</i> (Brackish water moquito)	+++	+	++	RRV, BFV (probable)	Oct - Jan
LEGEND					
RRV - Ross River virus	MVEV - Murray Valley encephalitis virus			+ Minor pest on Disease Potential	+++++ Major pest on Disease Potential
BFV - Barmah Forest 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

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

Pest Levels

* Indicative significant pest threshold levels (mosquitoes per CO₂ trap per night) at residence for relatively unprotected people at peak biting times.

Indicative significant pest threshold levels (mosquitoes per CO₂ 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.

Problem Mosquito Species In The Top End Of The NT Habitat and Flight Range Peter Whelan 1997 Medical Entomology Branch, Department of Health and Community Services			
Species/Common name	Habitat Description	Habitat Indicators	Flight Range & Pest Solutions
<i>Ochlerotatus vigilax</i> (Salt marsh mosquito)	Brackish reed swamps Upper mangrove margin and tidal creek extremities	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 <i>Schoenoplectus</i> reeds.	0 - 5 km major pest 5 - 50 km pest numbers 50 - over 200 km dispersal
<i>Ochlerotatus normanensis</i> (Floodwater mosquito)	Flooded freshwater sub-coastal or inland floodways and creeks	Broad, flat sub-coastal and inland drainage floors of minor and major creeks.	0 - 2 km major pest 2 - 5 km pest numbers
<i>Culex annulirostris</i> (Common banded mosquito)	Freshwater and coastal reed swamps. Streams, storm drains, and sewage effluents	Extensive reed swamps with <i>Eleocharis</i> or <i>Typha</i> reeds. Temporary flooded grasslands in sub-coastal and inland areas with organic matter. Sewage effluent and organic waste water with grass, <i>Lemna</i> (Duckweed), <i>Azolla</i> (water fern).	0 - 3 km major pest 2 - 10 km pest numbers 10 - 15 km dispersal
<i>Verrallina funerea</i> (brackish mosquito)	Upper reaches of mangroves with fresh water inflow. Rain filled coastal swamps	Brackish mangroves & mangrove fern. <i>Schoenoplectus</i> reed swamps. Shaded rainfilled coastal depressions & creeklines. Under beach hibiscus & <i>Casuarina</i> trees	0-500m minor pest Day pest in closed forrest near breeding sites.
<i>Anopheles bancroftii</i> (Black malaria mosquito)	Freshwater and coastal reed swamps. Shaded streams and swamps	Extensive seasonally inundated <i>Melaleuca</i> paperbark swamps. <i>Eleocharis</i> and <i>Typha</i> reed swamps.	0 - 3 km major pest 3 - 5 km pest numbers
<i>Coquillettidia xanthogaster</i> (The golden mosquito)	Freshwater swamps with reeds Vegetated streams	Extensive <i>Eleocharis</i> and <i>Typha</i> reed swamps. Paperbark creek lines.	0 - 3 km major pest 3 - 5 km pest numbers
<i>Mansonia uniformis</i> (Waterlily mosquito)	Extensive freshwater reed swamp	Extensive <i>Eleocharis</i> and <i>Typha</i> reed swamps with water lilies.	0 - 2 km major pest 2 - 3 km dispersal
<i>Anopheles farauti s.l.</i> (Australian malaria mosquito)	Coastal and brackish reed swamps Freshwater swamps and vegetated streams	Brackish <i>Schoenoplectus</i> and <i>Eleocharis</i> reed swamps. Upper reaches of mangrove creeks with freshwater influence.	0 - 1.5 km minor pest 1.5 - 3 km dispersal
<i>Culex quinquefasciatus</i> (Brown house mosquito)	Storm drains, artificial containers Septic tanks Waste water ponds	Polluted ground or artificial containers. Filamentous green algae, <i>Lemna</i> (Duckweed), <i>Azolla</i> (water fern), or high organic water. Tyres, drums and other containers	0 - 500 m major pest 500 m - 1 km pest numbers
<i>Ochlerotatus notoscriptus</i> (Container mosquito)	Tree holes or artificial containers	Trees with natural collections of water including <i>Eucalyptus</i> , <i>Ficus</i> , <i>Poinciana</i> and <i>Adansonia</i> . Tyres, drums, pot plant drip trays, roof gutters, rainwater tanks.	0 - 500 m minor pest 500 m - 1 km dispersal

Appendix 4



**Northern
Territory
Government**

Department of Health
and Community Services

PERSONAL PROTECTION FROM MOSQUITOES & BITING MIDGES IN THE NT

**PETER WHELAN
SENIOR MEDICAL ENTOMOLOGIST
DARWIN
NORTHERN TERRITORY
AUSTRALIA**

April 2004*

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For more information contact:

Department of Health and Community Services
Medical Entomology Branch
PO Box 40596
Casuarina NT 0811

Telephone: 08 89228333
Fax: 08 89228820
Email: peter.whelan@nt.gov.au

PERSONAL PROTECTION FROM MOSQUITOES & BITING MIDGES

**P. I. Whelan,
Department of Health and Community Services
April 2004**

Adapted from paper by P. Whelan in “Australian Mosquito Control Manual” by a panel of authors, Editors C. Morris and P. Dale. Australian Mosquito Control Association, 1998, ISBN 0-646-35310-1.

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 *Aedes 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, Muskol, 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 can not 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, Medicrome, 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 usually give immediate relief for painful and itchy bites and swelling or blisters from 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 Vallergran. 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, warnulpa, 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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Appendix 5

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

By

H. Standfast¹, I. Fanning², L. Maloney², D. Purdie³, & M. Brown⁴

1. International Vector Consultants, 41 Henry St., Chapel Hill, Brisbane, Queensland 4069, Australia.
2. Hervey Bay City Council, Vector Control, PO Box 5045, Torquay, Queensland 4655, Australia.
3. Queensland Institute of Medical Research, PO Royal Brisbane Hospital, Queensland 4029, Australia.
4. Griffith University, Australian School of Environmental Studies, Nathan Campus, Brisbane, Queensland, Australia & FMC Chemicals, PO Box 329 Hamilton Central, Queensland 4007, Australia.

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 known (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 cyano (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 g/litre) and good stability to hydrolysis and photolysis (2 years at 50°C. under natural daylight); and
- 4) long residual efficacy against target insects (WHO 1998, 2002; Hougard et al. 2002; Yadav et al. 2003).
- 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.

<u>Treatment</u> <u>Property No.</u>	<u>Property Size</u>	<u>Volume of</u> <u>8% SC Applied¹</u>
1	1012 m ²	875 ml
2	1012 m ²	750 ml
3	1012 m ²	500 ml
4	1012 m ²	625 ml

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. 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:

$$\% \text{ control} = 100 \times \left[1 - \frac{T_a \times C_b}{T_b \times C_a} \right]$$

Where: T_a = population in treatment post-treatment
T_b = population in treatment pre-treatment
C_a = population in control post-treatment
C_b = 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 $\pm$ SD 24 hour environmental conditions during field evaluation.

Temperature °C.	% Relative Humidity	Wind Speed km/hr	Wind Direction (Degrees)
23 $\pm$ 3	78 $\pm$ 17	7 $\pm$ 3	118 $\pm$ 66

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.

<u>Group</u>	<u>N</u>	<u>Mean</u>	<u>Std Dev</u>	<u>t</u>	<u>Df</u>	<u>95%CI</u>	<u>P</u>
Pre-Treatment Biting Midges	4	51	81	0.84	6	-65 to 134	0.43
Control Biting Midges	4	17	11				
Pre-Treatment Mosquitoes	4	56	38	0.70	6	-408 to 227	0.51
Control Mosquitoes	4	147	257				

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.

Group	N	Median Number	25%	75%	T	P
Biting Midge						
Treatments	54	276	66	682	2652	<0.02
Controls	54	425	122	1856		
Mosquitoes						
Treatments	54	8	4	34	1802	<0.01
Controls	54	106	46	210		

Table 5. Descriptive Statistics for 6 weeks field Data.

Biting Midge (n = 54 trap collections)						
	<u>Skewness</u>	<u>Range</u>	<u>Max</u>	<u>Min</u>	<u>Median</u>	<u>Mean</u>
Treatment	1.46	2,011	2,012	1	276	441
Control	2.21	21,914	21,948	34	425	2,989
Mosquitoes (n = 54 trap collections)						
	<u>Skewness</u>	<u>Range</u>	<u>Max</u>	<u>Min</u>	<u>Median</u>	<u>Mean</u>
Treatment	2.50	186	186	0	8	25
Control	2.40	875	879	4	106	169

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).

Efficacy of Bistar 80SC Insecticide Barriers

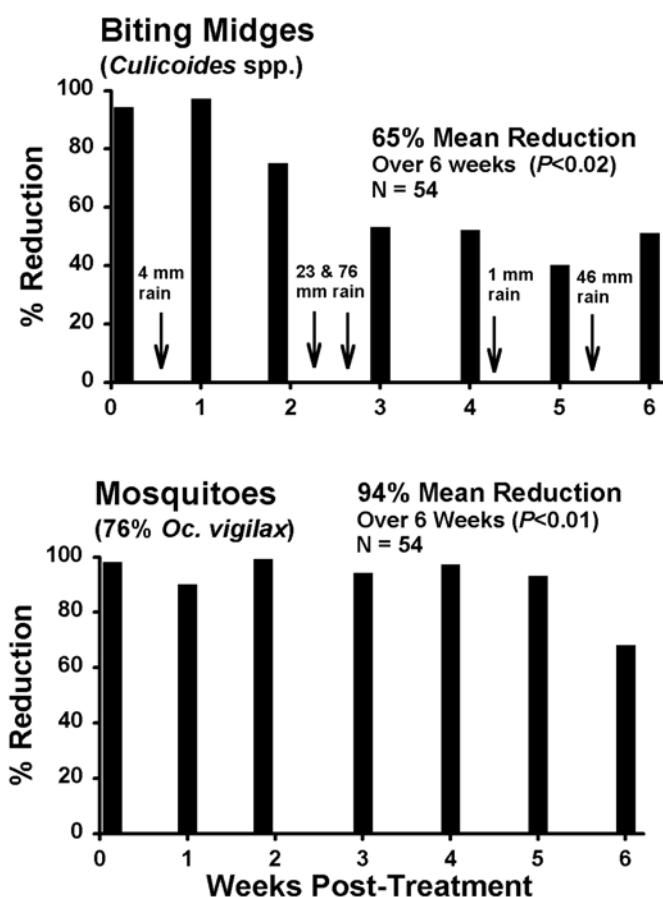


Fig. 1. % Reduction of peri-domestic biting midge and mosquito numbers over a six week study period. Rainfall events are also recorded.

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 LC₉₅) 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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Appendix 6

TABLE 16:

ARBOVIRUS RISK PERIODS IN THE NORTHERN TERRITORY

VIRUS	FROM VECTORS/ ABUNDANCE & LONGEVITY	FROM VIRUS ISOLATION	FROM SENTINEL ANIMALS	FROM CASE DATA	PEAK RISK PERIOD	PROBABLE MAIN RISK PERIOD
MVE	JAN-SEPT	MAR	DEC-OCT	FEB-JULY	FEB-MAY	JAN-JULY
KUNJIN	JAN-SEPT	APRIL-JUN	DEC-SEPT	MARCH-JUN	FEB-MAY	JAN-JULY
RR	NOV-SEPT	JAN-APR	-	JAN-DEC	JAN-MAR	DEC-JUN
BF	NOV-SEPT	DEC-APR	-	DEC-OCT	JAN-MAR	DEC-JUN