Biting Insect Assessment
Andranangoo Creek West and Lethbridge Bay West mining prospects, Tiwi Islands

29 September - 1st October 2005

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

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Synopsis

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.

Investigation
Late September biting insect trapping was conducted on the night of the 29th September 2005 at the Andranangoo Creek West prospect, and on the night of the 30th at the Lethbridge Bay West prospect. Brief ground investigations were also conducted at the natural actual and potential breeding sites in and surrounding the mining prospects. 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 other seasonal trapping will be addressed in a supplementary report once trapping in May 2006 has been completed.

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

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 marksi* 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. marksi* 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 closed eucalypt forest areas adjacent to 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.

**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 December and January 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.

### Recommendations

#### 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

#### 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.

- 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.
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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).

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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

![Diagram of study areas on Melville Island](F:/ENTO/ento_files/public_information/branchReports/darwin_region/darwin_rural/melville/Andranangoo_Ck_and_Lethbridge_Bay_2005-06/Report_Andranangoo_Creek_West_and_Lethbridge_Bay_West_Sandmining.doc)
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 0.1 ms/cm, and the water in the Larval Site 10 pit was 0.5 ms/cm, indicating freshwater. No breeding was located.

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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 marksi, accounting for 57% of all midges, followed by
**Spatial abundance**

Table 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, 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 bancfoftii* 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 *Lasiohelia* 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 MHWS (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 in 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 marksi* 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. marksi*. 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. marksi* 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. marksi*.

**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 marksi* 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 CO$_2$ trap over one night at the same position (Whelan et. al. 1997a). For example if there were 240 *C. ornatus* in a CO$_2$ 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 marksi* 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 (e.g., 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.

*Lasiohelia* 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. marksi* (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 CO$_2$ 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 CO$_2$ baited EVS trap per trap night (DHCS and Darwin City Council 1989, P. Whelan unpublished data).

A CO$_2$ 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**
*Cx. 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**
*Cx. 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. *Verrallina 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 \textit{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 \textit{Oc. vigilax} and \textit{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 \textit{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 marksi* 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. marksi* 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
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.
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Figures
mosquito species; potential Culicoides or ansae breeding sites.

LEGEND

Figure 1. Trew Islands - CO2 Adult Mosquito Trap Results; Andrahanano Creek West, 29-30 September 2005; Spatial abundance of selected mosquitoes species; potential Culicoides or ansae breeding sites.
mosquito species; potential Culicoides ornatus breeding sites.

LEGEND

0 2 4 6 Kilometres

breeding sites
Potential C. ornatus
1 cm = 1250 adult mosquitoes
C. variipennis
C. demerarae
A. lemani
Aedes, Culex, Anopheles

Figure 2 - Two islands - CO2 adult mosquito trap results: LambSite Bay West, 30 September to 1 October 2005. Spatial abundance of selected
<table>
<thead>
<tr>
<th>Trap location</th>
<th>Biting midge species</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trap Site 1 Andranangoo Creek West. North edge of Andranangoo Creek West reed swamp, adjacent to NW arm of swamp.</td>
<td>C. (Mar grp) marksi</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>C. (Orn grp) ornatus</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>C. (Orn grp) undescribed sp. No 6</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>C. (Wil grp) austropalpalis</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Culicoides unidentifiable</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Lasiohelia sp.</td>
<td>0</td>
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<tr>
<td></td>
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<td>23</td>
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<tr>
<td></td>
<td>% of total</td>
<td>2.1</td>
</tr>
<tr>
<td>Trap Site 2 Andranangoo Creek West. Near western limit of proposed mining area, in Eucalypt woodland.</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td></td>
<td>32</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>200</td>
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<tr>
<td></td>
<td>17.9</td>
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</tr>
<tr>
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<td>594</td>
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<tr>
<td></td>
<td>1</td>
<td></td>
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<td>889</td>
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</tr>
<tr>
<td></td>
<td>79.7</td>
<td></td>
</tr>
<tr>
<td>Trap Site 4 Andranangoo Creek West. 3km south of construction camp, in Eucalypt woodland</td>
<td>3</td>
<td></td>
</tr>
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<td>0</td>
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<td>3</td>
<td></td>
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<td></td>
<td>0.3</td>
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<td>38</td>
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<td>1115</td>
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<tr>
<td>% of total</td>
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<td></td>
<td>3.4</td>
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<td>30.4</td>
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<td>1.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8.3</td>
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<td>0.1</td>
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<tr>
<td></td>
<td>100</td>
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</table>
Table 2 - Tiwi Islands - CO2 adult biting midge monitoring trap results, Lethbridge Bay West, 30 September - 1 October 2005

<table>
<thead>
<tr>
<th>Trap location</th>
<th>Biting midge species</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trap Site 5 Lethbridge Bay West. In paperbark forest northwest edge of proposed mining area, adjacent to northwest edge of extensive mudflat.</td>
<td>C. (Mar grp) marksi</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>C. (Mei) histrio</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>C. (Orn grp) omanus</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>C. (Orn grp) undescribed sp No 6</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>C. (Vic grp) bundyensis</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>C. (Wil grp) austropalpalis</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>C. (Wil grp) narrabeenensis</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Culicoides unidentifiable</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>31</td>
</tr>
<tr>
<td>Trap Site 6 Lethbridge Bay West. In paperbark forest adjacent to the eastern end of proposed mining area.</td>
<td>0</td>
<td>45.8</td>
</tr>
<tr>
<td>Trap Site 7 Lethbridge Bay West. In eucalypt open woodland near proposed construction camp.</td>
<td>16</td>
<td>39.7</td>
</tr>
<tr>
<td>Trap Site 8 Lethbridge Bay West. In eucalypt open woodland 3km south of proposed construction camp.</td>
<td>23</td>
<td>11.6</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>1091</td>
</tr>
<tr>
<td>% of total</td>
<td>3.6</td>
<td>100.00</td>
</tr>
<tr>
<td>Trap location</td>
<td>Ad. (Ad.) cristata</td>
<td>An. (Ano) barbartus</td>
</tr>
<tr>
<td>------------------------------------------------------------------------------</td>
<td>-------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Trap Site 1 Andranangoo Creek West. North edge of Andranangoo Creek West reed swamp, adjacent to NW arm of swamp.</td>
<td>0</td>
<td>168</td>
</tr>
<tr>
<td>Trap Site 2 Andranangoo Creek West. Near western limit of proposed mining area, in Eucalypt woodland.</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Trap Site 3 Andranangoo Creek West. Approximately 50m north of construction camp, in Eucalypt woodland.</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Trap Site 4 Andranangoo Creek West. 3km south of construction camp, in Eucalypt woodland</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>168</td>
</tr>
<tr>
<td>% of total</td>
<td>0.1</td>
<td>4.3</td>
</tr>
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</table>
# Table 4 - Tiwi Islands - CO2 adult mosquito monitoring trap results, Lethbridge Bay West, 30 September - 1 October 2005

<table>
<thead>
<tr>
<th>Trap location</th>
<th>Ad. (Ady) catasticta</th>
<th>An. (Cel) farauti s.l.</th>
<th>An. (Cel) hilli</th>
<th>Cq. (Cox) xanthogaster</th>
<th>Cx. (Cox) annulirostris</th>
<th>Cx. (Cox) sitiens</th>
<th>Cx. (Cox) Vishnui group</th>
<th>Oc. (Och) vigilax</th>
<th>mosquitoes unidentifiable (damaged)</th>
<th>An. (Cel) species</th>
<th>Total</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trap Site 5 Lethbridge Bay West. In paperbark forest northwest edge of proposed mining area, adjacent to northwest edge of extensive mudflat.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>57</td>
<td>228</td>
<td>32</td>
<td>13</td>
<td>1529</td>
<td>0</td>
<td>0</td>
<td>1859</td>
<td>23.3</td>
</tr>
<tr>
<td>Trap Site 6 Lethbridge Bay West. In paperbark forest adjacent to the eastern end of proposed mining area.</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>76</td>
<td>285</td>
<td>10</td>
<td>0</td>
<td>1298</td>
<td>0</td>
<td>15</td>
<td>1689</td>
<td>21.2</td>
</tr>
<tr>
<td>Trap Site 7 Lethbridge Bay West. In eucalypt open woodland near proposed construction camp.</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>77</td>
<td>179</td>
<td>6</td>
<td>0</td>
<td>2125</td>
<td>0</td>
<td>0</td>
<td>2396</td>
<td>30.0</td>
</tr>
<tr>
<td>Trap Site 8 Lethbridge Bay West. In eucalypt open woodland 3km south of proposed construction camp.</td>
<td>6</td>
<td>12</td>
<td>0</td>
<td>196</td>
<td>311</td>
<td>6</td>
<td>0</td>
<td>1498</td>
<td>6</td>
<td>0</td>
<td>2035</td>
<td>25.5</td>
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<tr>
<td>Total</td>
<td>13</td>
<td>13</td>
<td>6</td>
<td>406</td>
<td>1003</td>
<td>54</td>
<td>13</td>
<td>6450</td>
<td>6</td>
<td>15</td>
<td>7979</td>
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<tr>
<td>% of total</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>5.1</td>
<td>12.6</td>
<td>0.7</td>
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<td>80.8</td>
<td>0.1</td>
<td>0.2</td>
<td>100</td>
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</tr>
<tr>
<td>Record no</td>
<td>Date collected</td>
<td>Photo number</td>
<td>Trap Location</td>
<td>Specific conductivity (mS/cm)</td>
<td>Water presence</td>
<td>Estimated water area (m$^2$)</td>
<td>Breeding</td>
<td>Breeding area sampled (m$^2$)</td>
<td>Average no per dip</td>
<td>Species</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>----------------</td>
<td>--------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>------------------------------</td>
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<td>-----------------------------</td>
<td>-------------------</td>
<td>--------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LN01378</td>
<td>29-Sep-2005</td>
<td>1-6</td>
<td>Larval Site 1 - Andranangoo Creek West, NW edge of main body of large reed swamp</td>
<td>2.5</td>
<td>Flooded</td>
<td>800000</td>
<td>Yes</td>
<td>5</td>
<td>0.2</td>
<td>Cx. (Lop) species 153</td>
<td></td>
<td></td>
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<tr>
<td>LN01378</td>
<td>29-Sep-2005</td>
<td>1-6</td>
<td>Larval Site 1 - Andranangoo Creek West, NW edge of main body of large reed swamp</td>
<td>2.5</td>
<td>Flooded</td>
<td>800000</td>
<td>Yes</td>
<td>5</td>
<td>0.2</td>
<td>Cx. (Cux) annulirostris</td>
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<td></td>
</tr>
<tr>
<td>LN01379</td>
<td>29-Sep-2005</td>
<td>7-8</td>
<td>Larval Site 2 - Andranangoo Creek West, north edge of extensive reed swamp</td>
<td>1.9</td>
<td>Flooded</td>
<td>800000</td>
<td>No</td>
<td>0</td>
<td>0</td>
<td>Nil mosquitoes</td>
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<td></td>
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<tr>
<td>LN01380</td>
<td>29-Sep-2005</td>
<td>9-11</td>
<td>Larval Site 3 - Andranangoo Creek West, at entrance to small arm of swamp, NW edge of extensive reed swamp</td>
<td>1.9</td>
<td>Flooded</td>
<td>800000</td>
<td>No</td>
<td>0</td>
<td>0</td>
<td>Nil mosquitoes</td>
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<td></td>
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<tr>
<td>LN01381</td>
<td>29-Sep-2005</td>
<td>12-14</td>
<td>Larval Site 4 - Andranangoo Creek West, top of small NW arm of large reed swamp</td>
<td>22.2</td>
<td>Pooling</td>
<td>800000</td>
<td>Yes</td>
<td>5</td>
<td>1</td>
<td>Cx. (Cux) sitiens</td>
<td></td>
<td></td>
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<tr>
<td>LN01381</td>
<td>29-Sep-2005</td>
<td>12-14</td>
<td>Larval Site 4 - Andranangoo Creek West, top of small NW arm of large reed swamp</td>
<td>22.2</td>
<td>Pooling</td>
<td>800000</td>
<td>Yes</td>
<td>5</td>
<td>1</td>
<td>An. (Cel) hilli</td>
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<td>LN01382</td>
<td>29-Sep-2005</td>
<td>15</td>
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<td>0</td>
<td>Dry</td>
<td>0</td>
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<td>LN01383</td>
<td>29-Sep-2005</td>
<td>16-19</td>
<td>Larval Site 6 - Andranangoo Creek West, interdune area adjacent to western limit of prospect area</td>
<td>0</td>
<td>Dry</td>
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<td>LN01384</td>
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<td>Dry</td>
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<td>Nil mosquitoes</td>
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<td>0</td>
<td>Dry</td>
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<td>0</td>
<td>Nil mosquitoes</td>
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<td>29-Sep-2005</td>
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<td>Larval Site 9 - Andranangoo Creek West, test pit in dune area</td>
<td>0.1</td>
<td>Pooling</td>
<td>15</td>
<td>No</td>
<td>0</td>
<td>0</td>
<td>Nil mosquitoes</td>
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<td>LN01387</td>
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<td>Larval Site 10 - Andranangoo Creek West, test pit</td>
<td>0.5</td>
<td>Pooling</td>
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<td>No</td>
<td>0</td>
<td>0</td>
<td>Nil mosquitoes</td>
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<tr>
<td>LN01388</td>
<td>30-Sep-2005</td>
<td>27-30</td>
<td>Larval Site 11 - Lethbridge Bay West, north edge of extensive mudflat</td>
<td>n/e</td>
<td>Pooling</td>
<td>10</td>
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<td>0</td>
<td>0</td>
<td>Nil mosquitoes</td>
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<td></td>
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<td>LN01389</td>
<td>30-Sep-2005</td>
<td>31-33</td>
<td>Larval Site 12 - Lethbridge Bay West, interdune area between tidal mudflat and beach</td>
<td>0</td>
<td>Dry</td>
<td>0</td>
<td>No</td>
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<td>Nil mosquitoes</td>
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<td>LN01390</td>
<td>30-Sep-2005</td>
<td>34-35</td>
<td>Larval Site 13 - Lethbridge Bay West, interdune area behind main beach dune</td>
<td>0</td>
<td>Dry</td>
<td>0</td>
<td>No</td>
<td>0</td>
<td>0</td>
<td>Nil mosquitoes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 1 – Photos of the Andranangoo Creek West and Lethbridge Bay West larval mosquito sampling points, 29-30 September 2005

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 inland from swamp margin.

Larval Site 1 – north edge of Andranangoo Creek reed swamp. Looking south.
Appendix 1 – Photos of the Andranangoo Creek West and Lethbridge Bay West larval mosquito sampling points, 29-30 September 2005

Larval Site 2 – north edge of Andranangoo Creek reed swamp, at south end of peninsula. Extensive areas of *Eleocharis* reeds. 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 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.
Appendix 1 – Photos of the Andranangoo Creek West and Lethbridge Bay West larval mosquito sampling points, 29-30 September 2005

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

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.
Appendix 1 – Photos of the Andranangoo Creek West and Lethbridge Bay West larval mosquito sampling points, 29-30 September 2005

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 north.

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.
Appendix 1 – Photos of the Andranangoo Creek West and Lethbridge Bay West larval mosquito sampling points, 29-30 September 2005

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.
Appendix 1 – Photos of the Andranangoo Creek West and Lethbridge Bay West larval mosquito sampling points, 29-30 September 2005

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, Coastal Vine forest behind main beach dune, 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

<table>
<thead>
<tr>
<th>Species</th>
<th>Larval Ecology</th>
<th>Adult Ecology</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. ornatus</em></td>
<td>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 <em>Avicennia</em> pneumatophores. Breeds in <em>Sonneratia</em> foreshore habitats associated with mud substrates. Wet season – breeds in transitional Ceriops zone just below Mean High Water Spring (MHWS) at back edge of creekbank forest, and <em>Rhizophora</em> transitional zone adjacent to <em>Sonneratia</em> foreshore habitats.</td>
<td>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.</td>
</tr>
<tr>
<td><em>C. undescribed species</em> (Ornatus grp) No. 6 (Dyce) (formerly <em>C. sp. near hewitti</em>)</td>
<td>Upper estuary, freshwater influenced extensive mangrove areas. Breeds in highest numbers just below MHWS.</td>
<td>Crepuscular. Rarely bites people.</td>
</tr>
<tr>
<td><em>C. marksi</em></td>
<td>Breeds in the margins of freshwater lakes and streams.</td>
<td>Crepuscular to diurnal; feeds on cattle and occasionally bites people; a minor pest at times.</td>
</tr>
<tr>
<td><em>C. narrabeenensis</em></td>
<td>Breeds at edge of fresh water.</td>
<td>Rarely bites people.</td>
</tr>
<tr>
<td><em>C. undescribed species</em> (Victoriae grp) No. 42 (Dyce) (formerly <em>C. ?pangkorensis</em>)</td>
<td>Upper estuary.</td>
<td>Occasionally bites people.</td>
</tr>
<tr>
<td><em>C. pallidothorax</em></td>
<td>Breeds near fresh water.</td>
<td>NT species, rarely bites people.</td>
</tr>
<tr>
<td><em>C. flumineus</em></td>
<td>Similar to <em>C. ornatus</em> but at a lower level on creekbanks of small upper tidal tributaries. Also breeds in crab burrows on creekbank.</td>
<td>Readily bites people but rarely encountered out of mangroves.</td>
</tr>
<tr>
<td><em>C. undescribed sp.</em> (near <em>C. immaculatus</em>)</td>
<td>Possibly breeds below neap tide zone in mangrove creeks. Spring tide species.</td>
<td>Relatively common in lower reaches of mangrove creeks and bites viciously.</td>
</tr>
<tr>
<td><em>C. immaculatus</em></td>
<td>Sandy wave washed beach sand often with rocks, near neap high</td>
<td>A relatively rare to minor pest. Found near breeding sites only.</td>
</tr>
</tbody>
</table>
Neap tide species

| **C. ?subimmaculatus** (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. |

### TABLE 2
SEASONAL PREVALENCE OF SELECTED *CULICOIDES* SPECIES IN THE TOP END OF THE NT

Peter Whelan  
Medical Entomology Branch, Territory Health Services

<table>
<thead>
<tr>
<th>Species</th>
<th>Seasonal Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. ornatus</em></td>
<td>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.</td>
</tr>
<tr>
<td><em>C. undescribed species</em> (Ornatus grp) No. 6 (Dyce) (formerly C. sp. near hewitti)</td>
<td>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.</td>
</tr>
<tr>
<td><em>C. marksi</em></td>
<td>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.</td>
</tr>
<tr>
<td><em>C. narrabeenensis</em></td>
<td>A minor species with peak numbers in the early to mid dry season.</td>
</tr>
<tr>
<td><em>C. pallidothorax</em></td>
<td>A minor species. Peak populations during the early to mid wet season.</td>
</tr>
<tr>
<td><em>C. flumineus</em></td>
<td>An important pest species with high numbers inside mangroves only. Peaks in late dry season, early wet season.</td>
</tr>
<tr>
<td><em>C. undescribed sp. (near C. immaculatus)</em></td>
<td>A serious pest in lower reaches of mangrove creeks</td>
</tr>
<tr>
<td><em>C. immaculatus</em></td>
<td>A minor to rare species near rock-sand or sandy beaches only. Peak numbers in mid to late dry and early wet season.</td>
</tr>
<tr>
<td><em>C. ?subimmaculatus</em> (northern form)</td>
<td>An important pest species. Moderate numbers near favoured wave sheltered breeding sites only. Peak numbers in mid dry season tapering to late dry season.</td>
</tr>
</tbody>
</table>

Appendix 3
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 April 2007

For more information contact:
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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. *Ae. vigilax*, *Ae. normanensis* and *Cq. xanthogaster*) and some generally do not fly far at all (eg. *Ve. funerea*, *Ae. kochi*, *Ae. 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* s.s. (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 *Aedes vigilax* and *Aedes notoscriptus* within flight range of breeding sites and on a seasonal basis. Other species can be pests in shaded/heavily vegetated areas at times during the day but generally have peak biting levels in the first two hours after sundown.
### MAJOR PEST AND VECTOR MOSQUITO SPECIES

**IN THE TOP END OF THE NT**

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

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>PEST STATUS 1</th>
<th>VECTOR STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>An. annulipes</em> s.l. 2</td>
<td>Widespread pest, bites at night and will enter houses.</td>
<td>Potential malaria vector.</td>
</tr>
<tr>
<td><em>An. bancroftii</em></td>
<td>Major pest, widespread, bites anytime near breeding site, nightly or shaded areas elsewhere.</td>
<td>Potential malaria vector.</td>
</tr>
<tr>
<td><em>An. farauti</em> s.l. 2</td>
<td>Local pest, bites at night. Uncommon, except near mostly sub-coastal and extensive freshwater or brackish swamps.</td>
<td>Major potential vector of malaria.</td>
</tr>
<tr>
<td><em>An. hilli</em></td>
<td>Coastal pest, bites at night, enters houses. Common near brackish water swamps.</td>
<td>Potential malaria vector.</td>
</tr>
<tr>
<td><em>Ae. normanensis</em></td>
<td>Major pest, bites in evening and night within 3 km of breeding sites. Plagues in inland areas a week after widespread flooding rains in wet season.</td>
<td>Major vector of Ross River and Barmah Forest viruses. Potential vector of MVEV. Potential vector of many other arboviruses.</td>
</tr>
<tr>
<td><em>Ae. notoscriptus</em></td>
<td>Local urban pest, receptacle or tree hole breeder, bites persistently, anytime in cool shade. Found naturally in forest areas.</td>
<td>Potential Ross River virus vector. Major vector of heartworm of dogs.</td>
</tr>
<tr>
<td><em>Ae. tremulus</em></td>
<td>Local urban pest, receptacle or tree hole breeder, bites at sundown and dawn. Often caught in forest areas.</td>
<td>No diseases.</td>
</tr>
<tr>
<td><em>Ae. vigilax</em></td>
<td>Major pest, bites day or night within 5 km of breeding sites. Plagues associated with high tides in late dry season, early wet season. Fly up to 60 km in pest numbers.</td>
<td>Major vector of Ross River and Barmah Forest virus diseases and dog heartworm. Potential vector of many other arboviruses.</td>
</tr>
<tr>
<td><em>Cx. annulirostris</em></td>
<td>Major pest, very common and widespread in both urban and rural areas. Bites mainly in evening and at night.</td>
<td>Major arbovirus vector of Murray Valley encephalitis virus (MVEV), Kunjin virus, Ross River virus (RRV) and Barmah Forest virus (BFV) and dog heart worm. Vector of numerous other arboviruses.</td>
</tr>
<tr>
<td><em>Cx. quinquefasciatus</em></td>
<td>Major urban pest, bites at night, indoors, rests indoors, populations common with polluted water in dry season.</td>
<td>Potential arbovirus vector (MVEV). Vector of heartworm of dogs.</td>
</tr>
<tr>
<td><em>Cx. sitiens</em></td>
<td>Localized coastal pest, breeds in brackish or tidal waters, disperses widely, bites at night.</td>
<td>Probably no diseases. Possible RRV disease.</td>
</tr>
<tr>
<td><em>Cq. xanthogaster</em></td>
<td>Major localized pest near extensive reed swamps, disperses widely, bites at night, or in dense shade in day, attracted to lights.</td>
<td>No diseases. Filariasis in frill neck lizard.</td>
</tr>
<tr>
<td><em>Ma. uniformis</em></td>
<td>Localized pest, bites at night near the breeding site, attracted to lights, does not disperse far from breeding sites.</td>
<td>No diseases.</td>
</tr>
<tr>
<td><em>Fl. kochi</em></td>
<td>Local pest at breeding site, does not disperse. Restricted to <em>Pandanus</em> thickets.</td>
<td>No diseases.</td>
</tr>
<tr>
<td><em>Ve. funerea</em></td>
<td>Local pest near breeding grounds, does not disperse. Common by day only locally inclosed forest near tidal brackish swamps &amp; Creeks.</td>
<td>Potential RRV and BFV arbovirus vector.</td>
</tr>
</tbody>
</table>

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

F:\ENTO\ento_files\public_information\general_information\mosquitoes\probmos Top End (Apr 07 update).doc 3
<table>
<thead>
<tr>
<th>SPECIES</th>
<th>IMMATURE STAGES</th>
<th>ADULT STAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>An. annulipes s.l.</strong></td>
<td>Eggs laid singly on water surface; any freshwater body but numerous near <em>Eleocharis</em> reed swamps; temporary or permanent; some receptacles; larvae float on water surface and feed on particles on top of water.</td>
<td>Feeds on a variety of mammals 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.</td>
</tr>
<tr>
<td><strong>An. bancroftii</strong></td>
<td>Eggs laid singly. Dark larvae, feeds at water surface; found in heavily shaded fresh to slightly brackish ground pools or swamps, especially in paperbark or <em>Eleocharis</em> reed swamps.</td>
<td>Feeds on all mammals readily; will fly up to 4 km from breeding site; bites any time near breeding site, nightly or in shade elsewhere.</td>
</tr>
<tr>
<td><strong>An. farauti s.l.</strong> <em>(Includes An. farauti, An. hinesorum and An. torresiensis)</em></td>
<td>Eggs laid singly on surface; larvae feed on water surface. <em>An. farauti</em> breeds in brackish water; <em>An. hinesorum</em> and <em>An. torresiensis</em> breed in freshwater swamps and pools. Larval habitat often sunlit.</td>
<td>Bites readily at night; feeds on humans, other mammals and birds. Will fly approximately 2 km from the breeding site.</td>
</tr>
<tr>
<td><strong>An. hilli</strong></td>
<td>Eggs laid singly on surface; larvae feed at surface; sunlit or shaded brackish to saline ground pools or swamps. Numerous in <em>Schoenoplectus</em> reed swamps near coast.</td>
<td>Bites readily at dusk, feeds on humans and other mammals.</td>
</tr>
<tr>
<td><strong>An. meraukensis</strong></td>
<td>Eggs laid singly on surface of water; larvae feed at the surface; usually in freshwater <em>Eleocharis</em> reed swamps, sunlit or shaded.</td>
<td>Major and severe pest species; adults feed very readily on humans, other mammals and birds, day or night; will fly up to 60 km, highest numbers within 5km of breeding sites; shelter in thick vegetation.</td>
</tr>
<tr>
<td><strong>Ae. vigilax</strong></td>
<td>Eggs deposited singly in the mud or near plant stems in suitable habitats; breeds in tidal pools and marshes, usually those filled by tides in upper tidal zone associated with <em>Schoenoplectus littoralis</em> or landward ill draining mangrove areas; larvae browse on substrate.</td>
<td>Major and severe pest species; adults feed very readily on humans, other mammals and birds, day or night; will fly up to 60 km, highest numbers within 5km of breeding sites; shelter in thick vegetation.</td>
</tr>
<tr>
<td><strong>Ae. kochi</strong></td>
<td>Eggs laid singly on the axils of <em>Pandanus</em> leaves. Larvae feed on detritus and debris in the water collected in the axil space.</td>
<td>Severe pests near the breeding sites. Do not disperse far from the breeding habitat.</td>
</tr>
<tr>
<td><strong>Ae. normanensis</strong></td>
<td>Eggs deposited singly in drying mud substrate in poorly draining floodways. Pale larvae can be inconspicuous in colloidal clay suspension water. Tend to dive to bottom when disturbed. Feed by browsing on substrate. Mainly inland rural habitats.</td>
<td>Major pest species. Extreme numbers after flooding rains for 1-2 weeks. Feeds readily on humans and other mammals, mainly in evening and night. Will fly 3-5 km in pest numbers.</td>
</tr>
<tr>
<td><strong>Ae. notoscriptus</strong></td>
<td>Eggs laid singly on the sides of tree holes. Dark larvae hang from the surface by siphon and feed by browsing on the substrate. Common in domestic receptable habitats.</td>
<td>Feeds on humans and all mammals; bites day or evening in the cool shade. Does not disperse widely.</td>
</tr>
<tr>
<td><strong>Cx. annulirostris</strong></td>
<td>Eggs deposited as rafts of up to 200 on the water surface; larvae hang from surface and feed on suspended particles; breed in freshwater pools and swamps with emergent vegetation temporary or permanent; will colonize domestic receptacles and breed readily in semi polluted water in storm drains or sewage effluent with vegetation.</td>
<td>Adults are the most common species encountered in the NT and are present throughout the year; feed at night and will bite humans, other mammals and birds; will fly distances of up to 10 km from the breeding site, although common up to 4 km from breeding site.</td>
</tr>
<tr>
<td><strong>Cx. quinquefasciatus</strong></td>
<td>Eggs laid as rafts on the surface; breeding grounds are polluted to fresh domestic waters; major sources are septic tanks, leach drains, primary sewage ponds and other polluted ground waters.</td>
<td>Severe domestic pest of humans but will feed on poultry and dogs as well; will feed and rest indoors; bites at night; flies up to 1 km from breeding site.</td>
</tr>
<tr>
<td>SPECIES</td>
<td>IMMATURE STAGES</td>
<td>ADULT STAGES</td>
</tr>
<tr>
<td>---------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Cx. sitiens</td>
<td>Eggs laid as rafts on surface; brackish coastal ground pools under tidal influence with or without vegetation; larvae hang from the surface and rest on bottom. Feed on suspended matter or on substrate.</td>
<td>Bites mammals and birds at night; pest near coast, will fly up to 5 km but common within 2 km of breeding site.</td>
</tr>
<tr>
<td>Cq. xanthogaster</td>
<td>Eggs laid as small raft on the surface; larvae attach themselves to the stems of aquatic plants by a modified siphon and obtain oxygen from the plants; breed in semi-permanent to permanent swamps with emergent vegetation; associated with <em>Eleocharis</em> and <em>Typha</em> reeds, water lilies and paperbark; larvae feed on suspended material in the water.</td>
<td>Adults are strong 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.</td>
</tr>
<tr>
<td>Ma. uniformis</td>
<td>Eggs laid as small cluster attached to the under surface of floating leaves water lilies and plant stems; larval habitats and breeding area similar to <em>Cq. xanthogaster</em>.</td>
<td>Adults bite humans, other mammals and birds readily at night. Severe pest in cool shade near breeding site during the day and evening; generally does not fly more than 1 - 2 km from breeding sites; strongly attracted to light; adults rest in dense vegetation; pest in the wet season near breeding areas only.</td>
</tr>
<tr>
<td>Ve. funerea</td>
<td>Eggs laid singly on moist substrate at edge of breeding area, usually shaded with some salt influence. Dark larvae hang from water surface, generally feeding by browsing on the bottom of the water body.</td>
<td>Vicious biter in cool shaded vegetation near breeding site in day and in evening. Does not continue biting in sun. Do not disperse far from the breeding habitat.</td>
</tr>
</tbody>
</table>

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

^ Applicable for general area of Top End north of and including Mataranka, Larrimah, from Victoria River to Roper River mouths.
### SEASONAL PREVALENCE OF THE MAJOR PEST AND VECTOR MOSQUITO SPECIES IN THE TOP END OF THE NT*

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

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

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

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F:\ENTO\ento_files\public_information\general_information\mosquitoes\probmos Top End (Apr 07 update).doc 6
# PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT

## PEST AND DISEASE VECTOR STATUS

**Peter Whelan 1997**

Medical Entomology Branch, Department of Health and Community Services

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

**LEGEND**

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

* The ability to vector these pathogens has not necessarily been established
PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT

INDICATIVE PEST LEVELS

Peter Whelan 2002
Medical Entomology Branch, Department of Health and Community Services

<table>
<thead>
<tr>
<th>Species</th>
<th>Main distribution</th>
<th>Peak Period</th>
<th>CO₂ Trap at Residence *</th>
<th>CO₂ Trap at Monitoring Site #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aedes vigilax</td>
<td>Top End, north of Wave Hill, Larrimah and Borroloola</td>
<td>September - January</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>Aedes normanensis</td>
<td>Subcoastal Top End south to Ti Tree</td>
<td>January - April</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Culex annulirostris</td>
<td>NT wide</td>
<td>January to August</td>
<td>50</td>
<td>600</td>
</tr>
<tr>
<td>Anopheles bancroftii</td>
<td>Top End north of Victoria and Roper River, south to Larrimah</td>
<td>February - July</td>
<td>30</td>
<td>300</td>
</tr>
<tr>
<td>Coquillettidia xanthogaster</td>
<td>Top End north of Victoria and Roper River, south to Larrimah</td>
<td>March - August</td>
<td>30</td>
<td>300</td>
</tr>
<tr>
<td>Mansonia uniformis</td>
<td>Top End south to Larrimah</td>
<td>March - June</td>
<td>30</td>
<td>200</td>
</tr>
<tr>
<td>Anopheles farauti s.l.</td>
<td>Top End north of Port Keats inclusive, Pine Creek, and Numbulwar</td>
<td>March - June</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Culex quinquefasciatus</td>
<td>NT wide, primarily near residential areas</td>
<td>January - June</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Aedes notoscriptus</td>
<td>NT wide, generally near residential areas</td>
<td>January - June</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Verrallina funerea</td>
<td>Top End primarily coastal and sub-coastal but occasionally south to Larrimah</td>
<td>Nov - March</td>
<td>20</td>
<td>200</td>
</tr>
</tbody>
</table>

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

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PERSONAL PROTECTION
FROM MOSQUITOES & BITING MIDGE

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
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 cannot be relied on for protection from biting insect attack (Mitchell 1992). When used in outdoor situations it is possible that they can increase local problems by attracting insects to...
the vicinity of people. Attractive odours and carbon dioxide emitted by humans then divert the insects from the trap device to the people.

11.0 TREATMENT OF BITES

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

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

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

12.0 EMERGENCY BITING INSECT PROTECTION

There are a number of emergency measures that can be taken when exposed to biting insects with no protection. Sheltering downwind next to smoky fires can offer considerable protection. Burning dung or aromatic and oil producing foliage from plants such as Hyptis (horehound), Vitex (black plum), Calytrix (Turkey bush), Melaleuca species (Paper bark) and Eucalyptus species (gum trees) can make the smoke more effective. A small native plant Pterocaualn 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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Lee, D. J. (1975), ‘Arthropod bites and stings and other injurious effects’, *School of Public Health & Tropical Medicine, University of Sydney*.


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

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Abstract

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

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

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

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

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

Accordingly, Bifenthrin (FMC Chemicals) was selected for evaluation as an effective insecticide surface treatment for biting midges and mosquitoes harbouring on ornamental plants, fences and walls surrounding domestic situations at River Heads, Hervey Bay (Queensland, Australia). This suburb was selected as a test site, as a recent public health study found that residents experience reduced health levels as a consequence of biting midges, and that an effective control method is desperately needed (Howie 2002). Bifenthrin, a non-alpha 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 µg/litre) and good stability to hydrolysis and photolysis (2 years at 500C. under natural daylight); and
5) safety to humans: “Noting its safety and efficacy, Bifenthrin 10WP is recommended for indoor residual spraying” (WHO/CDS/WHOPES/2001.4).

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

**Materials and Methods**

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

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

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

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

**Table 1. Property treatment rates.**

<table>
<thead>
<tr>
<th>Treatment Property No.</th>
<th>Property Size</th>
<th>Volume of 8% SC Applied¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1012 m²</td>
<td>875 ml</td>
</tr>
<tr>
<td>2</td>
<td>1012 m²</td>
<td>750 ml</td>
</tr>
<tr>
<td>3</td>
<td>1012 m²</td>
<td>500 ml</td>
</tr>
<tr>
<td>4</td>
<td>1012 m²</td>
<td>625 ml</td>
</tr>
</tbody>
</table>

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 5. Descriptive Statistics for 6 weeks field Data.

<table>
<thead>
<tr>
<th>Biting Midge (n = 54 trap collections)</th>
<th>Skewness</th>
<th>Range</th>
<th>Max</th>
<th>Min</th>
<th>Median</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>1.46</td>
<td>2,011</td>
<td>2,012</td>
<td>1</td>
<td>276</td>
<td>441</td>
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<tr>
<td>Control</td>
<td>2.21</td>
<td>21,914</td>
<td>21,948</td>
<td>34</td>
<td>425</td>
<td>2,989</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mosquitoes (n = 54 trap collections)</th>
<th>Skewness</th>
<th>Range</th>
<th>Max</th>
<th>Min</th>
<th>Median</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>2.50</td>
<td>186</td>
<td>186</td>
<td>0</td>
<td>8</td>
<td>25</td>
</tr>
<tr>
<td>Control</td>
<td>2.40</td>
<td>875</td>
<td>879</td>
<td>4</td>
<td>106</td>
<td>169</td>
</tr>
</tbody>
</table>

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

**Acknowledgements**

Dr Pat Dale (Griffith University – Australian School of Environmental Studies), Darran Thomas (Gold Coast City Council - Entomology) and Mike Muller (Brisbane City Council – Mosquito & Pest Services) reviewed this article. The Hervey Bay City Council, River Heads Community and the Biting Midge Research and Management Committees provided guidance and encouragement. Ian Francis, Kim Watson (FMC), Nicholas Woods, Gary Dorr (Centre for Pesticide Application & Safety), and Darryl McGinn (Mosquito Consulting Services) provided technical guidance and useful discussion. Garrard’s Pesticides Pty Ltd provided the Solo Backpack sprayer.
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Appendix 6
## Arbovirus Disease Risk Periods in the Northern Territory

<table>
<thead>
<tr>
<th>Virus</th>
<th>From Vectors/Abundance &amp; Longevity</th>
<th>From Virus Isolation</th>
<th>From Sentinel Animals</th>
<th>From Case Data</th>
<th>Peak Risk Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVE</td>
<td>JAN-SEPT</td>
<td>MAR</td>
<td>DEC-OCT</td>
<td>FEB-JULY</td>
<td>MAR-MAY</td>
</tr>
<tr>
<td>Kunjin</td>
<td>JAN-SEPT</td>
<td>APRIL-JUN</td>
<td>DEC-SEPT</td>
<td>MAY-JUN</td>
<td>MAR-MAY</td>
</tr>
<tr>
<td>RRV</td>
<td>NOV-SEPT</td>
<td>JAN-APR</td>
<td>-</td>
<td>JAN-DEC</td>
<td>JAN-MAR</td>
</tr>
<tr>
<td>BF</td>
<td>NOV-SEPT</td>
<td>DEC-APR</td>
<td>-</td>
<td>DEC-OCT</td>
<td>JAN-MAR</td>
</tr>
</tbody>
</table>

Handout\'risk.xls