Biting Insect Assessment

Condensate Processing Facility East Arm, Darwin

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Study undertaken on behalf of URS Australia Pty Ltd
for
Darwin Clean Fuels Pty Ltd

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1.0 Introduction

Darwin Clean Fuels Pty Ltd plan to establish and operate a Condensate Processing Facility in Section 5720 and part Section 5633 at the Darwin Business Park at East Arm (Figure 1). The Condensate Processing Facility will produce a range of products, principally unleaded petrol, diesel and kerosene/jet fuel. It is anticipated that the condensate would be sourced principally from the Bayu Undan field in the Timor Sea and North West Shelf off Western Australia.

Surface water ponding and mosquito breeding has been an issue in the East Arm area, primarily due to reclamation works conducted for the development of Darwin Business Park and the port facility. Water ponding and mosquito breeding has also been located in Section 5720 and part Section 5633 by the Medical Entomology Branch during previous surveys. The Darwin Business Park is also located adjacent to extensive mangrove areas of Blesers Creek, Elizabeth River and Hudson Creek, which are expected to be large sources of pest biting midges.

Due to the proposed development site and adjacent areas containing potential mosquito breeding sites, and the close proximity of mangrove areas, which are potentially large sources of pest biting midges, the Medical Entomology Branch (MEB) was commissioned by URS Australia Pty Ltd on behalf of Darwin Clean Fuels Pty Ltd to conduct a Biting Insect Assessment for the proposed facility. The Biting Insect Assessment was to include:

- Ground inspections in the proposed development site and adjacent areas to locate existing actual and potential mosquito breeding sites.
- Trapping one night before the full moon on the 7th September 2006 to monitor peak monthly abundance of the main human pest biting midge species *Culicoides ornatus*. Four traps were proposed to be set adjacent to the development site.
- An evaluation of the results from the routine weekly Australian Quarantine Inspection Service (AQIS) adult mosquito monitoring trap set at the entrance to nearby East Arm Port, from January 2005 to January 2006, to determine likely seasonal mosquito abundance and diversity, and the potential for mosquito borne disease transmission at the development site.
- An evaluation of the 12-month baseline biting midge trap results from the Hidden Valley area (Whelan et al 1994), located on the north side of Blesers Creek, which is likely to be one of the major sources of pest biting midges to the development site.
- An evaluation of aerial photography to determine the likely sources of pest biting midges to the development site.
- Recommendations on the rectification of existing mosquito breeding sites within and adjacent to the development site.
- Recommendations on how to manage biting insect pest problems and how to prevent the development from creating new mosquito breeding sites.
2.0 Project aims

2.1 Aims

The aims of the Biting Insect Assessment were to:

- Conduct ground inspections in the proposed development site and adjacent areas to locate existing actual and potential mosquito breeding sites.
- Set four traps one night before the full moon on the 7th September 2006 to monitor peak monthly abundance of the main human pest biting midge species *Culicoides ornatus*.
- Evaluate the results from the routine adult mosquito monitoring trap set weekly at the entrance to nearby East Arm Port from January 2005 to January 2006, to determine likely seasonal mosquito abundance and diversity, and the potential for mosquito borne disease transmission at the development site.
- Evaluate the 12-month baseline biting midge trap results from the Hidden Valley area (Whelan et al, 1994), located on the north side of Blesers Creek, to determine the importance of this creek to the development area as a biting midge breeding site, and likely seasonal trend in pest biting midge populations.
- Examine aerial photography to determine the likely sources of pest biting midges to the development site.
- Provide recommendations on the rectification of existing mosquito breeding sites within and adjacent to the development site.
- Provide recommendations on how to manage biting insect pest problems and how to prevent the development from creating new mosquito breeding sites.

2.2 Significance and scope of the project

An evaluation of the Condensate Processing Facility development area for potential biting insect problems is required for the Environmental Impact Statement. It is also a requirement to consider the impact of the development on biting insect populations and outline management procedures to reduce the impact of these insects.

Biting midges can be considerable pests within a few kilometres of the coast in the NT (Whelan 1991a). 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.

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 disease caused by Murray Valley encephalitis virus (MVEV), and a number of other diseases caused by Kunjin virus (KUNV), Ross River virus (RRV) and Barmah Forest virus (BFV).

The proposed development area is located on reclaimed land in the Darwin Business Park at East Arm. Mosquito breeding has been found during occasional larval surveys on Section 5720, with potential mosquito breeding sites also located on part Section 5633. Actual and potential mosquito breeding sites also exist in other undeveloped areas of East Arm, most notably the large sediment (“mud”) ponds adjacent to the port. The main mosquito species of importance at East Arm is likely to be the salt marsh mosquito *Aedes vigilax*, due to its day biting habits and potential to transmit Ross River virus disease and Barmah Forest virus disease. This species has been the most common mosquito recovered during previous larval mosquito surveys at East Arm, and is most likely to breed in reclaimed coastal areas such as East Arm. Other potentially important mosquito species likely to breed in the East Arm area include the common banded mosquito *Culex annulirostris* and the North Australian malaria mosquito *Anopheles farauti s.l.*

The seasonal trend in mosquito abundance and diversity at the proposed development site was determined using the results from the Australian Quarantine and Inspection Service (AQIS) trap set at
the entrance to nearby East Arm Port. Weekly results from January 2005 to January 2006 were used. Data from previous larval mosquito surveys at East Arm was obtained from the Medical Entomology Branch database, which was used to identify some actual and potential mosquito breeding sites at East Arm. A ground inspection was also carried out on the 8th September 2006, 12th and 17th October 2006, to locate potential mosquito breeding sites that had not been previously identified.

The proposed development site is located adjacent to extensive mangrove areas associated with Bleezers Creek and the Elizabeth River. These mangrove areas were expected to be significant sources of the mangrove pest biting midge species Culicoides ornatus, with Bleezers Creek previously identified as a significant source of C. ornatus during baseline trapping in the Darwin South area (Whelan et al 1994). It was expected that pest biting midge levels within the proposed development site would be very high to extreme during certain periods of the year.

In order to assess the biting midge population at the proposed development site, four traps were proposed to be set around the edges of the development area one night before the full moon in September 2006, to monitor peak monthly abundance of C. ornatus. Peak biting midge dispersal generally occurs one night before the full moon during the warmer months (Shivas & Whelan 2001), with September chosen as it falls within the peak season months of August to October. The likely seasonal trend in pest biting midge abundance at the proposed development site was determined using 12-month baseline data from the Hidden Valley area (Whelan et al 1994), which is located on the north side of Bleezers Creek. Potential C. ornatus breeding sites were located using aerial photography, based on previous information on breeding sites for this species (Shivas et al 1997, Shivas et al 1998, Shivas 1999, Whelan et al 1997).
3.0 Methods

3.1 Biting midges
Adult biting insect traps were set on the afternoon of September 7th, and collected the following morning after sunrise. The traps used were carbon dioxide baited EVS traps (Rohe and Fall 1979). The traps consisted of an insulated bucket, a suction fan powered by two ‘D’ cell batteries, a ‘grain of wheat’ light, and a rigid collection container (4 litre, 220 mm in diameter) fitted with a muslin sleeve and very fine wire mesh vents. The traps were set around chest height and baited with approximately 1kg of dry ice.

Adult biting insect traps were set in a variety of sites in an effort to reveal maximum numbers of pest biting midges, in particular *Culicoides ornatus*. This included setting traps at the mangrove margin, and setting traps on escarpment areas adjacent to the development site.

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.

Potential *C. ornatus* breeding sites were deduced by examining aerial photography, using information on the breeding sites for this species (Shivas et al 1997, Shivas et al 1998, Shivas 1999, Whelan et al 1997). Sites of interest were upper tidal tributaries and foreshore mangrove areas. The likely seasonal abundance of *C. ornatus* at the proposed development site was determined using the 12-month baseline biting midge trap results from the Hidden Valley area, on the north side of Blesers Creek. Traps for this study were set on the night of the full moon and the results represent the likely seasonal trend in *C. ornatus* abundance at the proposed development site.

3.2 Mosquitoes
An AQIS officer set Carbon Dioxide baited EVS traps weekly at selected sites in Quarantine areas around Darwin, which included a trap set near the guardhouse at the entrance to East Arm Port. Catch containers were brought back to the MEB laboratory in Darwin, the mosquitoes were killed by freezing and then sorted into petri dishes for identification. Data from this trap site from January 2005 to January 2006 was used to determine the likely seasonal abundance and diversity of mosquito species at the proposed development site.

For mosquito collections under 300 individuals, all mosquitoes were individually identified. For mosquito collections over 300 individuals, a sub-sample of approximately 300 individuals was taken for identification and weighed, with the remaining bulk sample also weighed. The bulk weight was divided by the sub-sample weight, to determine the multiplication factor for which the sub-sample was multiplied by to determine total numbers. All individuals in the sub-sample were identified, with the remaining bulk scanned for any species not detected in the sub-sample. Any additional species located in the bulk were entered into a database with the species from the sub-sample, but were excluded from multiplication.

Information from previous larval mosquito investigations at East Arm was obtained from the Medical Entomology Branch database. This information highlighted previous actual and potential mosquito breeding sites located in and nearby to the development area. Potential breeding sites were also
examined on the 8th September 2006, 12th October 2006 and 17th October 2006. Potential breeding sites were characterised by the presence of tide water ponding, or by the presence of depressions on the ground surface. Potential breeding sites highlighted during the September and October surveys were photographed and co-ordinates taken using a hand held GPS.

Development plans were examined and evaluated for the potential to create mosquito breeding sites, and also for the possibility of rectifying actual and potential mosquito breeding sites that are present within and adjacent to the development boundary. Recommendations were then provided based on the evaluation of development plans.
4.0 Results

4.1 Habitat survey

4.1.1 Nearby sites larval mosquito survey 8th September 2006 and 17th October 2006

Various sites were examined in and adjacent to the proposed development site on the 8th September 2006 and 17th October 2006. Potential breeding sites located during the surveys are shown in Figure 3, with results displayed in Table 1 and Photos displayed in Appendix 1. The survey was conducted to highlight potential breeding sites only, as the optimum time to conduct a larval survey at the proposed development site and surrounding areas would have been after heavy rainfall in November or December, as this would have highlighted ponding in both tidal and reclaimed areas at East Arm.

Nearby sites larval mosquito survey 8th September 2006

Larval Site 1
Larval Site 1 was a large borrow pit near the south-east corner of the part Section 5633. The borrow pit had a central drainage channel and appeared it would be relatively free draining during the wet season. Some minor depressions were also evident on the ground surface in disturbed areas nearby to the borrow pit. The borrow pit and minor depressions could be potential breeding sites for Cx. annulirostris, Coquillettidia xanthogaster and Anopheles species mosquitoes.

Larval Site 2
Larval Site 2 was the open unlined drain from the Railway Terminal and north boundary of Section 5720. The drains joined at a road culvert, and passed through a railway culvert before terminating just inside the mangrove margin. Both drains upstream of the first culvert as well as the lower reaches of the drain had a relatively rocky base, and some tide water was ponding in the lower eroded reaches of the drain near the mangrove margin. No mosquito breeding was located, although the lower reaches of the drain was a likely breeding site for Aedes vigilax and Culex sitiens.

Larval Site 3
This site was a depression, approximately 40m², in the tidal mangrove area adjacent to the north-west boundary of Section 5720, near the railway embankment. Fish were present in the depression during the survey. This site appeared to be a potential breeding site for Ae. vigilax, Cx. sitiens and Anopheles hilli.

Larval Site 4
This site was a depression, approximately 80m², in the tidal mudflat area opposite the Vopak Fuel Terminal, west of Section 5720 and adjacent to the railway embankment. Fish were present in the depression during the survey. This site appeared to be a potential breeding site for Ae. vigilax, Cx. sitiens and An. hilli.

Larval Site 5
This site was the railway culvert which collected water from the Vopak Fuel Terminal main drain. Significant silt deposition was evident in the tidal flat area downstream of the culvert and shallow ponding was evident, although the tide had recently inundated the area. It appeared that water ponding at this site would be relatively temporary (ie less than 3 consecutive days), therefore this site was not considered as a potentially significant mosquito breeding site.

Larval Site 6
This site was a small depression in Section 5720. Numerous other shallow depressions also existed on Section 5720. Previous wet season surveys (Table 3) have located An. hilli, Ae. vigilax and Cx. annulirostris larvae in similar depressions on Section 5720.
**Larval Site 7**
This site was a Paperbark swamp located at the south edge of Quarantine Island. An access track passed between the swamp and the mangrove margin, which would have restricted water flow out of the swamp but in turn was likely to prevent tide entry into the swamp. The swamp appeared to be a potential *Cx. annulirostris, Anopheles* species and *Cq. xanthogaster* breeding site. If tide entry is allowed into the swamp, it will become a potential *Ae. vigilax* breeding site.

**Larval Site 8**
This site was a poorly draining drainage line in the north-east area of part Section 5633, between the reclaimed portion of part Section 5633 and the remnant hill area of part Section 5633. The drainage line started near Berrimah Road and had an end point at the mangrove margin near the south-east boundary of part Section 5633. Due to the presence of vegetation, the drainage line is likely to be a potential *Cx. annulirostris* breeding site in the upper reaches, and potential *Ae. vigilax, An. hilli, An. farauti s.l.* and *Cx. sitiens* breeding site in the lower reaches.

**Larval Site 9**
This site was a deep open unlined drain through part Section 5633, from a pipe outfall at Berrimah Rd to the upper reaches of a tidal tributary of the Elizabeth River. Tide water was still flowing out of the drain during the survey, although it appeared that there would be some minor residual ponding in the drain that could be potential *Ae. vigilax* and *Cx. sitiens* breeding sites.

**Larval Site 10**
This site was an open unlined drain from Berrimah Rd to the mangrove margin, near the south boundary of part Section 5633. The OUD appeared to collect water from a small pipe outfall at the head of the drain, and roadside runoff from Berrimah Rd, which included a pipe culvert that fed into the upper reaches of the OUD via a small unlined channel. The OUD had recently been cleared of grass and shrubs.

Several areas in the OUD appeared likely to pond water during the wet season. The invert of the small channel feeding into the upper reaches of the OUD was lower than the invert of the OUD, which suggested water would pond in the small channel. There were also numerous low spots along the length of the drain that appeared likely to pond water during the wet season. *Aedes vigilax* had previously been found breeding in the lower reaches of this drain (Table 3), with *An. hilli* and *An. farauti s.l.* also likely to breed in the lower reaches of the drain (when grass re-grows in the drain). *Culex annulirostris* had previously been found breeding in the upper reaches of this drain (Table 3).

**Nearby sites larval mosquito survey 17th October 2006**

**Larval Site 11**
This site was a silt trap near the northern edge of Quarantine Island, south of Section 5633. Provision for drainage from this silt trap was via a pipe culvert through an earth embankment to the mangrove margin. The pipe outlet was lower than the mangrove margin. A small plunge pool was present at the pipe outlet, and some of the pipe had rusted away. The pipe inlet was a curved structure designed to allow significant water ponding (approximately 1m) in the silt trap, but designed to prevent water from overtopping the walls of the silt trap by allowing water to flow into the pipe once a certain level was reached. The invert of the silt trap appeared to be slightly lower than the surrounding mangrove margin, which may have allowed tide seepage through the floor of the silt trap.

Water was ponding in the silt trap. Dead *Typha* sp. reeds, grasses and leaf matter were evident in the water. A salinity sample taken revealed the water was fresh (2.45mS/cm), which was surprising as recent rainfall in the two weeks before the survey had been only light in the Darwin area. It is possible that the 7.9m tides on the 9th of October had seeped through the floor of the silt trap and caused some waterlogging or even some ponding, which then allowed subsequent rainwater runoff into the silt trap to pond. The dead *Typha* reeds indicated that the silt trap had only recently been flooded with
freshwater, as regrowth had not started. The dead *Typha* sp. reeds indicated extended ponding occurs in the silt trap.

*Culex annulirostris* and *Cx. sitiens* larvae were located in the silt trap. The presence of *Cx. sitiens* indicated that this site was also a probable breeding site for *Ae. vigilax*, *Coquillettidia xanthogaster* and *Anopheles* species mosquitoes were also likely to breed in this silt trap.

**Larval Site 12**
This site was a similar silt trap to Laval Site 11, and was located upstream of Larval Site 11. This site was dry when surveyed. Water ponding potential in this silt trap appeared to be less than the Larval Site 11 silt trap, as the pipe inlet structure had been modified such that water would have entered the pipe when at a much lower level (approximately 100mm). The presence of dead *Typha* sp. reeds indicated extended water ponding occurred in this silt trap. The pipe outfall from the silt trap emptied into a drainage channel approximately 10m before the mangrove margin, and a plunge pool was present at the pipe outfall.

This site was a potential breeding site for *Cx. annulirostris*, *Cq. xanthogaster* and *Anopheles* species. It did not appear that this silt trap had any tidal influence.

### 4.1.2 Distant sites larval mosquito survey 12th October 2006

Distant potential mosquito breeding sites were surveyed on the 12th of October 2006. Results are displayed in Table 2, site locations are displayed in Figure 3 and photos are displayed in Appendix 1. The survey was conducted three days after the highest tide of the year.

**Larval Site 13**
This site was a large embanked mangrove area between the railway culvert and the Darwin Business Park (formerly Trade Development Zone (TDZ). The embanked area was a result of the railway culvert being installed at a level higher that the upstream mangrove area, therefore allowing water to pond in the lower lying mangrove area. This site consisted of a large area of dead mangroves, with green *Typha* sp. and grass growing underneath and alongside the dead mangroves in some areas, and a mudflat area vegetated with dead *Eleocharis* reeds located on the upstream side of the mudflat. The green *Typha* sp. reeds and grass, and the dead mangroves, indicates freshwater/brackish water ponding occurs for extended periods of the year.

This site had a relatively large section of tide water ponding in the dead mangrove area when surveyed. *Culex sitiens* larvae were widespread throughout the flooded area. This site was also a potentially significant *Ae. vigilax*, *Cx. annulirostris*, *Cq. xanthogaster* and *Anopheles* species breeding site.

The low lying mangrove area was also fed by a stormwater drain from the Darwin Business Park (DBP), which retains water all year and would have contributed to the extended water ponding in the low lying mangrove area. The sides of the drain were vegetated with *Typha* sp. reeds and weeds, while the centre of the drain was vegetation free as the water was relatively deep. The drain was a potential *Cx. annulirostris*, *Cq. xanthogaster*, *Anopheles* species and *Culex quinquefasciatus* breeding sites.

**Larval Site 14**
This site was a pipe outlet from the end of Muramats Rd to the *Paperbark* fringe, with water travelling a short distance to the mangrove margin. A plunge pool was present at the pipe outfall, and some minor erosion was also evident downstream of the plunge pool. The plunge pool was breeding high numbers of *Cx. sitiens*, with a small eroded pool downstream of the plunge pool also breeding *Cx. sitiens*. This site was also a potential *Ae. vigilax* breeding site.

**Larval Site 15**
This site was a broad, shallow open unlined drain from the eastern end of Hamaura Rd to a low lying *Paperbark* and *Pandanus* grassy area. The invert of the drain was lower than the *Paperbark/Pandanus*
area, suggesting some water will pond in the drain, although the drain had a relatively rocky and sandy base, suggesting vegetation growth on the drain floor would be minimal, unless dry season flows occur in drain, which was not evident during the survey. At its current state, this drain had minimal potential to be a significant mosquito breeding site.

**Larval Site 16**

This site was a low lying grassy *Pandanus* and *Paperbark* area located adjacent to the end point of an open unlined drain (Larval Site 15). It appeared that water ponding would occur in this area during the wet season and early dry season, in which case it would be a potential *Cx. annulirostris*, *An. bancroftii* and *Cq. xanthogaster* breeding site.

**Larval Site 17**

Larval Site 17 was an open unlined drain from the middle section of Hamaura Rd, which extended to the mangrove margin. A small plunge pool was evident at the pipe outfall, and the invert of the drain appeared to be slightly lower than the mangrove margin, suggesting wet season ponding would occur. The recent high tides had not resulted in any significant ponding in the drain, probably due to the sandy nature of the lower reaches of the drain allowing the tide water to infiltrate into the ground.

There was evidence of dry season polluted water in the plunge pool, most likely from the adjacent business. The plunge pool was found breeding *Cx. quinquefasciatus* in very low numbers. The drain is also a potential *Ae. vigilax* and *Cx. sitiens* breeding site.

**Larval Site 18**

This site was the western most open unlined drain from Hamaura Rd, which terminated inside the mangrove margin. The invert of the drain appeared lower than the surrounding mangrove area, which resulted in significant tide water ponding. A small plunge pool was also present at the pipe outfall. Fish were present throughout the drain and no mosquito larvae were found. This drain could be a potential *Ae. vigilax* and *Cx. sitiens* breeding site if fish access becomes restricted.

### 4.1.3 Biting midge breeding site desktop survey

Aerial photography was examined to locate potential breeding sites for the main human pest biting midge species *Culicoides ornatus*, which breeds in tidal mangrove areas. *Culicoides ornatus* is usually found in greatest numbers within 1.5km of the mangrove margin, and in lower numbers for at least 3.5km (Shivas & Whelan). Breeding occurs in two distinct areas in the mangrove forest, the upper reaches of small tidal tributaries and mangrove lined foreshores (Shivas, Whelan & Webb 1997, 1998; Shivas 1999).

Based on the information above, aerial photography was examined to locate potential *C. ornatus* breeding sites within 3km of the proposed development site. Potential breeding sites were likely to be the upper reaches of the small tidal tributaries in Bleezers Creek, the *Sonneratia* foreshore mangrove area between East Arm Port and the mouth of Bleezers Creek, the upper reaches of the small tidal tributary located in part Section 5633, and the *Sonneratia* foreshore mangrove area between East Arm Port and the mouth of Hudson Creek. The Bleezers Creek upper tidal tributaries appeared to be the most significant potential *C. ornatus* breeding sites (Figure 1).

### 4.2 Ad-hoc larval surveys East Arm Precinct

The Medical Entomology Branch has conducted larval mosquito surveys in the East Arm area over the 2004/05 and 2005/06 wet seasons to investigate mosquito complaints (Table 3). The surveys highlighted that numerous mosquito breeding sites existed in the East Arm area, with *Ae. vigilax*, *Cx. annulirostris*, *Cx. sitiens* and *An. hilli* the mosquito species found breeding during the surveys. The most common breeding sites were temporary ground pools and poorly draining drainage lines, although the largest breeding sites were two of the mud ponds between the port facility and Northern Cement (Mud Ponds A & B). Approximate locations of these sites are shown in Figure 3.
4.3 Biting midges

4.3.1 Species present
A total of 27,401 adult female biting midges were collected during trapping on the 8th-9th September 2006, representing a total of three species (Table 5). *Culicoides ornatus* was by far the most common species trapped, accounting for 93% of all biting midges. *Culicoides papuensis* was the next most abundant biting midge species, accounting for 1% of all biting midges trapped, followed by *Culicoides immaculatus* (0.5%) (Table 5).

*Culicoides unidentifiable (damaged)* accounted for 5% of biting midges, due to damage occurring to the wings of some specimens when being processed, which makes identification impossible.

4.3.2 Spatial abundance
Trap Site 3 was the most productive trap site, accounting for 40% of all biting midges trapped, followed by Trap Site 2 (31%), Trap Site 4 (23%) and Trap Site 1 (6%). *Culicoides ornatus* was most abundant at Trap Site 3 (10,560 females), followed by Trap Site 2 (8,160), Trap Site 4 (5,292) and Trap Site 1 (1,568) (Table 5).

4.3.3 Seasonal abundance
The seasonal abundance of *Culicoides ornatus* at the proposed development site can be inferred from 12-months baseline data from the Hidden Valley area, located on the north side of Bleezers Creek, as Bleezers Creek is likely to be the main source of biting midges to the proposed development site. The 12-months data is shown in Figure 2, with the trap location shown in Figure 1. Trap Site 19, adjacent to Portion 1591 RAAF explosive reserve, was used from the Darwin South Stage II study (Whelan et al 1994).

Highest numbers of *C. ornatus* were recorded at Trap Site 19 in the months of July to November and also in January (Figure 2). February recorded the lowest total numbers, while lower abundance was recorded in March to June. This indicates a general mid to late dry season trend in peak *C. ornatus* abundance.

4.4 Mosquitoes

4.4.1 Species present
A total of 167 adult female mosquitoes were collected during trapping on the 7th-8th September 2006, representing a total of seven species (Table 6). *Culex annulirostris* was the most common species trapped, accounting for 72% of all female mosquitoes, followed by *Coquillettidia xanthogaster* (12%) and *Aedeomyia catasticta* (10%). *Culex quinquefasciatus* (2.4%), *Culex sitiens* (2.4%), *Culex Vishnui grp.* (1.2%) and *Aedes tremulus* (0.6%) made up the remaining mosquito species (Table 6).

Table 4 represents 12-months trapping results from the AQIS mosquito surveillance trap that was set nearby to the entrance to East Arm Port. The most common mosquito species collected at this trap site was *Aedes vigilax*, accounting for 52% of all mosquitoes trapped from July 2005 to June 2006. The next most common mosquito species was *Cx. annulirostris* (30%), followed by *Aedes notoscriptus* (5.07%) and *Cq. xanthogaster* (4.76%).

4.4.2 Spatial abundance
Trap Site 3 was the most productive trap site, accounting for 38% of all mosquitoes trapped, followed by Trap Site 4 (29%), Trap site 2 (26%) and Trap Site 1 (7%) (Table 6).
Culex annulirostris was most abundant at Trap Site 3, with a total of 48 females mosquitoes trapped at this site. This was followed by Trap Site 4 (36), Trap Site 2 (28) and Trap Site 1 (8). Coquillettidia xanthogaster was most common at Trap Site 2 (9), followed by Trap Site 3 (8) and Trap Site 1 (3). Aedeomyia catasticta was most common at Trap Site 4 (10), followed by Trap Site 3 (5) and Trap Site 2 (1) (Table 6).

4.4.3 Seasonal abundance

Aedes vigilax was most abundant at the AQIS mosquito surveillance trap in the months of September to March, with highest numbers in December and February. Culex annulirostris was most abundant in the months of December, February and March, with minor abundance from April to June. Coquillettidia xanthogaster was most abundant in May and June, and Aedes notoscriptus was most common from February to April (Table 4).
5. Discussion

5.1 Biting midges

5.1.1 Species present

*Culicoides ornatus* was trapped in very high numbers during the September 2006 trapping and will be the most abundant biting midge species at the Condensate Processing Facility. Other species may be present at the proposed development site, but are unlikely to be encountered in numbers as high as *C. ornatus*. *Culicoides ornatus* is considered the most significant human pest biting midge species around coastal areas in the NT (Shivas 1999, Shivas & Whelan 2001), and is also by far the most common biting midge pest around coastal areas of the Northern Territory (Shivas 1999, Whelan 2003, Appendix 4).

Two other biting midge species, *Culicoides flumineus* and *Culicoides* species near *subimmaculatus* can be severe human pests in mangrove areas across the Top End of the NT, but are rarely found outside mangrove forests (Whelan 2003, Appendix 4), therefore are not expected to present in any significant numbers at the proposed development site.

*Culicoides immaculatus* was trapped in low numbers at Trap Site 4. This species can be a minor pest of humans near their rock-sandy or sandy beach breeding sites.

*Culicoides papuensis* was recorded in low numbers at Trap Sites 2 & 4, but this species has not been recorded biting man in Australia (Shivas 1999), therefore is not likely to be of any pest significance at the Condensate Processing Facility.

5.1.2 *Culicoides ornatus* breeding sites

Breeding sites for *C. ornatus* are discussed in Appendix 4. Essentially, prime breeding sites are characterised by upper tidal tributaries around the mean high water neap tide mark, in association with pneumatophores of *Avicennia marina* mangroves (Whelan 2003). Potential upper tidal tributary breeding sites likely to affect the proposed Condensate Processing Facility are highlighted in Figure 1. Bleesers Creek contains numerous upper tidal tributaries that can be expected to be very productive *C. ornatus* breeding sites. A small upper tidal tributary is also located in the southern edge of part Section 5633, which is also likely to be a productive *C. ornatus* breeding site. These upper tidal tributaries are expected to be very large sources of *C. ornatus* to the development site.

Other breeding sites of low to medium productivity occur at the front edge of the mangrove forest in the *Sonneratia* or woodland mangrove zone facing open water (Whelan 2003). These breeding sites are usually associated with mud substrates and not sandy substrates (Whelan 2003). Potential foreshore mangrove breeding sites are highlighted in Figure 1. The *Sonneratia* foreshore between the mouth of Bleesers Creek and East Arm Port, and the *Sonneratia* foreshore in the Elizabeth River between East Arm Port and Hudson Creek are likely to be significant sources of *C. ornatus* to the proposed development site.

The trap results revealed that Bleesers Creek would be the largest source of *C. ornatus* to the proposed development site, as highest numbers were collected at Trap Sites 2 & 3, located at the mangrove margin of Bleesers Creek. The Quarantine Island trap (Trap 4) revealed that the nearby upper tidal tributary and foreshore mangrove area is also a very significant source of *C. ornatus*.

The project area is shown to encompass the upper tidal tributary in part Section 5633. If this upper tidal tributary is removed by development, it will remove this area as a potential *C. ornatus* breeding site.
5.1.3 Spatial abundance and dispersal

Detailed information on the flight activity of *C. ornatus* can be found in Appendix 4. *Culicoides ornatus* actively disperses inland from their mangrove breeding sites (Shivas 1999, Shivas & Whelan 2001), which is a characteristic that makes this species a significant pest of humans. Mass movement of adults can occur to 0.5 to 1.5 km from the mangrove margin of their major breeding sites, with minor numbers up to 3km from the nearest mangrove margin (Whelan 2003). Greatest midge abundance is usually found at the top of the leading edge of escarpments within 1.5km of the mangrove margin (Shivas & Whelan 2001).

The proposed development site is located entirely within 1.5km of a mangrove margin. *Culicoides ornatus* abundance will reach very high levels throughout all areas of the proposed development site. Very high numbers at Trap Sites 2 & 3 indicates very high dispersal from Bleesers Creek breeding sites, and very high numbers at Trap Site 4 indicates very high dispersal from adjacent breeding sites in the Elizabeth River. Trap Site 1 was located inland of the mangrove margin compared to the other three trap sites, which were located at or adjacent to the mangrove margin. This may explain the much lower numbers at Trap Site 1, as the day of peak fortnightly midge abundance is more consistent at the mangrove margin than at inland sites (Shivas & Whelan 2001).

In summary, it is expected that *C. ornatus* will be widespread in very high numbers throughout all areas of the proposed development site, with highest dispersal occurring from the Bleesers Creek upper tidal tributaries, and very high dispersal from the part Section 5633 upper tidal tributary, and very high dispersal from the *Sonneratia* mangrove foreshores between East Arm Port and the mouth of Bleesers Creek, and East Arm Port and the mouth of Hudson Creek.

5.1.4 Seasonal fluctuations

The annual peak in *Culicoides ornatus* adult abundance in the NT is encountered in the August to October period in the late dry season, with lowest numbers in January and February (Whelan 2003). Populations start to build up from the end of the wet season to the late dry season, with a slight decrease in the coldest months of June and July (Whelan 2003). Further information on seasonal abundance of *C. ornatus* can be found in Appendix 4.

The results from the trap set adjacent to the RAAF explosives reserve at Hidden Valley revealed a very large peak in *C. ornatus* abundance in September, with elevated numbers in August and October, as per the usual trend in peak numbers. The peak in January at this trap site was unusual, and may have been due to various environmental factors that year, as *C. ornatus* abundance in January from other 12-month biting midge studies and most other trap sites from the Darwin South Stage II study have always been much lower than in the peak season months of August to October (Whelan et al 1994, Whelan et al 1998, Warchot & Whelan 2004). The peak in July was also unexpected as it is usually one of the coolest months of the year. Midge dispersal during the dry season is related to temperature (Shivas & Whelan 2001). It is possible that warmer July temperatures were experienced that year, thus leading to greater midge dispersal inland of their breeding sites.

The seasonal abundance of *C. ornatus* at the Condensate Processing Facility for most years is likely to follow the usual trend of numbers increasing from the end of the wet season, before a slight decrease in numbers in June and July, with peak numbers occurring from August to October inclusive. Abundance during the wet season months of January and February is likely to be the lowest of the year for most years.

*Culicoides ornatus* occurs in highest numbers over a four day period around the full moon, with a smaller peak, approximately half the size of full moon peaks, occurring over a four day period during new moons (Shivas & Whelan 2001). In areas affected by both *Sonneratia* and upper tidal tributary breeding sites, midge levels can be heightened for at least six days in each fortnight (which includes the four days of highest numbers), as biting midge dispersal from the foreshore mangrove areas occur
approximately four days before the larger peak in dispersal from the upper tidal tributary breeding sites (Shivas & Whelan 2001).

5.1.5 Pest problems and public health
Severe biting midge pest problems will occur at the Condensate Processing Facility during the months of August to October inclusive, with moderate to high pest problems occurring for most, if not all other months of the year. Heightened midge numbers will occur over a 6 day period around the full and new moons, with two peaks in abundance likely to occur over a four day period during this 6 day period of heightened midge abundance. Therefore pest problems can be expected over a 6 day period around the full and new moons, with full moon pest problems generally being twice as large as new moon pest problems.

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

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 400 $C. ornatus$ in a CO$_2$ trap this would equate to 100 bites per hour.

The trapping results indicate that the number of $C. ornatus$ in a trap equating to 60 bites per hour (240 $C. ornatus$ per trap night) was greatly exceeded at the four traps sites, with the numbers collected at Trap Site 3 (10,560) equating to approximately 2,600 bite per hour for an unprotected worker. The lowest trap level of 1,568 $C. ornatus$ at Trap Site 1 still represents approximately 390 bites per hour for an unprotected worker, which indicates a very high pest problem.

Peak biting times for this species are in the two hours either side of sunset and sunrise (Whelan 2003). This species also bites in low levels throughout the night (Logan et al 1991). It is these periods when people at the Condensate Processing Facility will be subject to potential pest problems.

Culicoides ornatus 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.

When considering the other Culicoides species collected during trapping, C. immaculatus can be a minor pest of humans but are usually only found near their breeding sites at rock-sand or sandy beaches. Minor potential habitat occurs off Quarantine Island, but does not appear to be present directly adjacent to the proposed development site, therefore this species is not expected to cause pest problems at the Condensate Processing Facility site.

5.1.6 Limitations
Ideally to fully gauge the $C. ornatus$ population affecting the Condensate Processing Facility site, sampling would need to be carried out over four nights around the full moon for every month of the year, to cater for the expected maximum peak dispersal and seasonal abundance. This species has a range of breeding sites, which exhibit different breeding and dispersal characteristics over a four-day period (Shivas 1999, Shivas & Whelan 2001). The results from the Hidden Valley area (Whelan et al 1994) provided a good indication of likely seasonal trends in $C. ornatus$ abundance, but could not be used to predict monthly peaks at the proposed development site. This is due to the Hidden Valley area also being subject to $C. ornatus$ dispersal from breeding sites in Reichardt Creek.
Traps set one day before the full moon in September 2006 were likely to sample peak numbers from upper tidal tributary habitats, but were likely to miss peak numbers from the *Sonneratia* foreshore habitats, due to maximum dispersal from these sites occurring approximately four days before peak dispersal from upper tidal tributary habitats (Shivas 1999, Shivas & Whelan 2001).

5.1.7 Measures to reduce biting midge pest problems

**Alteration or removal of breeding habitat**

It appears that the development may remove most of the upper tidal tributary habitat located in part Section 5633, as the proposed facility site boundary covers the upper reaches of the small tidal tributary (Figure 1). If this upper tidal tributary is filled by development activities, this prevent *C. ornatus* breeding at this site, but due to considerable dispersal from other breeding sites the filling of this site will not make any noticeable difference to *C. ornatus* numbers at the development site.

To remove the *C. ornatus* pest problem, mangrove habitats within at least 2km of the development site will require removal by either filling or permanent flooding, which will be deemed environmentally unacceptable.

**Biting midge buffer zones**

A biting midge buffer zone can be defined as an area of separation between the biting midge breeding or harbouring areas and the development. An effective buffer width should be a minimum of 1.5km (Liehne 1985, Shivas & Whelan 2001). It is not possible to have a buffer zone for this development.

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), and with the high levels of *C. ornatus* expected at the proposed development site, diversion of some midges will not make a significant difference to overall pest problems.

**Biting midge larval control by insecticides**

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

**Biting midge adult control**

‘Fogging’ or the application of aerosols against adult biting midges can offer some scope for the reduction of biting midge populations. Aerosol application 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.

Pest biting midge levels will be seasonally very high and there are likely to be requests from personnel for fogging of adult midges at the Condensate Processing Facility. This can achieve effective short term control if weather conditions (eg wind) are suitable, although this will require treatments around sunset and sunrise for the 6 day period around full and new moons when pest problems will be greatest, which may prove to be time consuming and costly in the long term.

When there is a need to reduce biting midge pest problems, a residual insecticide product aimed at adult biting midge and mosquito barrier control (Bistar 80SC, active ingredient 0.1% bifenthrin) has been proven to be very successful in reducing adult biting midges around residences for up to six weeks in Hervey Bay QLD (Standfast et al 2003, Appendix 7). It is likely to reduce adult biting midge numbers in prepared or landscaped areas and could be used as part of a strategy for biting midge protection at the Condensate Processing Facility.
Part of the strategy could include specific landscaping such as planting shrub type vegetation around the sections of the development site facing mangrove areas, or installing shade cloth (around 2m high) on the boundary fence facing mangrove areas, either of which could be treated with bifenthrin when required to provide a barrier to midge dispersal.

**Personal protection and avoidance**

There will be periods when biting midge populations reach levels that warrant personal protection strategies. The main pest period will be the two hours either side of sunset and sunrise (Whelan & Hayes 1993, Whelan et al 1994).

There are a number of avoidance and personal self-protection measures that can be taken to reduce biting midge pest problems. These include fine insect screens on personnel buildings, light proof curtains, avoiding the use of incandescent or white fluorescent lights outside personnel areas where practical, avoidance of exposure at times of pest biting midge activity, and personal protective clothing and personal repellents at times of exposure to biting midges (Appendix 4 and 5).

Normal insect screening will not be adequate to stop *C. ornatus* entering buildings. However, normal screening, including outwardly opening insect screen doors will stop a considerable portion of *Culicoides* from entering personnel areas and can be made much more effective by applying a residual insecticide such as bifenthrin on the screening. There are finer insect screens that can prevent biting insect entry, and if these are acceptable, should be used. The use of light proof curtains at doors and windows, and avoiding incandescent or white fluorescent lights directly outside doors or windows where practical can reduce the numbers of midges attracted to these entry sites.
5.2 Mosquitoes

5.2.1 Species present
Over 100 mosquito species have been recorded in the Northern Territory. Twenty-six species of mosquitoes were recorded at the AQIS East Arm Port trap site from January 2005-January 2006. The most significant species recorded in terms of abundance, pest and disease potential was the salt marsh mosquito *Aedes vigilax*, followed by the common banded mosquito *Culex annulirostris*. Other species of potential disease significance were the various *Anopheles* species, *Ae. notoscriptus*, *Cx. palpalis*, *Cx. sitiens* and *Ve. funerea*. Mosquito species of pest significance were *Cq. xanthogaster*, *Cx. quinquefasciatus* and *Ma. uniformis*. Further information on these mosquito species can be found in Appendix 3.

5.2.2 Potential breeding sites at East Arm
Information on general breeding sites for the important mosquito species collected at East Arm can be found in Appendix 3 (Whelan 1997). Actual and potential breeding sites for the important mosquito species found at East Arm are discussed below, with actual and potential breeding sites highlighted in Figure 3.

Nearby breeding sites

*Mud Ponds*
Three mud ponds have been found breeding *Ae. vigilax* during past surveys. Mud Pond B, located directly south of Northern Cement was found breeding *Ae. vigilax* in low densities, probably mainly due to the timing of the survey in mid January 2005, which would have missed the major breeding event Pond B. The major breeding event would have occurred after initial flooding in weeks before the survey. There were also aquatic bug predators in the pond at the time of the survey. It is also possible that *Ae. vigilax* productivity in Mud Pond B is generally low, as there is an absence of vegetation growth or vegetation debris that generally promotes high breeding productivity by providing shelter for larvae.

Mud Pond A, to the south-east of Northern Cement, was the most productive *Ae. vigilax* breeding site located at the East Arm Port area during recent surveys by MEB, due to the pond containing grasses and saline vegetation which provided harbourage for mosquito larvae. This mud pond is currently undergoing partial reclaiming by Territory Iron, who are also committed to improving drainage of the remaining section of Mud Pond A that will not be reclaimed by Territory Iron (Duncan Beggs pers. comm.). This should reduce water ponding and reduce *Ae. vigilax* breeding.

Mud Pond D was found to be breeding *Ae. vigilax* in very low densities in mid January 2005. The mud pond had since been filled with further sediment. Culvert provisions had been provided to allow water from this mud pond to drain into an adjacent mud pond to the south, and it appeared that water ponding in this mud pond would be limited.

Mud Pond C had drainage provisions to allow water to drain into an adjacent mud pond to the south-west, although could be a potentially significant *Ae. vigilax* and *Cx. sitiens* breeding site if significant ponding occurs, as the pond is partly vegetated. Mud Pond C would have to be investigated in the wet season to determine if water ponding and mosquito breeding would be an issue.

*Culex sitiens* has been found breeding in very low densities in Mud Pond B, with productivity low possibly because of the same reasons for low *Ae. vigilax* productivity in this pond. Mud Ponds A & C would also be potential breeding sites for this species if water ponding for periods greater than 3 consecutive days is an issue in these ponds. All mud ponds are also potential *An. hilli* and *An. farauti. s.l.* breeding sites.
Aedes vigilax breeding in the mud ponds will be primarily from October to early January, when rainfall leads to initial and progressive flooding of the mud ponds. The other mosquito species are likely to breed anytime water is present in the mud ponds, although the early wet season months are likely to be the most productive when aquatic predators are at a minimum.

**Stormwater drains and drainage lines**

Poorly draining drainage lines were wet season breeding sites for Culex annulirostris, Ae. vigilax and An. hilli at the East Arm Port area. Problem drains generally had some vegetation growth or organic matter (ie leaves from overhanging trees, dead grass), and were generally minor drainage lines collecting roadside drainage or unformalised site runoff. Culex sitiens and An. farauti s.l. are other mosquito species likely to take advantage of wet season ponding in these minor drainage lines.

Drainage lines in the East Arm Port area subject to tide inundation could be potential Ae. vigilax breeding sites. This includes the tidal reaches of the major stormwater drains from Section 5720 and from the Vopak Terminal.

Most mosquito breeding in rain affected drainage lines is likely to occur after rainfall from October to January. Minor breeding will occur in drainage lines in February and March when there are extended periods without significant flushing rainfall. The majority of mosquito breeding in tide affected drainage lines and major stormwater drains is likely to occur during the late dry season and early wet season months of September to December inclusive.

**Temporary ground pools or depressions**

There seems to be enough salt content in the East Arm reclaimed areas that allows brackish water mosquito species such as Ae. vigilax and An. hilli to breed in most temporary ground pools. Culex sitiens and An. farauti s.l. are also brackish water mosquito species that could take advantage of the brackish water conditions, while Cx. annulirostris, which breeds in freshwater as well as brackish water, has also been found breeding alongside An. hilli and Ae. vigilax in the East Arm area. Ground pools that have been found breeding mosquitoes usually contained some vegetation growth. Mosquito breeding in temporary ground pools will occur after rainfall in the months of October to April inclusive.

The depressions in the tidal area adjacent to Section 5720 (Larval Sites 3 & 4) could be potential Ae. vigilax, Cx. sitiens and An. hilli breeding sites, but the presence of numerous fish in these depressions after a 7.4m tide indicates the depressions may be too low in the tidal zone for productive mosquito breeding. The silted mud flat area from the Vopak drain also appeared too low in the tidal zone for productive mosquito breeding, but it is possible that the pooling areas in the silted mudflat are potential Ae. vigilax, Cx. sitiens and An. hilli breeding sites. These tidal areas are potential breeding sites for all these species during the months of September to early January, when tides and rainfall floods breeding sites. In the post wet season, these depressions could be potential breeding sites for Cx. sitiens, An. hilli and An. farauti s.l.

**Borrow pits**

The large borrow pit (Laval site 1) could be a wet season and post wet season breeding site for Cx. annulirostris, Cq. xanthogaster, An. farauti s.l. An. annulipes and An. bancroftii if drainage is restricted. If ponding occurs, mosquito breeding productivity is likely to be low, due to the absence of semi-aquatic reeds and dense grass in this area.

**Quarantine Island Paperbark Swamp**

The Paperbark Swamp on Quarantine Island (Larval Site 7) is relatively small and is not fed by any significant drainage lines, therefore the swamp is expected to be dry by late May in most years. Once flooded, the swamp could be a breeding site for Cx. annulirostris, An. farauti s.l. An. annulipes, An. bancroftii and Cq. xanthogaster.
Silt traps

Larval Site 11. The silt trap located south of Section 5633 and adjacent to the north edge of Quarantine Island, has been found breeding *Cx. annulirostris* and *Cx. sitiens*, and is a potential *Ae. vigilax*, *Cq. xanthogaster*, *An. farauti s.l.*, *An. annulipes*, *An. bancroftii* and *An. hilli* breeding site. Potential *Aedes vigilax* breeding will occur from October to January inclusive, when rainfall leads to flooding of the silt trap. It is also possible that tide water ponds in the silt trap, due to the floor of the silt trap appearing slightly lower than the adjacent mangrove margin, which may allow high tides to seep through the floor of the silt trap. If tide ponding occurs in the silt trap, *Ae. vigilax* breeding may result after monthly high tides in the months of September to January inclusive.

*Culex sitiens* and *An. hilli* are likely to breed in the silt trap during the months of October to January inclusive from rainfall and potentially tide water ponding, and possibly in September if tide ponding occurs. *Culex annulirostris*, *Cq. xanthogaster*, *An. farauti s.l.*, *An. annulipes* and *An. bancroftii* are likely to breed in the silt trap when it is ponding rainwater, with highest productivity from mid April to early June when the water level recedes and vegetation growth is at a maximum. Elevated *Cx. annulirostris* productivity is also likely to occur in the early wet season when aquatic predator numbers in the silt trap are likely to be low. It is expected that the silt trap would be dry by mid June in most years.

The plunge pool at the silt trap pipe outfall is a potential *Ae. vigilax* and *Cx. sitiens* breeding site during the months of September to early January, and a potential *Cx. sitiens* breeding site in the post wet season.

Larval Site 12. This silt trap is a potential breeding site for *Cx. annulirostris*, *Cq. xanthogaster*, *An. annulipes* and *An. bancroftii* during the months of October to May, with highest productivity likely to be in the months of April and May when vegetation growth will be at a maximum. The mosquito breeding productivity of this silt trap is expected to be generally low, due to the minimal presence of vegetation. The outflow drain from the silt trap pipe outfall is a potential breeding site for *Ae. vigilax* and *Cx. sitiens* in the months of September to early January, with *Cx. sitiens* also likely to breed in the outflow drain during the post wet season.

Artificial receptacles

Numerous artificial receptacles near East Arm Port such as old car bodies, drums, used tyres, bins and construction material have been identified as potential breeding sites for receptacle breeding mosquitoes such as *Ae. notoscriptus*, as well as the exotic dengue mosquito species *Aedes aegypti* and *Ae. albopictus* (Matt Shortus pers. comm.). Some have been removed from the East Arm Port area by the relevant authorities. Artificial receptacles in the East Arm area represent a potential quarantine risk, as international vessels potentially carrying exotic dengue mosquito species dock at East Arm Port, and any exotic dengue mosquito species that may escape quarantine procedures could breed in nearby receptacles.

Distant breeding sites

DBP embanked mangrove area

The large embanked mangrove area between the Darwin Business Park and railway embankment is a potentially significant *Ae. vigilax* and *Cx. sitiens* breeding site during September to January inclusive, after flooding by monthly high tides and significant rainfall. *Culex sitiens* is also likely to breed in the embanked mangrove area during all other months of the year when flooded. When flooded, *Cx. annulirostris* and *Cq. xanthogaster* are likely to breed in the sections of the cut of mangrove area vegetated with *Typha* and *Eleocharis* reeds and grasses, with highest productivity in the post wet season when water levels recede and vegetation growth is at a maximum. High *Cx. annulirostris* productivity is also likely to occur after extensive rainfall flooding in January, when aquatic predator numbers are likely to be low.
This embanked area is fed by stormwater drains from the adjacent railway business area and a stormwater drain from the DBP, which is subject to dry season flows, so it is likely that water ponding will be present in this embanked area until at least July in most years, although the presence of green Typha reeds during early October suggests some ponding may continue into August or even early September in some years. Anopheles hilli and An. farauti s.l. are other mosquito species that are likely to breed in this area, with greatest productivity in the early to mid dry season, although these species are likely to breed in this area whenever water ponding is present.

The stormwater drain from DBP is likely to be a dry season breeding site for Cx. annulirostris, Cq. xanthogaster and various Anopheles species.

**Stormwater drains**

Stormwater drains from Muramats Rd and the middle and western stormwater drains from Hamaura Rd are potential breeding sites for Ae. vigilax and Cx. sitiens, while the middle stormwater drain from Hamaura Rd is also a Cx. quinquefasciatus breeding site as the drain is subject to dry season low flows. Other stormwater drains from the railway embankment into tidal areas could also be breeding sites for Ae. vigilax and Cx. sitiens.

**Paperbark/Pandanus swamp**

The grassy Paperbark/Pandanus swamp (Larval Site 16) is a potential breeding site for Cx. annulirostris from January to late May, with peak productivity occurring after initial flooding in January and in the post wet season months of April and early May when grass growth is expected to be at a maximum. Coquillettidia xanthogaster is also likely to breed in this swamp. This swamp is likely to have minimal surface water ponding by late May/early June in most years.

5.2.3 Spatial abundance and dispersal

**Aedes vigilax**

This species has a large flight range, and can travel up to 50km from extensive breeding sites (Whelan 1997a). Most Ae. vigilax at the East Arm Port vicinity are probably sourced from nearby breeding sites, although the DBP embanked mangrove area is also likely to be a source when significant breeding occurs there, and in some years there may be some dispersal from the large coastal swamps in Shoal Bay. When present, Aedes vigilax is likely to be widespread throughout the Condensate Processing Facility site.

**Culex annulirostris**

This species has a large flight range, and can travel up to 10km from extensive breeding sites (Whelan 1997a). Most Cx. annulirostris at the East Arm Port vicinity are probably sourced from nearby breeding sites, although there may be some dispersal from the DBP embanked mangrove area and Paperbark/Pandanus swamp when significant breeding occurs there. When present, Cx. annulirostris is likely to be widespread throughout the Condensate Processing Facility site.

When present, other mosquito species such as An. hilli, Cx. sitiens and Cq. xanthogaster will be widespread throughout the Condensate Processing Facility site, as they can disperse up to 2km or more from their breeding sites. These species will be mainly sourced from breeding sites in the East Arm Port vicinity, although Cq. xanthogaster, which has a wide dispersal range, will probably also be sourced from the DBP embanked mangrove area and the Paperbark/Pandanus swamp.

Anopheles farauti s.l. will be most common within 1.5km of their breeding sites, while Ae. notoscriptus and Cx. quinquefasciatus will be most common within a few hundred metres of their breeding sites. These species will be sourced from breeding sites nearby to the Condensate Processing Facility site.
5.2.4 Seasonal abundance

*Aedes vigilax*
This species is generally most abundant from September to January inclusive (Whelan 1997a, Appendix 3). Results from the AQIS trap near East Arm Port revealed this species was most abundant from September to March. Abundance of this species from September to December was likely to be due to high tides flooding breeding sites in the East Arm area. Abundance in October, November and December could also be attributed to early rainfall flooding breeding sites. Abundance from January to March would have been due to rainfall ponding in the East Arm area.

*Culex annulirostris*
This species is generally most common from January to August (Whelan 1997a, Appendix 3). The AQIS trap at East Arm Port revealed this species was most common from December to March, with elevated abundance also from April to early June. The December to April abundance was most likely a result of breeding in nearby rain filled vegetated depressions, silt traps and drainage lines in the East Arm area, and potentially the *Paperbark* swamp on Quarantine Island, while the early dry season abundance was probably a result of breeding in the Larval Site 11 silt trap, and potentially dispersal from the DBP embanked mangrove area and the *Paperbark/Pandanus* swamp.

*Coquillettidia xanthogaster*
This species is generally most common from March to August (Whelan 1997a, Appendix 3). The AQIS trap at East Arm Port revealed this species was most common in late May and early June, potentially sourced from the Larval Site 11 silt trap, the DBP embanked mangrove area or the *Paperbark/Pandanus* swamp.

*Anopheles hilli*
This species is generally most common in the late wet season and early dry season (Whelan 1997a, Appendix 3). The AQIS trap at East Arm Port revealed highest numbers in December, indicating probable breeding in the Mud Ponds, Larval Site 11 silt trap or rain filled vegetated ground pools and drainage lines, and potentially the depressions in the mudflat area adjacent to Section 5720.

*Anopheles farauti s.l.*
This species is generally most common in the months of April to June (Whelan 1997a, Appendix 3). This species was most abundant in May and June at the AQIS trap at East Arm Port. Due to the low dispersal range of *An. farauti s.l.*, it is likely that this species was sourced from a nearby breeding site, probably the Larval Site 11 silt trap but potentially Mud Pond B also.

*Culex sitiens*
This species is most common during late dry and early wet season, and late wet season (Whelan 1997a, Appendix 3). *Culex sitiens* was most abundant from December to February at the AQIS trap at East Arm Port, indicating breeding in nearby rain filled areas.

*Aedes notoscriptus*
This species is most common during the wet season, but persists in the dry season with artificial breeding sites (Whelan 1997a, Appendix 3). *Aedes notoscriptus* was most common during the months of February to April in the AQIS East Arm Port trap, indicating wet season breeding in artificial receptacles, some of which have since been removed from the East Arm Port area.

5.2.5 Pest problems
The main mosquito species likely to cause a noticeable pest problem at the Condensate Processing Facility site is the salt marsh mosquito *Ae. vigilax*. This species is a painful and persistent biter, and bites in shaded areas during the daytime and at night, and was also the most common species recorded at the AQIS East Arm Port trap. Generally over 20 *Ae. vigilax* adults in a CO2 baited trap set adjacent
to areas of human residence indicates a potential pest problem (Whelan 1997a). This number was greatly exceeded in the months of December and February, and exceeded in the months of September, October, January and March, representing a low to moderate pest problem. Pest problems will begin from 9 days after significant high tides or rain, and last for about 1 week in the months of low humidity, and for around two weeks during the high humidity months of November to March.

The next most abundant mosquito species, *Cx. annulirostris*, was recorded in numbers significant to cause a low to moderate pest problem. Generally 50 or more female *Cx. annulirostris* in a CO2 baited trap set adjacent to areas of human residence indicates a potential pest problem (Whelan 1997a). This number was exceeded in December, February and early March at the AQIS East Arm Port trap. This species bites at night, so will only affect exposed workers at night.

*Coquillettidia xanthogaster* was recorded in levels likely to cause a minor to low pest problem at night during the month of June, while other mosquito species were recorded in relatively low levels, and are not expected to cause any significant pest problem unless new mosquito breeding sites are created.

### 5.2.6 Potential mosquito borne disease

General information on the symptoms of mosquito borne disease that could potentially be present at the Condensate Processing Facility is provided in Appendix 8, with risk periods shown in Appendix 9. A discussion on possible vectors is provided below.

**Ross River virus disease and Barmah Forest virus disease**

*Aedes vigilax* is an important vector of Ross River virus (RRV) disease and Barmah Forest virus (BFV) disease in the NT (Whelan & Weir 1993, Whelan & Hayes 1992). This species will pose a potentially moderate risk of RRV and BFV disease transmission to exposed workers and visitors to the Condensate Processing Facility Site. Greater mosquito-human contact occurs with *Ae. vigilax* than probably all other mosquito species in the coastal areas of the NT due to its persistent and day biting habits, which makes this species an important vector. This species will pose a risk of RRV and BFV disease transmission during months of highest abundance (September to March), with the greatest risk being the high humidity months of November to March when the longevity of this species is enhanced.

*Culex annulirostris* is also an important vector of RRV and BFV disease in the NT (Whelan & Weir 1993). This species will pose a low to moderate risk of RRV disease transmission to exposed workers and visitors to the Condensate Processing Facility Site. This species bites only at night, therefore only exposed people after sundown will be at risk. This species will pose a risk of RRV and BFV disease transmission during months of highest abundance, with the greatest risk being the high humidity months of December to March when the longevity of this species is enhanced. This species may also pose a low risk during April to June.

*Culex sitiens* and *Aedes notoscriptus* are regarded as potential vectors of RRV disease (Whelan 1997a, Appendix 3). These species were recorded in low numbers at the AQIS adult monitoring trap, but will still pose a low RRV risk when present at the development site. *Culex sitiens* and *Ae. notoscriptus* will pose a potential risk at night only.

**Murray Valley encephalitis virus disease**

*Culex annulirostris* is a potential vector of Murray Valley encephalitis virus (MVEV) disease. The greatest risk months for MVEV transmission in the NT is from February to May (Whelan 1997b, Appendix 8). *Culex annulirostris* will pose a low MVEV transmission risk to exposed workers after sundown.

**Malaria**

Malaria is no longer present in the Northern Territory, but there is always a risk of re-introduction, if a proportion of the workforce is mobile and sourced from countries where malaria is present.
The primary potential vector species for malaria in Australia is generally considered to be *Anopheles farauti* s.l. because of its known association with the disease in Papua New Guinea, and because it was shown to be a vector in an epidemic in Cairns in 1942 (Russell 1987). It is the principal potential vector in the Top End of the NT (Whelan 1981). However, Russell (1987) showed that *An. annulipes* in south-east Australia was relatively long lived and therefore *An. annulipes* in the NT must also be considered a probable potential vector of malaria. *Anopheles annulipes* was the probable vector of malaria epidemics on some areas of the NT prior to 1962. *Anopheles hilli*, *An. bancroftii* and *An. amictus* must also be regarded as potential vectors, although *An. bancroftii* may not pose a significant risk as it is not as long lived as the other species (Russell 1987).

If more than 10 individuals of *An. farauti* s.l. or one of the other species bite a malarious person (with the sexual forms of the parasite in their blood) there is a good chance that at least one will survive the minimum of 10 days necessary before it is capable of transmitting malaria to another person. Malaria transmission is more likely to occur if relatively high numbers of female *An. farauti* s.l. have bitten the malarious person.

Any personnel that have returned from overseas malarious areas and experience a sudden onset of fever should be considered as possibly having malaria. Only patients exposed after sundown would be at risk of spreading malaria, as *Anopheles* species bite only after dusk. Suspected malaria patients should be advised to seek medical advice and should not be rostered on for night shifts until appropriately treated or cleared of having malaria.

*Anopheles* species numbers were relatively low at the AQIS East Arm Port trap site, with *An. hilli* the only *Anopheles* species recorded in numbers over 10 individuals, on one occasion only. The other potential vectors *An. farauti* s.l., *An. annulipes* s.l., *An. amictus* and *An. bancroftii* were recorded in very low numbers only. The risk of malaria transmission at the Condensate Processing Facility site will be very low, unless new *Anopheles* species breeding sites are created by the development.

**Dengue fever**

The mosquito species responsible for the transmission of dengue fever, primarily *Ae. aegypti* and to a lesser extent *Ae. albopictus*, are not present in the NT. There is always the risk of importation from overseas vessels sourced from countries where these mosquito species are present. AQIS officers inspect all international ships and cargo that dock at East Arm Port, but there is a possibility that some adults may escape undetected from a vessel and breed in local receptacles. It is therefore important to prevent the accumulation of artificial receptacles at the development site, to prevent the creation of potential breeding sites for dengue mosquitoes.

Machinery and other equipment supplies from North Queensland can also introduce exotic dengue mosquito species into the development area. See Section 5.2.7.1 *Artificial Receptacles* for further discussion.

### 5.2.7 Evaluation of development plans and suggested mosquito control measures

#### General Considerations

**Internal drainage**

The development will require internal drainage capacity. Any retention of water and particularly the colonization of reeds and grasses in temporary of perennial flooded drains or depressions could lead to new additional mosquito breeding sites. This internal system should be free draining, with erosion prevention structures wherever necessary, particularly at discharge points. Water discharged from drains should not be allowed to pool in nearby depressions or poorly draining areas.

Open unlined stormwater drains containing organically polluted water will breed mosquitoes. If there are dry season low flows in these drains from leaking ponds or other wastewater, the drains will
become significant mosquito breeding sites. Problem drains will be characterised by extensive grass growth and stagnant pools with greed filamentous algae. Any drain with dry season low flow that develops these characteristics will need to be formalised with impervious linings and low flow facilities. Water should not be allowed to pool at the drain end point.

Water storage features
Any water storage tanks and septic tanks should be completely sealed to prevent mosquito breeding. Any sewage treatment facility requires approval by the NT Department of Health and Community Services. If there is a likelihood of mosquito breeding in oily water separators, they should be emptied on a weekly basis.

Borrow pits
Borrow pits can be large sources of Cx. annulirostris and Anopheles species. The large borrow pit adjacent to part Section 5633 could be a potential mosquito breeding site if internal drainage of the borrow pit is restricted.

Artificial receptacles
Any artificial receptacles that can hold rainwater should be stored under cover, holed or disposed of such that they can not be filled with water. Receptacles such as old tyres, drums, and disused machinery can be breeding sites for exotic mosquito species such as Aedes aegypti and Aedes albopictus, which can transmit dengue fever, as well as the endemic pest species Ae. notoscriptus. Failure to have sanitation measures for receptacles will increase the potential for new pest mosquito problems, and increase the risk of importation and establishment of exotic dengue mosquito species.

Machinery and other equipment supplies from North Queensland can introduce exotic dengue mosquito species into the development area. Machinery and other equipment sourced from North Queensland should be inspected for the presence of water (even very small amounts) and mosquito larvae, with any water holding receptacles treated with a chlorine solution or a residual insecticide to kill any mosquito eggs that may be present. Any mosquito larvae found in equipment sourced from North QLD should be collected and forwarded to MEB for identification. MEB will identify the larvae and advise if further action is required.

Specific comments

Internal drainage
Section 5720 - It is most likely that the current mosquito breeding depressions on Section 5720 will be removed by the construction of the Condensate Processing Facility. Any areas of Section 5720 that may not be developed should be assessed for the potential to hold water, with appropriate measures such as filling and/or regrading implemented to remove all areas likely to pond water.

The open unlined drain that runs along the north boundary of Section 5720 may require upgrading with a concrete invert, if it is anticipated that dry season low flows will be directed into the drain. The concrete invert would need to be extended to the end point of the drain at the mangrove margin, with erosion protection at the drain end point, to prevent the creation of mosquito breeding. The development of Section 5720 will result in increased runoff into this drain from paved and roofed areas, so erosion prevention structures will be required at erosion vulnerable points in this drain, to prevent scouring and the formation of eroded pool, which can lead to mosquito breeding.

Part Section 5633 – The deep open unlined drain will most likely be upgraded to a stormwater pipe system as part of the development, which will remove the drain as a potential mosquito breeding site. The poorly draining drainage path in the north-east area of part Section 5633 should also be upgraded to prevent mosquito breeding, either by filling and contouring or upgrading the drainage path to a stormwater pipe system, depending on the requirements of the area.
All stormwater drains will require an end point at least at the mangrove margin, with appropriate erosion prevention structures. Drains with the potential for low flows should have an end point below the mangrove margin, at a daily flushed tidal area (generally 3m AHD or lower). All open stormwater drains will require placement on an annual maintenance program, to remove silt and vegetation that could lead to mosquito breeding, and to repair any erosion.

There will be a requirement for silt traps. Silt traps will be needed during the construction phase and early operational phase until the development site stabilises, to prevent the downstream siltation of water features that could lead to mosquito breeding. Ideally, silt traps should be designed to completely drain within 3 days of initial water ponding, to prevent any chance of mosquito breeding. For those silt traps designed to contain water for extended periods, they should be constructed with steep sides (ie vertical) with a sloping floor towards the downstream end, and be regularly inspected during the wet season for mosquito breeding. All silt traps would require annual inspections for maintenance requirement such as silt and vegetation removal. For larger silt traps, a ramp will need to be constructed to allow for machinery access. Silt traps should be removed once the development site has stabilised and is not subject to erosion.

Stormwater pits, such as side entry pits, grate inlet pits and letterbox pits should all be designed with a floor that is flush with the outlet pipe, to prevent the stormwater pits from ponding water and becoming potential mosquito breeding sites for endemic and exotic mosquito species.

Construction in tidal areas
Disturbance to tidal areas has the potential to create *Ae. vigilax*, *Cx. sitiens*, *An. hilli* and *An. farauti* s.l. breeding sites. If the mangrove area in part Section 5633 is to be reclaimed, specific construction methods are required to ensure mosquito breeding sites are not created. This includes preventing the occurrence of ‘mud waves’ when conducting fill activities in the mangrove area, ensuring upstream drainage of tidal areas is not restricted by development activities, and ensuring machinery disturbed areas are rehabilitated upon completion of construction works. Further information can be found in Appendix 6.

Containment bunding
It is mentioned in the NoI for this project that petroleum storage areas will have containment bunding. There is a potential for containment bunding to collect rainwater and breed mosquitoes. All containment bunding should have internal drainage facilities so that clean water can be completely drained on a weekly basis during the wet season.

Process wastewater
All process wastewater should be stored and disposed of in a manner that will prevent the creation of mosquito breeding.

5.2.8 Personal protection
Please refer to Appendix 5 for information on personal protection from mosquitoes.

5.2.9 Mosquito breeding site rectification
The development will remove some mosquito breeding sites at East Arm Precinct. Other mosquito breeding sites in reclaimed areas of East Arm will most likely be fixed with future development, although the exact timing of this is unknown. Mud Pond A, which is probably the most significant *Ae. vigilax* site in the reclaimed areas of East Arm, will be partially rectified and have drainage upgrades as part of the Territory Iron development. Any spare fill remaining after the completion of development could possibly be used to further rectify some of the mud ponds, the Port Authority should be contacted if this situation was to arise.

The lower reaches of the drain from Section 5720 (Larval Site 2), between the railway culvert and the mangrove margin, should be upgraded to prevent water ponding and mosquito breeding. A permanent
solution would be to construct a concrete invert from the railway culvert to just inside the mangrove margin, at a slope of less than 0.5% starting from the invert of the culvert. A temporary solution would be to fill the eroded areas of the drain floor and erosion protect, but this will require ongoing maintenance that may be costly in the longer term. It is recommended that the lower reaches of this drain be upgraded as part of this development, as there will be increased runoff into this drain from paved and roof areas in Section 5720, which will accelerate erosion and potentially increase the likelihood of mosquito breeding, which could then affect the Condensate Processing Facility.

The relevant authority should be requested to upgrade the Larval Site 11 silt trap, to prevent water from ponding within the silt trap for periods greater than 3 consecutive days. This could be achieved by raising the level of the outlet pipe and the floor of the silt trap to slightly above the 4m AHD level, and modifying the outlet pipe such that water can freely drain into the outlet pipe from the silt trap. The pipe outfall should also have an erosion prevention structure, and erosion prevention structures would also be required at the water entry point into the silt trap. A new outlet pipe may be required as the existing one is showing signs of rust damage.

The water outlet structure of the Larval Site 12 silt trap requires some maintenance works by the relevant authority. There is some undermining of the outlet pipe, which requires some erosion protection works. The water outlet structure should also be modified to allow the free flow of water into the pipe, which at present is restricted by earth bunds surrounding about two/thirds of the outlet pipe. Erosion protection structures are required at the pipe outfall and water entry point into the silt trap, and the outlet open unlined drain to the mangrove margin requires re-grading.

The borrow pit located adjacent to part Section 5633 should be periodically inspected during the wet season for water ponding for periods greater than five consecutive days. If significant water ponding is located, the relevant authority should be contacted and requested to rectify any drainage problems.

5.2.10 Larval mosquito control

Ponding in excavations, drains, silt traps and vehicle disturbed areas could lead to mosquito breeding during the construction phase. During the wet season, weekly inspections should be conducted by the environmental officer in the development area to locate areas of ponding that require rectification, or treatment with an appropriate larvicide such as Bacillus thuringiensis var. israelensis (b.t.i.) or methoprene until rectification can be achieved. If water ponding for periods greater than five consecutive days is noticed in areas outside of the development site, the environmental officer should report the matter to the relevant authority in charge of that land, who could then be requested to rectify the problem.
6. Conclusions

6.1 Biting midges

- The mangrove biting midge *Culicoides ornatus* was the most common biting midge species collected at the Condensate Processing Facility. This species will be encountered throughout all areas of the development site. Other biting midge species are only likely to be encountered in low numbers at the Condensate Processing Facility.

- *Culicoides ornatus* will be most abundant during the months of April and May, and August to October inclusive, where very high to severe pest problems can be expected. Elevated numbers will occur over a six day period around the full and new moons, with full moon abundance generally twice as high as new moon abundance. Peak biting times will be the two hours either side of sunset and sunrise, with low biting throughout the night. Moderate to high pest problems are likely to be experienced during most, if not all other months of the year.

- The breeding sites for this species will be the upper tidal tributaries associated with Blesers Creek, the extensive *Sonneratia* foreshore mangrove area between East Arm Port and the mouth of Blesers Creek, the upper tidal tributary located in part Section 5633, and the *Sonneratia* foreshore mangrove area between East Arm Port and the mouth of Hudson Creek.

- The development has the potential to remove the upper tidal tributary habitat located in the southern part of part Section 5633, if this site was to be filled for the development. However, the filling of this site is not likely to make any significant difference to *C. ornatus* abundance at the Condensate Processing Facility.

6.2 Mosquitoes

- The salt marsh mosquito *Aedes vigilax* was the most common mosquito species collected in the AQIS adult mosquito monitoring trap set weekly at the entrance to the nearby East Arm Port from January 2005 to January 2006. This was followed by the common banded mosquito *Culex annulirostris*, with other mosquito species recorded in low numbers only.

- *Aedes vigilax* was most common in the months of September to March. *Culex annulirostris* was most abundant from December to June.

- *Aedes vigilax* was recorded in numbers high enough to cause a low to moderate pest problem during the daytime in shaded areas and at night. *Culex annulirostris* was recorded in numbers high enough to cause a low to moderate pest problem at night.

- *Aedes vigilax* will pose a low to moderate risk of Ross River virus (RRV) disease and Barmah Forest (BFV) disease when present during the months of September to March, with November to March being the highest risk months. *Culex annulirostris* will pose a low to moderate risk of RRV and BFV transmission during the months of December to March, and low risk during April to June. *Culex annulirostris* will also pose a low risk of Murray Valley encephalitis virus (MVEV) transmission, with the main risk period being February to May. *Culex sitiens* and *Aedes notoscriptus* will also pose a low RRV risk when present at the Condensate Processing Facility.

- The risk of local malaria transmission at the development site is low, unless new breeding sites for *Anopheles* species are created by development.

- *Aedes vigilax* will be sourced primarily from nearby breeding sites, such as Mud Ponds A & B, temporary ground pools, poorly draining drainage lines, silt traps and depressions in tidal areas. This species may also disperse to the Condensate Processing Facility from distant breeding sites.
such as the embanked mangrove area between the railway and Darwin Business Park. In some years of very high abundance, this species may also disperse to the development area from the extensive Shoal Bay coastal swamps.

- *Culex annulirostris* will be sourced primarily from nearby breeding sites, such as temporary ground pools, poorly draining drainage lines, silt traps, the Quarantine Island *Paperbark* swamp and potentially the large borrow pit adjacent to part Section 5633. This species may also disperse to the Condensate Processing Facility from distant breeding sites such as the embanked mangrove area between the railway and Darwin Business Park, and the *Paperbark/Pandanus* swamp located to the east of the proposed facility.

- Other mosquito species will be sourced primarily from breeding sites nearby to the Condensate Processing Facility.

- The development has the potential to introduce exotic dengue mosquitoes from North Queensland, if machinery or other equipment with the potential to hold water is sourced from this area. The development also has the potential to provide breeding sites for exotic dengue mosquito species that may escape from ships docking at nearby East Arm Port.

- The development has the potential to create new mosquito breeding sites, such as in bunded areas, water storage facilities and from storage and disposal of process wastewater. Construction in tidal areas also has the potential to create new mosquito breeding sites.

- The development has the potential to remove existing mosquito breeding sites within the development site.

- Temporary mosquito breeding sites such as vehicle disturbed areas, temporary ground pools and silt traps may be created during the construction phase.
7. Recommendations

7.1 Biting midges

- All workers and visitors to the Condensate Processing Facility should be warned of the potentially severe biting midge pest problem, and be warned of potential problem times and periods. All workers should be supplied with the MEB handout ‘Biting midges or “sandflies” in the NT’.

- Normal screening, including outwardly opening insect screen doors, will stop a considerable portion of Culicoides from entering personnel areas and should be treated with a suitable residual insecticide such as bifenthrin. There are finer insect screens that can prevent biting insect entry, and if these are acceptable, should be used. The use of light proof curtains at doors and windows, and avoiding incandescent or white fluorescent lights directly outside doors or windows where practical can reduce the numbers of midges attracted to these entry sites.

- The development site should be designed to allow the future use of insecticide barrier sprays. This can be achieved by planting shrub type vegetation around the boundaries of the development site facing the mangroves, or erecting dark shade cloth (approximately 2m high) on the boundary fence facing mangrove areas. Suitable insecticides such as bifenthrin can then be applied when required to provide residual control of biting midges.

7.2 Mosquitoes

- Workers and visitors should be advised that seasonal mosquito problems are likely to be encountered at the Condensate Processing Facility, and be advised of appropriate personal protection measures, which can be found in the MEB handout ‘Personal Protection from mosquitoes and biting midges in the NT’.

- The Condensate Processing Facility should be constructed in a manner that removes all potential mosquito breeding sites that are currently present at the proposed development site. This includes ensuring the development site is suitably graded to prevent water ponding, and upgrading the open unlined stormwater drains in part Section 5633 to stormwater pipe drains.

- As part of the development, the lower reaches of the open unlined drain from Section 5720 should be upgraded to cope with the additional flows that will be created as a result of development. This should be achieved by constructing a concrete invert from the railway culvert to the mangrove margin, or by constructing erosion prevention structures in the lower eroded reaches of this drain. The upper reaches of this drain located in Section 5720 will require the installation of erosion prevention structures at erosion vulnerable points within this drain.

- The relevant authority should be requested to upgrade the two existing silt traps located near the south-west boundary of part Section 5633, to minimise water ponding and mosquito breeding.

- The large borrow pit adjacent to part Section 5633 should be inspected by the Condensate Processing Facility Environmental Officer during the wet season for significant water ponding (ie ponding for periods greater than five consecutive days). If significant water ponding is located, the relevant authority should be contacted and requested to rectify the problem.

- Construction in tidal areas should be in accordance with the MEB guideline ‘Construction practice near tidal areas in the Northern Territory-Guidelines to prevent mosquito breeding (Appendix 6)’. Fill activities in tidal areas should be conducted in a manner that prevents the creation of ‘mud waves’.
The development site should be maintained free of disused artificial receptacles, to prevent the creation of potential breeding sites for exotic dengue mosquitoes that may escape from international ships docking at nearby East Arm Port.

Any machinery or equipment sourced from North Queensland should be inspected for the presence of water and mosquito larvae. Any mosquito larvae should be collected and forwarded to the MEB for identification. Machinery or equipment found to be holding water should be treated with a chlorine solution or suitable residual insecticide to kill any mosquito larvae and eggs that may be present.

Bunded areas, water storage features and process wastewater should be managed in a manner that prevents the creation of mosquito breeding. Stormwater pits must be designed to be free draining structures i.e. the invert of all stormwater pits must be the same as the invert of the outlet pipe.

Silt traps will be required during the construction phase and early operational phase. These silt traps should be designed to be free draining structures, or alternatively with deep, steep sides, to prevent the creation of mosquito breeding. Silt traps should be removed once the development site has stabilised.

The Environmental Officer for the Condensate Processing Facility should inspect the development site weekly during the wet season for water ponding and mosquito breeding. Any mosquito larvae should be treated with an appropriate larvicide. The Environmental Officer should also report any water ponding areas (i.e. pond for periods greater than five consecutive days) outside of the development site to the relevant landowner, who should then be requested to rectify the ponding.
8. Acknowledgements
Biting midges were identified by Nina Kurucz from the Medical Entomology Branch (MEB). Adult mosquitoes were identified by Jane Carter from MEB.

AQIS adult biting insect traps were set by Geoff Kumjew, with samples brought to the MEB laboratory for identification by MEB Technical Officers.
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FIGURES
Figure 1: Condensate Processing Facility East Arm. Adult mosquito and biting midge trap locations and potential Culicoides ornatus breeding sites.
Figure 2 - Darwin South Stage 2 Biting Insect Investigations. Total number of *Culicoides ornatus* collected monthly during full moon trapping 8 April 1993 to 29 March 1994 at Site 19 adjacent to portion 1591 RAAF explosive reserve.
Figure 3: Condensate Processing Facility East Arm. Larval mosquito survey locations, including from ad-hoc investigations by MEB.
<table>
<thead>
<tr>
<th>Record no</th>
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<th>Trap Location</th>
<th>Water presence</th>
<th>Breeding</th>
<th>Breeding area (m²)</th>
<th>No. of dips</th>
<th>Average no per dip</th>
<th>Species</th>
<th>Total no in sample</th>
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<td>Average no per dip</td>
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<td>Total no in sample</td>
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<td>A3 - East Arm industrial zone - sediment pond south of Northern Cement (Mud Pond B)</td>
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<td>A4 - East Arm wharf, stockpile area SE corner</td>
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### Table 5 - Condensate Processing Facility East Arm biting midge trap results. Total number of female biting midges trapped using CO2 baited EVS traps 7th-8th September 2006

<table>
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<tr>
<th>Trap location</th>
<th>Biting midge species</th>
<th>C. (Orn grp) ornatus</th>
<th>C. (Orn grp) papuensis</th>
<th>C. (Wir) immaculatus</th>
<th>Culicoides unidentifiable (damaged)</th>
<th>Total</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condensate Facility Site 1 - South of Berrimah Rd, on north side of large borrow pit at SE corner of development site</td>
<td></td>
<td>1568</td>
<td>0</td>
<td>0</td>
<td>32</td>
<td>1600</td>
<td>5.84</td>
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<tr>
<td>Condensate Facility Site 2 - NE section of development area, at mangrove margin adjacent to Railway Terminal drain</td>
<td></td>
<td>8160</td>
<td>170</td>
<td>0</td>
<td>170</td>
<td>8500</td>
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<tr>
<td>Condensate Facility Site 3 - NW section of development area, in remnant hill area north of railway embankment</td>
<td></td>
<td>10560</td>
<td>1</td>
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<td>440</td>
<td>11001</td>
<td>40.15</td>
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<tr>
<td>Condensate Facility Site 4 - on leading edge of escarpment Quarantine Island, SW of development site</td>
<td></td>
<td>5292</td>
<td>126</td>
<td>126</td>
<td>756</td>
<td>6300</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td>25580</td>
<td>297</td>
<td>126</td>
<td>1398</td>
<td>27401</td>
<td>100</td>
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<tr>
<td><strong>% of total</strong></td>
<td></td>
<td>93.35</td>
<td>1.08</td>
<td>0.46</td>
<td>5.10</td>
<td>100</td>
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<tr>
<td>Trap location</td>
<td>Ad. (Ady) catastica</td>
<td>Cq. (Coq) xanthogaster</td>
<td>Cx. (Cux) annulirostris</td>
<td>Cx. (Cux) quinquefasciatus</td>
<td>Cx. (Cux) sitiens</td>
<td>Cx. (Cux) Vishnui group</td>
<td>Oc. (Mac) tremulus</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------</td>
<td>---------------------</td>
<td>------------------------</td>
<td>-------------------------</td>
<td>-----------------------------</td>
<td>------------------</td>
<td>------------------------</td>
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</tr>
<tr>
<td>Condensate Facility Site 1 - South of Berrimah Rd, on north side of large borrow pit at SE corner of development site</td>
<td>0</td>
<td>3</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Condensate Facility Site 2 - NE section of development area, at mangrove margin adjacent to Railway Terminal drain</td>
<td>1</td>
<td>9</td>
<td>28</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>44</td>
</tr>
<tr>
<td>Condensate Facility Site 3 - NW section of development area, in remnant hill area north of railway embankment</td>
<td>5</td>
<td>8</td>
<td>48</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Condensate Facility Site 4 - on leading edge of escarpment Quarantine Island, SW of development site</td>
<td>10</td>
<td>0</td>
<td>36</td>
<td>0</td>
<td>0</td>
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<td>1</td>
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<tr>
<td>Total</td>
<td>16</td>
<td>20</td>
<td>120</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>% of total</td>
<td>9.58</td>
<td>11.98</td>
<td>71.86</td>
<td>2.40</td>
<td>2.40</td>
<td>1.20</td>
<td>0.60</td>
</tr>
</tbody>
</table>

Larval Site 1 – drainage channel in lower reaches of borrow pit adjacent to south-east section of part Section 5633, looking downstream.

Larval Site 1 – drainage channel in lower reaches of borrow pit adjacent to south-east section of part Section 5633, looking upstream.

Larval Site 2 – Junction of OUD from Railway terminal and north boundary of Section 5720, at upstream culvert.

Larval Site 2 – Looking downstream from first culvert.

Larval Site 2 – Railway terminal drain, looking upstream from culvert where this drain joins the drain from the north boundary of Section 5720.

Larval Site 2 – Lower reaches of OUD on north boundary of Section 5720, looking upstream from culvert where the drain meets the railway terminal drain.
Condensate Processing Facility Biting Insect Survey.

Larval Site 2 – Lower reaches of drain, looking downstream from last culvert

Larval Site 2 – Lower reaches of drain near mangrove margin, tide water ponding.

Larval Site 2 – Lower reaches of drain inside mangrove margin. Trap Site 2 at left corner of picture.

Larval Site 2 – Looking upstream from mangrove margin, drain invert can be raised to remove tide ponding in the section of drain above the mangrove margin.

Larval Site 3 – Depression in tidal area adjacent to north-west boundary of Section 6720. Potential Aedes vigilax and Culex sitiens breeding site, although lots of fish present. Looking north-west from railway embankment.

Larval Site 4 – Depression in mudflat opposite Vopak Fuel Terminal. Potential Aedes vigilax and Cx. sitiens breeding site, although fish present in depression. Looking south-west along railway embankment.
Condensate Processing Facility Biting Insect Survey.

Larval Site 5 – Railway culvert which collects water from the Vopak Fuel Terminal. Silt deposition in mudflat area, minor ponding, appears unlikely to be a mosquito breeding site.

Larval Site 6 – Example of a shallow depression in Section 5720, looking south-west at Vopak Fuel Terminal. Potential breeding site for *Anopheles* species, *Ae. vigilax* and *Culex annulirostris*.

Larval Site 7 – Paperbark swamp at south corner of Quarantine Island. Potential *Coquillettidia anthogaster*, *Anopheles bancroftii* and *Culex annulirostris* breeding site.

Larval Site 8 – Poorly draining drainage line in north-east area of part Section 5633. Potential *Culex annulirostris* breeding site in upper reaches, potential *Aedes vigilax* and *Culex sitiens* breeding site in lower reaches.

Larval Site 9 – Large OUD through part Section 5633. Tide water ponding from recent high tide, water was still flowing out of drain although minor pools may persist. Potential *Ae. vigilax* and *C. sitiens* breeding site.

Larval Site 10 – Open unlined drain located south of part Section 5633. Recently cleared although depressions can be seen on the drain floor. Looking upstream from mangrove margin. Potential Ae. vigilax, An. illii, An. hilli and Cx. sitiens breeding site.

Larval Site 10 – OUD south of part Section 5633. Upper reaches of drain near west boundary of part Section 5633, looking at side drain from Berrimah Rd. Invert of main drain higher than invert of side drain. Potential Cx. annulirostris breeding site.

Larval Site 11 – silt trap near north edge of Quarantine Island. Cx. annulirostris and Cx. sitiens breeding. Dead reeds in foreground, hump in silt trap is the outlet pipe. Mangrove margin is located behind the silt trap wall. Looking east. Potential Ae. vigilax, Anopheles sp. and Cq. xanthogaster.


Larval Site 12 – Silt trap outflow channel to mangrove margin. Plunge Pool. Potential Ae. vigilax and Cx. sitiens breeding site.

Larval Site 13 – DBP embanked mangrove area. Dense dead Eleocharis reeds in foreground, dead mangroves and green Typha reeds in background. Looking NE at Railway shed. Potentially significant Ae. vigilax, Cx. annulirostris, Cx. sitiens, Cq. xanthogaster and Anopheles species.

Larval Site 13 – Green Typha reeds in dead mangrove area.

Larval Site 13 – Tide ponding in dead mangrove area, high Cx. sitiens breeding.

Larval Site 13 – Drain from DBP, looking upstream from mangrove margin. Potential Cx. annulirostris, Cq. xanthogaster, Anopheles species and Cx. quinquefasciatus breeding site.

Larval Site 14 – pipe outfall from Muramats Rd. Tide ponding and Cx. sitiens breeding. Potential Ae. vigilax breeding site.

Larval Site 15 – end point of eastern most drain from Hamaura Rd at Paperbark fringe.
Condensate Processing Facility Biting Insect Survey.

Larval Site 16 – Grassy Paperbark/Pandanus swamp at end point of drain from Hamaura Rd. Potential Cs. annulirostris, Cq. xanthogaster and Anopheles species breeding site.

Larval Site 17 – Middle drain from Hamaura Rd to mangrove margin. Plunge pool and stagnant water ponding, Cx. quinquefasciatus breeding. Lower reaches of drain potential Ae. vigilax and Cx. sitiens.

Larval Site 18 – western most drain from Hamaura Rd. Tide water ponding and fish. Potential Ae. vigilax and Cx. sitiens.
<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 <em>Ceriops</em> 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 C. sp. near hewitti)</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. 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 C. immaculatus)</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>
tide level. 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. |

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

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

Minor update January 2004

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

**Flight range**

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

**Species identities**

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

**Pest levels**

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

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

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

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>PEST STATUS</th>
<th>VECTOR STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>An. annulipes</em> s.l.</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.</td>
<td><em>Local pest, bites at night. Uncommon, except near mostly sub-coastal and extensive freshwater or brackish swamps.</em></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>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>Oc. 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>Oc. 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>Oc. 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>Oc. 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>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”.

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

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<table>
<thead>
<tr>
<th>SPECIES</th>
<th>IMMATURE STAGES</th>
<th>ADULT STAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>An. annulipes s.l.</td>
<td>Eggs laid singly on water surface; any freshwater body but numerous near <em>Eleocharis</em> reed swamps; temporary or permanent; some receptacles; larvae float on water surface and feed on particles on top of water.</td>
<td>Feeds on a variety of mammals including cattle and humans. Bites at night, especially dawn and dusk. Flies up to 2 km from breeding site; rests in cool shady locations such as stream margins, drains etc.</td>
</tr>
<tr>
<td>An. bancroftii</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>An. farauti s.l. (Includes <em>An. farauti</em>, <em>An. hinesorum</em> and <em>An. torresiensis</em>)</td>
<td>Eggs laid singly on surface; larvae feed on water surface. <em>An. farauti</em> breeds in brackish water; <em>An. hinesorum</em> and <em>An. torresiensis</em> breed in freshwater swamps and pools. Larval habitat often sunlit.</td>
<td>Bites readily at night; feeds on humans, other mammals and birds. Will fly approximately 2 km from the breeding site.</td>
</tr>
<tr>
<td>An. hilli</td>
<td>Eggs laid singly on surface; larvae feed at surface; sunlit or shaded brackish to saline ground pools or swamps. Numerous in <em>Schoenoplectus</em> reed swamps near coast.</td>
<td>Bites humans, cattle and horses; mainly after sunset. Disperses up to 4 km from breeding site.</td>
</tr>
<tr>
<td>An. meraukensis</td>
<td>Eggs laid singly on surface of water; larvae feed at the surface; usually in freshwater <em>Eleocharis</em> reed swamps, sunlit or shaded.</td>
<td>Bites at dusk, feeds on humans and other mammals.</td>
</tr>
<tr>
<td>Cx. annulirostris</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>Cx. quinquefasciatus</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>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>SPECIES</td>
<td>IMMATURE STAGES</td>
<td>ADULT STAGES</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Oc. vigilax</td>
<td>Eggs deposited singly in the mud or near plant stems in suitable habitats; breeds in tidal pools and marshes, usually those filled by tides in upper tidal zone associated with <em>Schoenoplectus littoralis</em> or landward ill draining mangrove areas; larvae browse on substrate.</td>
<td>Major and severe pest species; adults feed very readily on humans, other mammals and birds, day or night; will fly up to 60 km; shelter in thick vegetation.</td>
</tr>
<tr>
<td>Fl. kochi</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>Oc. normanensis</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>Oc. notoscriptus</td>
<td>Eggs laid singly on the sides of tree holes. Dark larvae hang from the surface by siphon and feed by browsing on the substrate. Common in domestic receptacle habitats.</td>
<td>Feeds on humans and all mammals; bites day or evening in the cool shade. Does not disperse widely.</td>
</tr>
<tr>
<td>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>An. annulipes s.l.</td>
<td>Freshwater streams and vegetated swamps. Low to moderate numbers in the wet season, the persistence of populations after the wet season dependent on surface water.</td>
</tr>
<tr>
<td>An. bancroftii</td>
<td>Freshwater, paperbark and <em>Eleocharis</em> reed swamps and creeks. High to very high numbers at post wet and early dry season, when emergent vegetation at peak and standing water starting to recede.</td>
</tr>
<tr>
<td>An. farauti s.l.</td>
<td>Brackish and freshwater species, in vegetated swamps or creeks. Low to moderate numbers in late wet and early post wet season.</td>
</tr>
<tr>
<td>An. hilli</td>
<td>Brackish/saltwater breeder, often associated with <em>Schoenoplectus</em> reed swamps or creeks or remnant pools in landward mangroves. Low numbers except near extensive brackish water swamps in late wet and early dry season.</td>
</tr>
<tr>
<td>An. meraukensis</td>
<td>Open shallow freshwater <em>Eleocharis</em> reed swamps and creeks. Moderate to high numbers in the late and immediate post wet season.</td>
</tr>
<tr>
<td>Ma. uniformis</td>
<td>Same as <em>Cq. xanthogaster</em> but more associated with floating vegetation, (water lilies). Moderate to very high numbers near habitats in late wet, early dry season.</td>
</tr>
<tr>
<td>Cx. annulirostris</td>
<td>Breeds in the vegetated margins and pools in permanent and semi-permanent swamps, creeks and floodways. Exploits temporary vegetated ground pools in wet season. High numbers in polluted or wastewater with vegetation in dry season. High to very high numbers in the early to mid dry season.</td>
</tr>
<tr>
<td>Cx. quinquefasciatus</td>
<td>Domestic water sites, often with organic pollution. Moderate numbers in mid to late dry season, but can be present all year.</td>
</tr>
<tr>
<td>Cx. sitiens</td>
<td>Breeds in salt to brackish coastal pools or swamps. Low numbers except locally in tidal pools in upper tide zone in late dry, early wet season, and late wet season.</td>
</tr>
<tr>
<td>Cq. xanthogaster</td>
<td>Breeds in freshwater <em>Eleocharis</em> reed swamps and creeks. Very high numbers in mid to late dry season when maximum plant growth present in permanent and semi permanent swamps and creeks.</td>
</tr>
<tr>
<td>Fl. kochi</td>
<td>Breeds in <em>Pandanus</em> axils. Moderate numbers in wet season in <em>Pandanus</em> thickets.</td>
</tr>
<tr>
<td>Oc. normanensis</td>
<td>Floodwater, ground pool breeder in poorly draining floodways associated with creeks and rivers. Very high numbers during wet season, absent at other times.</td>
</tr>
<tr>
<td>Oc. notoscriptus</td>
<td>Tree hole or artificial receptacle breeder. Low numbers in wet season but persists in dry season with artificial breeding sites.</td>
</tr>
<tr>
<td>Oc. tremulus</td>
<td>Tree hole or receptacle breeder. Low numbers in wet season and early dry season.</td>
</tr>
<tr>
<td>Oc. vigilax</td>
<td>Breeds in tidal to brackish swamp or tidal pools in creeks. Extreme numbers in the very late dry and early wet season.</td>
</tr>
<tr>
<td>Ve. funerea</td>
<td>Brackish to tidal ground pools in tidal creeks and swamps, often in shade. Localised pest numbers in the pre wet and wet.</td>
</tr>
</tbody>
</table>

* Adapted, revised and expanded from P. Liehne et al. “Mosquitoes and biting midge investigation, Palmerston 1982-85”. 
## PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT

### PEST AND DISEASE VECTOR STATUS

Peter Whelan 1997

Medical Entomology Branch, Department of Health and Community Services

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

### LEGEND

<table>
<thead>
<tr>
<th>Disease</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RRV</strong> - Ross River virus</td>
<td>Murray Valley encephalitis virus</td>
</tr>
<tr>
<td><strong>BFV</strong> - Barmah Forest virus</td>
<td>Japanese encephalitis virus</td>
</tr>
<tr>
<td><strong>KUNV</strong> - Kunjin virus</td>
<td></td>
</tr>
<tr>
<td>Minor pest on Disease Potential</td>
<td>Major pest on Disease Potential</td>
</tr>
</tbody>
</table>
### 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><em>Ochlerotatus vigilax</em></td>
<td>Top End, north of Wave Hill, Larrimah and Borroloola</td>
<td>September - January</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td><em>Ochlerotatus normanensis</em></td>
<td>Subcoastal Top End south to Ti Tree</td>
<td>January - April</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td><em>Culex annulirostris</em></td>
<td>NT wide</td>
<td>January to August</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td><em>Anopheles bancroftii</em></td>
<td>Top End north of Victoria and Roper River, south to Larrimah</td>
<td>February - July</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td><em>Coquilletidia xanthogaster</em></td>
<td>Top End north of Victoria and Roper River, south to Larrimah</td>
<td>March - August</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td><em>Mansonia uniformis</em></td>
<td>Top End south to Larrimah</td>
<td>March - June</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td><em>Anopheles farauti s.l.</em></td>
<td>Top End north of Port Keats, Pine Creek, and Numbulwar</td>
<td>March - June</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td><em>Culex quinquefasciatus</em></td>
<td>NT wide, primarily near residential areas</td>
<td>January - June</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td><em>Ochlerotatus notoscriptus</em></td>
<td>NT wide, generally near residential areas</td>
<td>January - June</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td><em>Verrallina funerea</em></td>
<td>Top End primarily coastal and sub-coastal but occasionally south to Larrimah</td>
<td>Nov - March</td>
<td>20</td>
<td>100</td>
</tr>
</tbody>
</table>

### Pest Levels
* Indicative significant pest threshold levels (mosquitoes per 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>
</table>
| Ochlerotatus vigilax (Salt marsh mosquito) | Brackish reed swamps. Upper mangrove margin and tidal creek extremities | Extensive mangrove areas with freshwater creek entry. Tidally or sea spray affected rock pools, depressions in coastal sand dunes and vegetated areas above tidal limit. Disturbed upper tidal areas. Tidal brackish swamps with *Schoenoplectus* reeds. | 0 - 5 km major pest  
5 - 50 km pest numbers  
50 - over 200 km dispersal |
| Ochlerotatus normanensis (Floodwater mosquito) | Flooded freshwater sub-coastal or inland floodways and creeks | Broad, flat sub-coastal and inland drainage floors of minor and major creeks. | 0 - 2 km major pest  
2 - 5 km pest numbers |
| Culex annulirostris (Common banded mosquito) | Freshwater and coastal reed swamps. Streams, storm drains, and sewage effluents | Extensive reed swamps with *Eleocharis* or *Typha* reeds. Temporary flooded grasslands in sub-coastal and inland areas with organic matter. Sewage effluent and organic waste water with grass, *Lemma* (Duckweed), *Azolla* (water fern). | 0 - 3 km major pest  
2 - 10 km pest numbers  
10 - 15 km dispersal |
Day pest in closed forest near breeding sites. |
| Anopheles bancroftii (Black malaria mosquito) | Freshwater and coastal reed swamps. Shaded streams and swamps | Extensive seasonally inundated *Melaleuca* paperbark swamps. *Eleocharis* and *Typha* reed swamps. | 0 - 3 km major pest  
3 - 5 km pest numbers |
| Coquillettidia xanthogaster (The golden mosquito) | Freshwater swamps with reeds. Vegetated streams | Extensive *Eleocharis* and *Typha* reed swamps. *Paperbark* creek lines. | 0 - 3 km major pest  
3 - 5 km pest numbers |
| Mansonia uniformis (Waterlily mosquito) | Extensive freshwater reed swamp | Extensive *Eleocharis* and *Typha* reed swamps with water lilies. | 0 - 2 km major pest  
2 - 3 km dispersal |
| Anopheles farauti s.l. (Australian malaria mosquito) | Coastal and brackish reed swamps. Freshwater swamps and vegetated streams | Brackish *Schoenoplectus* and *Eleocharis* reed swamps. Upper reaches of mangrove creeks with freshwater influence. | 0 - 1.5 km minor pest  
1.5 - 3 km dispersal |
| Culex quinquefasciatus (Brown house mosquito) | Storm drains, artificial receptacles. Septic tanks. Waste water ponds | Polluted ground or artificial receptacles. Filamentous green algae, *Lemma* (Duckweed), *Azolla* (water fern), or high organic water. Tyres, drums and other receptacles | 0 - 500 m major pest  
500 m - 1 km pest numbers |
| Ochlerotatus notoscriptus (Receptacle mosquito) | Tree holes or artificial receptacles | Trees with natural collections of water including *Eucalyptus*, *Ficus*, *Poinciana* and *Adansonia*. Tyres, drums, pot plant drip trays, roof gutters, rainwater tanks. | 0 - 500 m minor pest  
500 m - 1 km dispersal |
APPENDIX 4
BITING MIDGES OR “SANDFLIES” IN THE NT

PETER WHELAN
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DARWIN
NORTHERN TERRITORY
AUSTRALIA
July 2003

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Biting Midge or ‘Sandflies’ in the Northern Territory

Peter Whelan, Senior Medical Entomologist,
DHCS
Darwin NT

1.0 Introduction

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

Phlebotomus – a female “Sand Fly”
Simulium – a female “Black Fly”

Insects of Medical Importance
British Museum 1956

Insects of Medical Importance.
British Museum 1956

Biting midges are the major midge pest problem in Northern Australia.² A number of members of this family bite people in the Northern Territory. They include two species in the genus Lasiohelea, which are found biting in small numbers in shaded areas in or near dense forests during the day. A species of Styloconops is found in small numbers biting and swarming around the head on open sandy beaches during the day. The members of the Culicoides genus are more common, with many species and a wide range of breeding sites and biting habits.
Thirty-three species of *Culicoides* have been recorded from the Darwin area. The *Culicoides* species include some species that don’t bite vertebrates, some which preferentially bite cattle and other domestic animals, and the few species that are serious pests of people. The breeding sites include fresh water margins and cattle dung. Most of the serious human pest species breed in tidal and estuarine sites.
Culicoides midges are small, robust flies, approximately 1 mm in length with two wings usually showing a pattern of clear patches on a grey background. They have a short, forward directing proboscis or mouthparts for piercing skin and sucking blood.

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

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

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

2.0 Bites of Biting Midges

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

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

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

3.0 Treatment of Bites

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

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

4.0 Breeding Sites of Culicoides ornatus

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

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

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

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

\section{5.0 The Flight Activity of \textit{Culicoides ornatus}}

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

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

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

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

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

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

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

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

7.0 Protection from Bites of *Culicoides ornatus*

7.1 Avoidance

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

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

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

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

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

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

7.2 Clothing and Netting

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

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

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

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

7.3 Repellents

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

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

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

Smoke from a fire with green leaves will give some protection in emergency situations. Burning aromatic and oil producing foliage of plants such as Hyptis (horehound), Calytrix (turkey bush), Melaleuca species (paperbark) and Eucalyptus species (gum trees) can give appreciable protection.
Rubbing the skin with the leaves of some of these plants can also provide some protection, but this is not as good as recommended repellents.

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

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

### 7.4 Use of Lights

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

### 7.5 The reduction of vegetation

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

### 7.6 The use of attractant traps

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

### 8.0 Evaluation of Biting Midge Problems

The Medical Entomology Branch of the Department of Health and Community Services has conducted numerous investigations into biting midge problems in the Top End of the NT. Potential problems have been investigated by trapping midges overnight using special carbon dioxide (CO\textsubscript{2}) baited traps. The number of midges collected can be counted or estimated by weight or volume and identified to species under a microscope in the laboratory.
The number of bites by biting midges that constitute a pest problem will largely depend on an individual. It has been suggested that over 60 bites per hour for most experienced biting midge workers are the thresholds of acceptability. For people unaccustomed to biting midge bites, even 1 to 5 bites per hour may be considered unbearable.

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

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

9.0 Control of *Culicoides ornatus*

9.1 Insecticide fogging for Adult Midge

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

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

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

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

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

Aerial application of insecticides aimed at adult midges in breeding and harborage areas has given the best results in overseas investigations, but in some instances there has been immediate re-infestation. It is a difficult practice, as the breeding grounds have to be closely delineated and fogging must be based...
on an accurate forecast of adult emergence times. The fogging has to be with sufficient regularity to kill all the emerging dispersing females over the night and fog drift to nearby residential areas has to be avoided. Fogging is not carried out regularly for midge control in Australia and requires more local research. Fogging involves large continuing costs, which is often beyond the resources of many local authorities. Insecticide resistance and the killing of other insects pose additional potential problems.

9.2  **Barrier spraying**

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

9.3  **Insecticide Control of Larval Habitats**

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

9.4  **Elimination of Breeding Habitats**

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

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

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

9.5  **Buffer zones**

There is some evidence that creating a buffer zone between urban residential development and mangrove areas can reduce the dispersal of biting midges into residential areas. Clearing of vegetation and mowing to allow wind disruption, or extensive streetlights or roads with active traffic in the buffer zone may enhance the buffer to some extent. However extensive testing of a modified buffer with lights and
different vegetation types in Darwin have shown that unmodified buffers and lights by themselves are not effective barriers to *C. ornatus* dispersal from mangroves to urban areas. The effectiveness of buffers is generally related to the width of the buffer and the presence of blood sources or other attractions such as light in the buffer zone. However semi-urban residential or industrial development between mangroves and urban areas can reduce midge dispersal inland. In general, unmodified buffers need to be in the order of 1.5km, and modified buffers in the order of one kilometre to offer significant reduction in numbers.

**10.0 Planning Guidelines To Prevent Biting Insect Problems**

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

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

Good urban planning is required to;
- reduce the risk of biting insect pests
- recognize and avoid areas of biting insect breeding or harborage
- avoid costly and environmentally undesirable rectification methods
- avoid costly and ongoing biting insect control programs

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

**Selected References**


PERSONAL PROTECTION
FROM MOSQUITOES & BITING MIDGES
IN THE NT

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PERSONAL PROTECTION
FROM MOSQUITOES & BITING MIDGE

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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 Pterocaupon 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.


CONSTRUCTION PRACTICE NEAR TIDAL AREAS IN THE NORTHERN TERRITORY

GUIDELINES TO PREVENT MOSQUITO BREEDING

NORTHERN TERRITORY COASTAL MANAGEMENT COMMITTEE
JUNE 1988

Minor update 13/08/02
Minor update 25/8/05

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for the
Coastal Management Technical Advisory Group
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7.0 Consultation Authorities

Appendix I

Previous mosquito problems in the Top End of the Northern Territory created by construction practice.
1.0 **Introduction**

There have been many instances of construction in or near tidal areas in the Top End of the Northern Territory that have resulted in ecological disturbance and subsequent mosquito breeding. Many of the deleterious disturbances have been the result of little or no recognition of the ecological consequences of construction practices, either during the construction period or on completion of the project. Much of the deleterious ecological disturbance can be avoided or minimized by consultation between engineers or construction authorities and people with ecological expertise.

One of the most significant impacts of construction in or adjacent to tidal areas is the creation of new sources of pest and potential disease causing mosquitoes. The creation of new mosquito breeding sites can have an enormous bearing on the quality of life, land values, costly rehabilitation measures, mosquito control programs and most importantly, the health and legal implications involved in an outbreak of mosquito-borne disease.

2.0 **Aim of Guidelines**

These guidelines are intended as a checklist for planners, engineers or any supervisory officers, responsible for the planning or implementation of any construction activity near tidal areas, in order to prevent the creation of mosquito breeding sites.

They are also intended to be used as a checklist in the preparation and evaluation of any Preliminary Environment Report or Environmental Impact Statement. In this way it is hoped that the ‘potential for additional mosquito breeding areas will be recognized and avoided in the planning or implementation phases of any construction project, so that later costly or environmentally disruptive rectification works will not be necessary.

It is proposed to circulate these guidelines to the relevant construction or advisory authorities. Any doubts on the potential for creating mosquito breeding sites on any project can be referred to the Senior Medical Entomologist of the Department of Health and Community Services or any COMTAG member.

3.0 **Mosquitoes of Public Health Importance**

Background information on mosquito biology, breeding sites, potential diseases and specific control measures can be found in "Mosquitoes of Public Health Importance in the Northern Territory and their Control" (1984), available from the Department of Health and Community Services. Of the 100 species of mosquitoes in the Northern Territory, fifteen (15) species can breed in the intertidal zone, at least at certain sites and some times of the year. These include the principal vectors of malaria, epidemic polyarthritis, and a number of other virus diseases, as well as those species regarded as the most important pest species.
<table>
<thead>
<tr>
<th><strong>Salt Water Mosquitoes</strong></th>
<th><strong>Common Name</strong></th>
<th><strong>Importance</strong></th>
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<td><em>Ochlerotatus alternans</em></td>
<td>Scotch Grey</td>
<td>Negligible</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pest</td>
</tr>
<tr>
<td><em>Ochlerotatus vigilax</em></td>
<td>Saltmarsh mosquito</td>
<td>Major pest and disease vector</td>
</tr>
</tbody>
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<th><strong>Brackish Water Mosquitoes</strong></th>
<th><strong>Common Name</strong></th>
<th><strong>Importance</strong></th>
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<td>Australian malaria mosquito</td>
<td>Major malaria vector</td>
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<tr>
<td><em>Verrallina funerea</em></td>
<td>Brackish water mosquito</td>
<td>Important local pest</td>
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<th><strong>Common Name</strong></th>
<th><strong>Importance</strong></th>
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<td><em>Culex annulirostris</em></td>
<td>Common banded mosquito</td>
<td>Major pest and disease vector</td>
</tr>
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<td><em>Anopheles bancroftii</em></td>
<td>Black malaria mosquito</td>
<td>Potential malaria vector and pest</td>
</tr>
<tr>
<td><em>Anopheles annulipes s.l.</em></td>
<td>Australian Anopheles</td>
<td>Potential malaria vector</td>
</tr>
<tr>
<td><em>Anopheles meraukensis</em></td>
<td>Water reed Anopheles</td>
<td>Pest species</td>
</tr>
<tr>
<td><em>Coquillettidia xanthogaster</em></td>
<td>The orange mosquito</td>
<td>Important pest species</td>
</tr>
<tr>
<td><em>Mansonia uniformis</em></td>
<td>Water hyacinth mosquito</td>
<td>important pest species</td>
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</tbody>
</table>
3.1 Malaria

Malaria was only eradicated in the Northern Territory in 1962 and many communities in the Northern Territory remain vulnerable to malaria reintroduction, particularly those communities which are near large sources of Anopheles mosquitoes. Each year up to thirty malaria cases are imported into the Top End from overseas, and the Department of Health and Community Services investigates and follows up each case. With increasing numbers of people living in remote areas with large mosquito populations, or adjacent to mosquito sources in expanding urban areas, the potential for malaria reintroduction is increasing. In particular circumstances, adult mosquito control measures near urban areas may be necessary, but problems due to lack of access, thick vegetation, or the proximity to urban areas, may prevent or reduce the effectiveness of these measures. We need to reduce these potential problems by reducing the mosquito breeding areas adjacent to urban areas.

3.2 Arbovirus Diseases

Each year there are up to 20 cases of epidemic polyarthritis reported in the Top End. These are laboratory confirmed cases only, and it is thought the number of clinical cases is very much higher. All of these cases have been investigated and the likely sites of transmission were frequently in towns adjacent to particularly productive mosquito breeding areas. With a tropical lifestyle and an expanding population, it is becoming increasingly necessary to provide mosquito free urban areas.

4.0 Mosquito Breeding Sites in Coastal Areas

The breeding sites of the various mosquito species are illustrated in Fig. 1. The area of greatest potential for mosquito breeding lies within the upper high tide zone (from 7.3m to 7.9m A. C. D. in the Darwin area). In addition, the region up to 1.0m above maximum high tide can be a significant mosquito breeding area, as this region is usually the recipient of seepage, rain water and silt inputs being transported to the tidal areas. These regions have the capacity for both natural and human disturbances that can lead to significant increase in mosquito breeding.

The intertidal areas of wide expanse, thick vegetation, very flat topography, and fresh water inflows are the largest sources of mosquitoes. These large tidally influenced marshes (e.g. Leanyer Swamp) have variable salinity water which is shallow and thickly vegetated and is the ideal breeding habitat for most of the important mosquito species. Natural tidal marshes such as these can be extended and made much more productive sources of mosquitoes with increased silt, nutrient and water inputs from urban and industrial developments.

Any construction practice that increases the flow of water, silt or nutrients, or interrupts or prolongs the drainage through these areas, has the capacity to increase the amount of mosquito breeding. This is particularly so in the upper high tide area, where the often naturally self draining margin of the mangroves can be easily disturbed and result in the pooling of tidal water. Such sites can be quite small, but extremely productive in the numbers of salt water mosquitoes such as Ochlerotatus vigilax.

At present the Northern Territory Government and the Darwin City Council have a continuing mosquito engineering control program around urban Darwin, to rectify past poor construction practices. The annual expenditure for the three years 1985-1987 has been in the region of $180 000. This annual expenditure included funds for the construction of drains and a proportion to permanently upgrade those drains that repeatedly breed mosquitoes. The program will need to be
relatively long term to rectify all the past poor construction practices and achieve a relatively mosquito free city, particularly when poor construction practices are still proceeding. In contrast, planners of the new satellite city of Palmerston considered the potential for mosquito breeding at an early stage. The siting of the urban areas, the rectification of existing mosquito breeding areas, the design and endpoints of the storm drains, and reclamation works in Palmerston have resulted in a relatively mosquito free urban environment. This consideration in the planning stage has been a very cost effective solution.

5.0 **Construction practices that can result in mosquito breeding**

Mosquito problems created by previous construction "practices are detailed in Appendix I.

5.1 **Sand Extraction**

Deposits are usually found in low lying areas along swamps and creeks or close to the tidal areas. Any sand extraction activity has the capacity to produce wet season flooded depressions or waterfilled borrow pits that quickly become colonized with aquatic or semi aquatic vegetation and result in new mosquito breeding areas. These areas can be extremely productive, particularly if the borrow pits have some tidal influence, as this can eliminate many of the freshwater aquatic predators of mosquito larvae. Those sand extraction areas that are deep enough to penetrate the water table can become perennial mosquito sources.

5.2 **Storm Water Drainage**

Storm water drain construction can produce mosquito breeding sites by poor placement of berm material and the disruption of normal drainage patterns. If the disruption of drainage is in tidal areas it can create extreme mosquito problems.

Open unlined storm drains with relatively permanent dry season flows can be mosquito sources, particularly if the drain receives organic nutrients from urban run off or industrial processes.

If storm drains with considerable dry season flows are directed into low lying areas, particularly in the upper high tide zone, considerable ecological disturbance can result in dramatic increases in mosquito breeding.

5.3 **Road embankments and Access Roads**

Road embankments and access roads can result in impoundments or impedance of normal drainage patterns and frequently cause at least wet season pooling. Detailed topographic and vegetation surveys are usually necessary to avoid such disturbances.

5.4 **Water Retention in Tidal Areas**

The construction of water retention features can result in altered vegetation patterns that can give rise to mosquito breeding. Water retention in standing mangrove areas which results in the death of mangroves can create extremely productive sources of the salt marsh mosquito, the salt water *Anopheles* or the salt water *Culex* mosquito. Inundation of disturbed tidal areas by high tides, rain or waste water can result in emergence of large numbers of mosquitoes. Meticulous planning or water retention features is necessary to avoid creating mosquito breeding sites. Aspects that need
particular attention include the final water level, the quality and salinity range of the impounded water, the maintenance drainage capability, the potential vegetation growth in or at the edges, and the inflow of silt.

5.5 **Land Fill Operations**

Land fill in tidal areas can disrupt previously self draining areas and result in pooling of water. This is particularly so if the land fill has silt laden run off and is sited in a complex drainage pattern. Pollution and vegetation growth at the edge of land fill operation in water can eliminate or restrict the normal activity of aquatic predators and give rise to mosquito problems.

5.6 **Sewage Pond Construction**

The siting of sewage ponds is one of the most important factors in reducing potential mosquito problems. Recent siting of ponds in Darwin has been excellent, as disruption of mangrove drainage patterns has been avoided, and access and service embankments have not resulted in the inadvertent impoundment of water.

Maintenance needs, such as emptying certain ponds, can cause extreme mosquito problems unless the pond contents can be channelled or discharged directly to a daily flushed tidal area. These maintenance practices need to be considered in the planning stages and should be important factors in the choice of a site.

The type of ponds, particularly the depth, size and bank material can have a large bearing on whether the ponds are mosquito sources.

5.7 **Urban Subdivisions**

When urban subdivisions are poorly sited near pre-existing mosquito sources, or sites that have the potential to become sources, it is very likely that there will be public pressure at a later date to rectify the mosquito breeding. Sometimes the rectification works can be extremely expensive, or severely disrupt natural features such as swamplands. It is logical to avoid such costly rectification works or possible destruction of animal and fish habitats, by the correct siting of urban subdivisions.

The Health Department has recommended avoiding large and uncontrolled tidally influenced mosquito breeding areas by having a 1.6km buffer between the breeding areas and the proposed urban development.

This buffer is very relevant for those large salt marsh swamps with fresh water input such as Leanyer Swamp and Howard Swamp, but it is of little relevance for very small areas that are not very productive, or that can be easily controlled or rectified.

If urban areas are built near these large and at present uncontrollable mosquito breeding areas, then attempts will be necessary to control the breeding. Examples of types of physical control methods recommended include:

1. Swamp drainage by a system of channels
2. Tidal bunds, tide gates and an internal drainage system

3. Steep sided relatively deep (greater than 2. Om) excavated fresh water lake

4. Salt water lake.

Insecticide control for extended periods should not be contemplated as a control measure around urban areas, as there can be no certainty that such methods will be effective in the longer term.

6.0 **Guidelines for Construction Practice**

6.1 **Borrow Pits and Excavations**

6.1.1 No borrow pits, extractive industry or excavation should be conducted within the tidal zone, unless provision is made to prevent ecological changes.

6.1.2 Borrow pits or extractive operations should not excavate to a base level below maximum high tide level.

6.1.3 Cover material and vegetation should not be pushed into the tidal zone. There should be no impedance of overland flow into the tidal zone.

6.1.4 All borrowing or extractive areas should be rehabilitated immediately upon completion of the operation such that all operational areas are completely self draining.

6.1.5 Vehicle disturbed areas such as wheel ruts and compacted soil areas should be rectified as soon as practical to prevent water ponding.

6.2 **Storm Water Drainage**

6.2.1 Drains should be constructed to discharge direct into regularly flushed tidal areas, such as tidal creeks or a formalized channel dug back from a tidal creek. In Darwin 100 year flood drains should be constructed to the 3.7 AHD level and low flow drains to the 3.0 AHD (or below this level if silt accumulation is a potential problem).

6.2.2 Drains through tidal areas need to be of dimensions that will not result in silt accumulation in or near the drain. Low flow drains should be installed wherever there is the possibility of longer term dry season flows. Such drains can be either impervious above ground inverts or sub soil pipes.

6.2.3 Low flow drains should be installed wherever there is the possibility of longer term dry season flows. Such drains can be either impervious above ground inverts or sub soil pipes.

6.2.4 Access along all drains is necessary for regular maintenance.

6.2.5 Drains through tidal areas should follow the course of existing creeks or flow lines wherever possible.
6.2.6 Drains for mosquito control purposes should be only of dimensions that are necessary to drain over a period of 2 to 3 days for tidal areas, and 4 to 5 days for fresh water, unless there are other considerations requiring larger drains.

6.2.7 Silt traps should be installed in drains that are likely to carry considerable silt loads. This is particularly necessary in large urban drains during subdivision construction.

6.3 Embankments and Access Roads

6.3.1 No embankments should be constructed across tidal areas unless provision is made for sufficient tidal exchange to prevent any considerable ecological change. If upstream impoundments of tidal water are completely flushed at least once in 7 days, there is usually no significant mosquito breeding in the impounded tidal water.

6.3.2 Embankments should have provision for complete drainage of upland areas at least over a period of less that five days after flooding. This particularly applies to areas near the tidal limit, which would only be reached by tides once in 10 to 14 days.

6.3.3 Embankments for land reclamation purposes should have an internal drainage system with tide valves at the embankment. If upland flows are diverted around the reclamation area, the diverted flow should be discharged direct to the major tidal drainage line immediately seaward of the embankment.

6.3.4 Vehicle access along the upper high tide zone should be restricted as much as possible, to prevent the creation of vehicle disturbed areas that could pond tide and rainwater.

6.4 Water Retention in Tidal Areas

6.4.1 An ecological and hydrological study should be undertaken before any water retention feature is constructed in a tidal area.

Those aspects that are considered critical to the success of an aquatic feature include: the levels and seasonal fluctuations in salinity; the possible aquatic and semi aquatic vegetation changes likely to occur; the effect on aquatic animal life; the number of days under tidal influence; the depth of the retained water; inputs of organic and other pollutants into the system; the source, amounts and quality of possible top up water; the provisions for periodic maintenance; possible ecological effects seaward of the retention.

6.4.2 If the tidal regime in the water feature is significantly reduced or eliminated, all existing mangroves in the retention area should be removed.

6.4.3 Silt traps should be constructed at all significant silt entry points.

6.4.4 Regular vegetation maintenance or control programs will be necessary. The provision of 1:1 side slope or impervious margins should be considered to reduce maintenance needs.

6.4.4 There should not be any small cut off areas at any height level of the water.
6.5 Land Fill in Tidal Areas

6.5.1 Land fill operations should not impede any established drainage patterns, either by the land fill operations, or possible erosion from the fill area.

6.5.2 There should be drainage provisions all around the base of sanitary land fill operations, and these drains should discharge direct to a daily flushed tidal system.

6.6 Sewage Pond Construction.

6.6.1 Sewage ponds should be sited preferably on bare mud flat areas in preference to existing mangrove areas to minimize ecological disturbances.

6.6.2 The siting of ponds should not result in any impedance to pre-existing drainage lines, either landward or within the tidal area.

6.6.3 Pond drainage during maintenance should be direct to daily flushed tidal areas.

6.7 Urban Subdivision

6.7.1 A mosquito buffer zone for the exclusion of urban residential development is recommended within 1.6km of large and uncontrolled tidally influenced mosquito breeding areas.

6.7.2 No urban residential developments are recommended within 1km of mangroves, unless biting midges are not likely to be a significant problem.

6.7.3 Any subdivisions bordering tidal areas should incorporate a buffer distance between the high tide level and property boundaries, so that access is possible for management purposes, and to prevent the creation of new mosquito breeding sites.

7.0 Consultation

The Medical Entomology Branch of the Northern Territory Department of Health and Community Services is available for advice on what may constitute a potentially significant mosquito breeding site. In some instances where detailed entomological investigations are necessary, 12 months entomological monitoring may be required before the detailed planning stage. For significant entomological investigations, it may be necessary for the developer to engage an entomological consultant.

Consultation for any project within a tidally affected area may be required with the Northern Territory Department of Lands, the Environment Unit of the Conservation Commission, or the Coastal Management Technical Advisory Group (C. O. M. T. A. G).
Appendix I

Previous mosquito problems in the Top End of the Northern Territory created by Construction Practice

1.0 Sand Extraction

Bynoe Harbour

Sand extraction on a beach area in Bynoe Harbour resulted in an area of mangroves being bulldozed and pushed further into a tidal area to form a retarding barrier. Fresh water inflow into the retarding basin resulted in an area of impounded water varying from brackish to salt, depending on tidal movement. The large quantities of dead and dying mangroves contributed to high levels of organic matter and flotsam. The area proceeded to breed very large numbers of salt marsh mosquitoes and a range of other pest and potential disease carrying mosquitoes.

Casuarina Beach

Sand mining at Casuarina Beach was carried out behind the frontal dunes, to a depth below high tide level. Although initially the pits only collected freshwater, the weakened frontal dunes soon collapsed, allowing tidal entry into the pits.

The result was a range of fresh, brackish and tidal water pools, with mangroves and dense salt water couch grass, providing ideal habitats for a large range and huge numbers of mosquitoes. These mosquitoes seriously disrupted the recreational use of the nearby park, and affected nearby residential areas and the hospital area.

2.0 Storm Water Channelization Ludmilla Creek

During the installation of storm water drainage in the Ludmilla area, a large channel was constructed through the upper reaches of the Ludmilla mangroves to convey the increased storm water further downstream. The spoil from the channelization was thrown up on the sides of the channel to form a continuous embankment. This embankment disrupted the free drainage of the nearby mangrove and mud flat areas, resulting in cut off tidal depressions throughout the upper reaches of mangroves. These depressions created the breeding sites for hordes of salt marsh mosquitoes that plagued the general area for many years until rectified by the re-establishment of a drainage system under the combined mosquito engineering control group.

3.0 Storm Water Discharge, Sandy Creek, Tiwi

The construction of storm water drainage in the Tiwi area resulted in the discharge of storm water into the upper reaches of Sandy Creek along Rocklands Drive. With residential development, this extensive drainage system had considerable dry season flows from overwatering and wash down activities, which transformed the seasonal drainage line into a permanently flowing creek. Ecological changes occurred in the creek and for a considerable
distance downstream into the mangrove areas of Sandy Creek. Fresh water and brackish water reeds began growing beneath mangroves and on former bare mud flat areas. Silt accumulation caused drainage pattern changes and pooling of both fresh and tidal waters over considerable areas. Some areas of mangroves died while others colonized new areas. These ecological changes led to the creation of a range of mosquito breeding habitats and serious mosquito pest problem.

4.0 **Road Embankments and Access Tracks**

**Tiger Brennan Drive**

During the construction of the Tiger Brennan Drive extension, a large area of mangroves was cut off from regular tidal influence by an earth embankment. Some areas of the mangroves were flattened and left in situ, while other areas were bulldozed clear, leaving deep machinery tracks. Inadequate temporary drainage pipes were installed which were too small to allow sufficient drainage of impounded water, sited too high to allow complete drainage, and yet sufficient to allow tidal ingress and water level fluctuations. This situation led to a stagnant brackish water impoundment, with periodic tidal flooding of sheltered shallow water and artificial depressions. The resultant emergence of salt marsh and other species of mosquitoes required regular surveys and mosquito control operations in areas of inaccessible swamp. Notwithstanding that the affected area will soon be landfilled for future commercial development, even short-term impoundment of brackish water provides an unacceptable environment that promotes mosquito breeding.

**Access Tracks**

Access tracks, particularly those constructed by Electricity or Sewerage authorities, are frequently just above tidal reach, due to the positioning of many of their facilities. These tracks sometimes have inadequate drainage provisions which can interrupt overland water flow into tidal areas or disrupt tidal drainage patterns. This can result in the retention of water in drainage lines and creeks, creating swampy areas, or cause pooling on the uphill sides of the track. In some instances, when drainage is constructed under the road, scouring on the downhill side of the drain can result in depressions that can fill after rain or high tides.

5.0 **Water Retention Features in Tidal Areas**

Examples of the range of problems created by water retention in tidal areas can be illustrated by the construction of the Frances Bay Mooring Basin, the old Fannie Bay Golf Club dam, the Gove alumina final retention pond and Palmerston Lake on the Darwin City Council Golf Course. All of these projects had water retained either permanently or temporarily during construction, and were periodically under water level fluctuations by tidal or storm water influence. Each impoundment exhibited a range of salinities and resulted in vegetation changes which included either death of mangroves, growth of fresh or brackish water reeds, death of fish or other aquatic mosquito predators or prolific algal growth.

Any of these factors can result in prolific breeding of mosquitoes. The ecological modifications caused by the construction has usually been considerable and the mosquito breeding can only be alleviated by expensive or critically timed water management procedures.
In the mooring basin, the mangrove death and coincident mosquito breeding was caused by the embankment of an area of mangroves upstream of the mooring basin, with inadequate provision for stormwater drainage from the impounded area.

The Old Fannie Bay Dam mosquito problems arose from the creation of a non draining tidal depression which was periodically flooded by high tides.

Extensive algal growth and colonization by dense reeds in the Palmerston Lake resulted from infrequent tidal entry, inadequate pumping capacity for top up sea water, inflow of organic rich storm water and the insufficient side slope and depth of the impoundment.

The Gove waste water retention pond was created by impounding a large area of mangroves behind an embankment. The low salinity and high PH of the impounded water caused the death of a large area of dense mangroves and destroyed all aquatic life except for periodic pulses of enormous numbers of mosquito larvae. The periodic plagues of salt marsh mosquitoes from this area precipitated industrial problems and ushered in a mosquito control program which was frequently inefficient. The large area of mosquito breeding and the inaccessibility of the breeding areas by a tangle of dead mangroves hindered larval control, and adult mosquito control by fogging was restricted by the lack of all around access to cope with varying wind directions.

6.0 **Sanitary Land Fill, Leanyer Dump**

Urban refuse fill into the edge of a salt marsh resulted in areas of polluted marsh becoming significant mosquito breeding sites as the normal aquatic predators such as fish beetles and bugs were eliminated. Other areas became breeding sites by poor placement of the fill creating cut off pools or silt runoff interrupting surface drainage patterns. Additional problems were created by depressions left by the operation of machinery on the salt marsh floor. In one instance, the stockpiling of a large number of tyres without a covering of soil led to appreciable numbers of artificial container breeding mosquitoes affecting nearby suburbs.

7.0 **Sewer Line Construction**

The installation of sewer lines, by the nature of gravity flow requirements, are invariably installed near the tidal zone. The creation of mosquito breeding has been caused by the construction of embankments to carry pipes across tidal areas, the subsidence of excavations, or the pushing of earth and debris into the mangroves. An embankment across a former tidal creek in Coconut Grove resulted in changing a free draining section of tidal creek into a dense swampy fresh water reed swamp. The ecological changes were not confined to upstream of the embankment. Continued seepage through the embankment caused mangrove species change in the tidal area below the embankment and the resultant root growth and silt accumulation created a series of brackish and saline cut off pools. A section of the control zone sewerage scheme bordering tidal areas of Fannie Bay created depressions by machinery disturbance and subsidence of earth cover. More recent installations for the Trade Development Zone created additional mosquito breeding sites by pushing earth and mangroves into the tidal zone.
8.0 **Construction of Leanyer Sewage Ponds**

The siting of the Leanyer Ponds and associated embankments led to severe disruption of mangrove drainage patterns. One embankment had provision for drainage but the culvert was not installed with any consideration for possible ecological consequences. This area retained fresh water in the wet season, but was still subject to very high tides. Mangroves within the embankment died and the previous mud flat was transformed into a dense brackish water reed swamp. In addition, the maintenance of certain ponds could only be achieved by effluent release into the impounded area. In the tidal area, the drainage pattern disruptions led to very large areas of mangrove channels and flow lines without the capacity to drain freely at low tides. Subsequent mangrove vegetation growth further aggravated the disruption and resulted in large areas of tidal pooling. The consequences of these practices led to enormous populations of a range of mosquito species, severely affecting nearby residential areas.

Peter Whelan  
Senior Medical Entomologist  
DEPARTMENT OF HEALTH AND COMMUNITY SERVICES 1987
Plate 1  This tidally flooded ex-sand mining pit is now the site of prolific breeding by Ochlerotatus vigilax, Culex annulirostris and Anopheles farauti s.l..

Plate 2  An artificial drain constructed without an outlet to the tidal zone will simply pond and stagnate – and breed mosquitoes.

All Photos C.peterwhelan
Plate 3  Inappropriate landfill here has blocked natural drainage on the salt marsh, leading to ponding and mosquito breeding.

Plate 4  Interruption of drainage by nearby roadworks has led to tidally influenced ponding and killed the mangroves: large numbers of the saltmarsh mosquitoes, absent before, were a problem here during the construction phase.

All Photos C.peterwhelan
Plate 5  Pooling of stormwater through inadequate drainage creates mosquito breeding sites.

Plate 6  A sand dam placed through mangroves leads to upstream ponding; mangrove death and high numbers of mosquitoes.

All Photos C. peterwhelan
Plate 7  Machinery disturbance of the tidal area can give rise to significant numbers of mosquitoes after high tides.

Plate 8  Damming of a mangrove creek for water storage, killed the mangroves and the resultant brackish water gave rise to very high numbers of mosquitoes.

All Photos C. peter whelan
MOSQUITO AND BITING MIDGE BREEDING SITES - COASTAL DARWIN N.T.

NOTE: ON ADP = 0.396 TIDE (OR MEAN SEA LEVEL)

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

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

**Materials and Methods**

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

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

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

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

Table 1. Property treatment rates.

<table>
<thead>
<tr>
<th>Treatment Property No.</th>
<th>Property Size</th>
<th>Volume of 8% SC Applied</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 Biting Midges</td>
<td>4</td>
<td>51</td>
<td>81</td>
<td>0.84</td>
<td>6</td>
<td>-65 to 134</td>
<td>0.43</td>
</tr>
<tr>
<td>Control Biting Midges</td>
<td>4</td>
<td>17</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Treatment Mosquitoes</td>
<td>4</td>
<td>56</td>
<td>38</td>
<td>0.70</td>
<td>6</td>
<td>-408 to 227</td>
<td>0.51</td>
</tr>
<tr>
<td>Control Mosquitoes</td>
<td>4</td>
<td>147</td>
<td>257</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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

Table 5. Descriptive Statistics for 6 weeks field Data.

<table>
<thead>
<tr>
<th>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>
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<tr>
<td>Treatment</td>
<td>1.46</td>
<td>2,011</td>
<td>2,012</td>
<td>1</td>
<td>276</td>
<td>441</td>
</tr>
<tr>
<td>Control</td>
<td>2.21</td>
<td>21,914</td>
<td>21,948</td>
<td>34</td>
<td>425</td>
<td>2,989</td>
</tr>
<tr>
<td>Mosquitoes (n = 54 trap collections)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>2.50</td>
<td>186</td>
<td>186</td>
<td>0</td>
<td>8</td>
<td>25</td>
</tr>
<tr>
<td>Control</td>
<td>2.40</td>
<td>875</td>
<td>879</td>
<td>4</td>
<td>106</td>
<td>169</td>
</tr>
</tbody>
</table>

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


Marks, E. N. 1982. An atlas of common Queensland mosquitoes. Queensland Institute of Medical Research, Brisbane, Australia.

Ratnayake, J., P. Dale, P. Daniels, and N. Sipe. 2003. Economic impact of biting midges in Hervey Bay. Report for Hervey Bay City Council, Griffith University, Faculty of Environmental Sciences, Nathan Campus, Australia.


What is MVE?
Encephalitis is inflammation of the brain tissue and is usually caused by an infectious agent such as a virus. MVE is potentially fatal and a person is infected after being bitten by a mosquito carrying the MVE virus.

How is MVE spread?
The MVE virus is spread by the bite of an infected mosquito (usually *Culex annulirostris* also known as the “common banded” mosquito). Not all of these mosquitoes carry the virus, and only about 1 person in a 1000 who get bitten by infected mosquitoes will become unwell.

Where does MVE usually occur?
Although MVE can occur throughout Australia, it is most common in northern Australia. The MVE virus is seasonally present in the north west of Western Australia, inland North Queensland and the Top End of the Northern Territory (NT) during most years, and can extend into the Barkly and Central Australia in wet years.

MVE can occur from February to July although most cases are detected in the months March to May.

What are the symptoms?
It usually takes 5 to 15 days (normally 7 to 12 days) between getting bitten and becoming sick.

Symptoms include: high fever, severe headache, seizure or fits (especially in young children) neck stiffness, drowsiness, confusion and progression to delirium and coma in severe cases.

Who is at risk?
People most at risk are babies, young children and newcomers to the region.

What is the treatment?
There is no specific treatment or vaccine available for MVE.

How can MVE be prevented?
The only protection from MVE is to avoid being bitten by mosquitoes. This applies to all residents and travellers throughout the NT. Everyone should take measures to avoid being bitten by mosquitoes, particularly those visiting and camping in or near swamp or river systems during the evening and night, and in rural areas near sites of relatively high mosquito activity.
Mosquito protection for young children and babies is absolutely essential.

**Personal protection includes:**

- Avoiding being outside when mosquitoes are most active, from just before and until 2 hours after sunset.
- Wearing loose light coloured clothing with long sleeves, long trousers and socks (mosquitoes can bite through tight-fitting clothes).
- Applying a protective repellent containing up to 20 percent diethyl toluamide (DEET) or picaridin to exposed areas of skin. Lotions and gels are more effective and long lasting than sprays.
- Ensuring flyscreens in houses or caravans are in good repair.
- If camping out, either sleep in a mosquito-proof tent or under a mosquito net. Repellents only protect against mosquito bites for up to four hours, not all night.

For more information on disease aspects and prevention contact your nearest Centre for Disease Control.

- Darwin 8922 8044
- Katherine 8973 9049
- Nhulunbuy 8987 0359
- Tennant Creek 8962 4259
- Alice Springs 8951 7549

For more information on mosquitoes and virus ecology contact the Medical Entomology Branch.

Darwin 89228901

April 2004
Ross River virus

What is Ross River virus (RRV) disease?

It is a viral disease caused by the Ross River virus and is characterised by painful or swollen joints lasting from days to months. Symptoms usually settle by themselves.

How is it spread?

RRV infection cannot be spread from person to person. The virus is transmitted to humans by the bite of an infected mosquito. The mosquitoes present in the Northern Territory (NT) that can spread the virus are Culex annulirostris (common banded mosquito), Ochlerotatus vigilax (salt marsh mosquito), Ochlerotatus normanensis (flood water mosquito) and Ochlerotatus notoscriptus (backyard mosquito). Many people, particularly children, even if bitten by an infected mosquito, do not develop any symptoms of the disease.

Where and when is the virus found?

RRV is found throughout Australia, Papua New Guinea, parts of Indonesia and the western Pacific Islands.

In the NT, the main risk season is from December to March inclusive with the highest risk period in January when large numbers of mosquitoes result from either high tides or increased rainfall. Humid conditions enable mosquitoes to live longer, which allows more chance for a mosquito to pick up a virus from an animal and to live long enough to pass it on to humans.

What are the symptoms?

Symptoms vary from person to person and may appear from 3 days to 3 weeks after being bitten, most commonly within 7 to 14 days.

The illness generally begins with painful (sometimes swollen) joints and muscle and tendon pain. The most commonly affected joints are the ankles, fingers, knees and wrists. The pain usually develops rapidly, may be intense, and may be more severe in different joints at different times. Other symptoms include a raised red rash affecting mostly limbs and trunk, fever, fatigue, headache, light intolerance and swollen glands. Less common symptoms include sore eyes and throat, nausea and tingling in the palms of the hands or soles of the feet.

Fever, nausea and the skin rash usually disappear within the first 1 or 2 weeks of illness. Joint, muscle and tendon pain may last much longer, and can be distressing. Some people also have lingering fatigue, lethargy and depression.

Symptoms subside eventually and leave few or no after-effects. It is not possible at present to say how long an individual person will take to get better.

Some adults with RRV infection recover within 2 to 6 weeks of onset of the illness and most people will progressively improve over 3 to 6 months. A minority of people (about 15%) will still be unwell at 3 months, and at 6 months about 5% will have persistent joint pains and lethargy.
A small minority (up to 2%) of people may have residual symptoms after a year. In general people with symptoms after a year should be re-investigated and other forms of arthritis considered.

People with long-term symptoms are not sick all the time. By 3 months, many people experience some days when they are well and others when they are not, and as time goes by, the latter become less frequent, but symptoms may recur suddenly and without warning.

As a rule, once you’ve had RRV once, you won’t get it again. However, there have been a few rare cases of people developing RRV more than once in their lifetime.

Children tend to experience milder symptoms of shorter duration than adults.

What is the treatment?

RRV infection is diagnosed by a blood test. There is no vaccine to prevent RRV infection, and there is no medical cure for the disease.

Medical treatment is aimed at easing joint pains and swelling, and minimising fatigue and lethargy. For some people, simple pain-killers like aspirin or paracetamol are sufficient. Others will require stronger medications to ease the inflammation.

Emotional stress, physical fatigue and alcohol may cause symptoms to worsen or to last longer.

How can it be prevented?

The only protection from RRV is to avoid being bitten by mosquitoes.

Personal protective measures include:

- Wearing loose light coloured clothing with long sleeves, long trousers and socks (mosquitoes can bite through tight-fitting clothes).
- Applying a protective repellent containing up to 20 percent diethyl toluamide (DEET) or picaridin to exposed areas of skin. Lotions and gels are more effective and long lasting than sprays.
- Ensuring flyscreens in houses or caravans are in good repair.
- If camping out, either sleep in a mosquito-proof tent or under a mosquito net. Repellents only protect against mosquito bites for up to four hours, not all night.
- Try to reduce the number of places on your property where mosquitoes can breed. Any pools of water, even if tiny, can provide breeding sites for mosquitoes.

For more information on disease aspects and prevention contact your nearest Centre for Disease Control.

Darwin 8922 8044
Katherine 8973 9049
Nhulunbuy 8987 0359
Tennant Creek 8962 4259
Alice Springs 8951 7549


For more information on mosquitoes and virus ecology contact the Medical Entomology Branch.

Darwin 89228901

For information regarding support groups and education call the Arthritis Foundation of the NT on 89485232.
What is Malaria?

Malaria is a parasitic disease transmitted by Anopheles mosquitoes. There are 4 types of parasites that cause malaria: *Plasmodium ovale*, *P. malariae*, *P. vivax*, and *P. falciparum*. The last 2 are the most common.

Primarily, malaria is an infection of the red blood cells, causing paroxysmal fevers, but other parts of the body may be affected. Malaria caused by *P. falciparum* is life threatening and can cause multiple organ damage, coma and death.

How is it spread?

Malaria is spread by the female *Anopheles* mosquitoes. The parasite enters the body in mosquito saliva when a person is bitten by an infected *Anopheles* mosquito. The parasite first infects the liver where it begins to multiply. After some days, the resulting parasites are released into the blood stream to infect the red blood cells, where they continue to multiply, eventually bursting the red blood cells and further infecting others. If they reach high numbers they may then clog up blood vessels and cause organ damage and severe disease. Some of the parasites in the red blood cells develop into the sexual stages (gametocytes). If these stages are ingested when a mosquito bites an infected person, they develop in the gut of the mosquito for 10 –14 days, and then enter the salivary glands, ready for the next bite.

Where is it found?

Malaria is found throughout the tropical and subtropical regions of the world. Areas of high transmission are found predominantly in rural areas in South America (e.g. Brazil), south-east Asia (e.g. Thailand, Indonesia and East Timor), Western Pacific (Papua New Guinea, Solomon Islands and Vanuatu) and throughout sub-Saharan Africa.

The last case of locally acquired malaria in the Northern Territory was in 1962 and Australia was declared free of malaria by the World Health Organisation (WHO) in 1981. However, a number of species of *Anopheles* mosquitoes exist in the NT and the malaria parasite could be re-introduced into local mosquitoes if infected travellers from overseas are bitten here. The disease could become established anywhere in the Top End, down to a latitude of 19 degrees which is just north of Tennant Creek.

What are the symptoms?

Symptoms appear about 9-14 days after a bite from an infected mosquito, and coincide with the rupture of the red blood cells. Symptoms are often delayed in people who have lived in malarious areas and who may have developed some immunity.

Typically malaria produces fever, rigors (shakes), sweating, headache, vomiting and other flu-like symptoms. Sometimes there is a 2 or 3 day period of reduced symptoms before a recurrence on the third or fourth day. Untreated, infection can progress rapidly and become life threatening. Malaria can kill by infecting and destroying red blood cells (anaemia) and by clogging the blood vessels to the brain (cerebral malaria) or vital organs.

Why does malaria relapse?

Some forms of malaria such as *P. vivax* and *P. ovale* exist as dormant forms that remain in the liver for months or years before producing the disease.

With other forms such as *P. falciparum* and *P. malariae*, the disease can reoccur after apparent recovery, due to either inadequate treatment or infection with a drug resistant strain.
How is it diagnosed?
Malaria is diagnosed by a blood test. The blood is examined under a microscope looking for malaria parasites inside the red blood cells. All travellers from malarious areas who become ill or develop a fever should be tested.

What is the treatment?
All cases of *P. falciparum* malaria in the NT are admitted to hospital because this form of malaria can rapidly become life threatening. Cases of malaria other than *P. falciparum* can sometimes be treated at home if the house is adequately screened and if the patient agrees to stay indoors between dusk and dawn. This is to avoid any risk of transmission of the parasite to the local *Anopheles* mosquitoes.

Treatment must be given in consultation with specialist physicians.

Before travelling overseas
Check whether the countries you are travelling to are affected by malaria by contacting your GP, Travel Health Clinic or visit the:

WHO International Travel and Health website at: http://www.who.int/ith/index.html

Or the Centers for Disease Control and Prevention at: http://www.cdc.gov/travel/diseases.htm#malaria

If you are travelling to an affected country you will need preventative medication. Contact your GP or Travel Clinic to organise anti-malarial medication for your trip. Some medication must be started 1 week prior to entry to the affected area.

While in affected areas there are measures which should be taken to reduce the risk of mosquito bites.

How to protect yourself from mosquito bites
- Avoid being outdoors between dusk and dawn to avoid mosquito bites, particularly in poorly lit areas, rural areas, or the outskirts of large towns.
- Cover your body (especially arms, legs and feet) between dusk and dawn. Loose, light coloured clothing is best.
- Apply insect repellent to exposed skin at risk times; choose one containing either DEET or picaridin.
- Avoid scents on the body, e.g. perfume, deodorants, and sweat, since these can attract mosquitoes.
- If accommodation is not well screened, sleep inside mosquito netting. Use insecticide impregnated bed nets and clothing in high risk areas.
- Use mosquito coils or insecticide vaporisers in enclosed areas.

If you return from a malarious area and develop symptoms
If you develop symptoms of malaria within 2 years of visiting a malarious area contact your GP or hospital emergency department immediately for an urgent medical assessment. Remember to inform the medical officer of where you have travelled as this will help determine your risk of malaria and the type of treatment required.

If you have malaria, the people you have travelled with (particularly to high risk areas such as PNG, East Timor and parts of Indonesia including Flores, Lombok and surrounding islands) should also be tested.

For more information contact your nearest CDC or Medical Entomology Branch.

Medical Entomology 89228548
CDC Darwin 89228044
CDC Katherine 89739049
CDC Nhulunbuy 89870359
CDC Tennant Creek 89624259
CDC Alice Springs 89517549


June 2004
# Arbovirus Risk Periods in the Northern Territory

<table>
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<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>
<th>Probable Main Risk Period</th>
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<tr>
<td>MVE</td>
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<td>MAR</td>
<td>DEC-OCT</td>
<td>FEB-JULY</td>
<td>FEB-MAY</td>
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<td>APRIL-JUN</td>
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<td>FEB-MAY</td>
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<td>RR</td>
<td>NOV-SEPT</td>
<td>JAN-APR</td>
<td>-</td>
<td>JAN-DEC</td>
<td>JAN-MAR</td>
<td>DEC-JUN</td>
</tr>
<tr>
<td>BF</td>
<td>NOV-SEPT</td>
<td>DEC-APR</td>
<td>-</td>
<td>DEC-OCT</td>
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<td>DEC-JUN</td>
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