

Appendix O Biting Insects Assessment



Northern
Territory
Government

DEPARTMENT OF HEALTH

East Arm Port Expansion Project Biting Insect Investigation

October to December 2010

Medical Entomology
Centre for Disease Control
Northern Territory Department of Health
February 2011

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Study undertaken on behalf of URS Australia Pty Ltd

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Executive summary

The Northern Territory Department of Planning and Infrastructure (DPI) propose to expand the area around East Arm Port for port related infrastructure (Notice of Intent June 2009). As outlined in the Notice of Intent the proposal is to provide the following elements at the East Arm Wharf and adjacent areas:

- a Department of Defence (Defence) hardstand.
- a marine supply base.
- filling of an area to provide land for an additional rail spur into the bulk stockpile area.
- development of the additional rail spur to the bulk stockpile area and filling of an area north of the existing East Arm Wharf ponds.
- extension of the existing East Arm Wharf key line, as identified in the Port Masterplan 2030.
- Land Development Corporation (LDC) subdivisional works and filling adjacent to the new East Arm Boat Ramp and Muramats Road (Although included in this assessment and listed as part of the proposal in the NOI, the Draft Environmental Impact Statement (EIS) for which this report was prepared does not include the LDC subdivisional works and filling adjacent to the new East Arm Boat Ramp and Muramats Road).
- disposal of dredge spoil, with dredging to commence in the first quarter of 2012.

The East Arm Port Area contains numerous mosquito breeding sites created by the original development, with notable sites including the large mud ponds, shallow depressions on reclaimed land, shallow depressions on an extensive site used for borrow material, small sediment traps and numerous drainage lines.

The northern salt marsh mosquito *Aedes vigilax* and the common banded mosquito *Culex annulirostris* are known to occur in seasonally high numbers at East Arm Port (Warchot and Whelan 2010). Both species are known vectors of Ross River virus (RRV) and Barmah Forest virus (BFV), with the latter a known vector of the potentially fatal Murray Valley encephalitis virus and other arboviruses. High numbers of the receptacle breeding mosquito *Aedes notoscriptus* have also been collected at East Arm. This species can transmit RRV and BFV, while breeding of this species also indicates ample available receptacles and the potential for favourable breeding sites for exotic dengue mosquitoes (*Aedes aegypti*).

The presence of very appreciable and productive mosquito breeding sites created by the first stage of development indicates future development has the very high potential to create new mosquito breeding sites. Future development also has the opportunity to rectify existing mosquito breeding sites. Rectification of existing mosquito breeding sites will be of benefit to workers in the East Arm area, by reducing pest problems and the risk of mosquito borne disease transmission. More importantly, the breeding of vector mosquitoes close to international port facilities is in contravention to the International Health Agreement, and also contravenes the Northern Territory Public Health Act.

The East Arm area is subject to very high seasonal biting midge pest problems, caused by the mangrove biting midge *Culicoides ornatus* (Warchot and Whelan 2006). Breeding sites are associated with the nearby Bleesers Creek and Hudson Creek, which surround the East Arm Port Area.

Due to the known biting insect issues affecting the site, a biting insect investigation was recommended as part of the Environmental Impact process for the proposed development, to provide an updated assessment of the biting insect issues. Medical Entomology of the Northern Territory Department of Health (DOH) was commissioned by URS Australia Pty Ltd to conduct the following assessment;

- Conduct peak season biting midge trapping throughout the East Arm Peninsular.
- Conduct a range of larval mosquito surveys to determine the breeding sites for salt marsh mosquitoes and other pest and vector mosquitoes.
- Evaluate previous biting insect reports on the East Arm area and incorporate relevant information into the current assessment.
- Evaluate development concepts for the potential to create new mosquito breeding sites.
- Provide recommendations on rectifying existing mosquito breeding sites, and preventing the creation of new mosquito breeding sites.
- Provide recommendations on minimising the impact of biting midges on the workforce.

Findings

Mosquitoes

The East Arm area, between the wharf and Hudson Creek east of Berrimah Road, is subject to very high levels of the northern salt marsh mosquito *Aedes vigilax*. Seasonal abundance of between 2,500 and 5,500 *Ae. vigilax* per trap per night were recorded in various traps at East Arm from the late dry season (October) to mid wet season (January). Pest thresholds for this mosquito begin at around 50 per trap per night, indicating the potential for very high pest problems. This mosquito is the most serious pest in coastal areas of the Northern Territory, and is a major vector of Ross River virus (RRV) and Barmah Forest virus (BFV).

The common banded mosquito *Culex annulirostris* was also recorded in seasonally very high numbers nearby to the wharf, with up to 3,000 per trap per night during the mid to late wet season (January to April). Pest thresholds for this mosquito begin at around 600 per trap per night, indicating the potential for high pest problems. This species is a potential vector of RRV, BFV, the potentially fatal Murray Valley encephalitis virus and many others.

The receptacle mosquito *Aedes notoscriptus* was recorded in seasonally high numbers during the wet season nearby to the wharf. Pest thresholds begin at around 30 per trap per night, with up to 300 per trap per night recorded during the wet season. *Aedes notoscriptus* is a potential vector of RRV and BFV.

Almost all of the current mosquito breeding sites at East Arm are a result of past development. Large and productive breeding sites for *Ae. vigilax* and *Cx. annulirostris* were located nearby to the wharf. These included two large, shallow remnant areas of Mud Pond A, and two large paperbark depressions as well as many ground pools located on disturbed land used for borrow material (Sections 5421 and 6117), nearby to the wharf. Sediment ponds with vegetation, as well as non-draining drains were also breeding sites for both of these mosquitoes. The large mud ponds near the wharf were potential low productivity breeding sites for *Ae. vigilax*. Breeding sites for the receptacle mosquito *Ae. notoscriptus* have been in building material and other items stored in

yards nearby to the wharf guardhouse, and potentially on the wharf and in other areas of East Arm. Breeding sites for *Ae. notoscriptus* are potential breeding sites for exotic dengue mosquitoes if an incursion occurs at the nearby wharf.

New breeding sites could be created due to the creation of borrow pits and scrapes, sediment ponds, mud ponds, some aspects of Water Sensitive Urban Design, site clearing and reclaiming, stormwater drains and water discharge sites, road and railway construction over tidal areas, and inappropriate storage of artificial receptacles and materials that could pond water.

Biting midges

The mangrove biting midge *Culicoides ornatus* is the only species of biting midge likely to cause appreciable human pest problems at East Arm. Whilst biting midges are considered appreciable human pests, they are not known to transmit disease to humans in Australia.

The upper tidal mangrove tributaries of Bleesers Creek will be the most productive breeding sites affecting all of the East Arm Port Area, followed by the upper tidal mangrove tributaries of Hudson Creek, and the foreshore mangrove areas of Hudson Creek, Bleesers Creek and the Elizabeth River.

Very high pest problems will be encountered in all areas of East Arm within 1.5km of the nearest mangrove margin. Trapping indicated levels of up to 21,000 *C. ornatus* in a single trap set over one night, with high pest levels starting at around 1000 *C. ornatus* per trap per night. Peak season problems will occur from August to November, with appreciable pest problems expected during all other months.

Trapping indicated that biting midge numbers inland of areas of industrial development were lower compared to areas adjacent to the mangroves, and subsequently the outer areas facing the mangroves are likely to experience the greatest pest problems.

The control of mangrove biting midge breeding sites using aerially applied insecticides is not practical or environmentally acceptable, due to dense mangrove canopies, the mud breeding habitat, and the lack of a suitable specific larvacide for mangrove biting midges in Australia. The only long term way to reduce biting midge breeding is to remove or alter their tidal mangrove breeding sites. The proposed development will remove some foreshore mangrove breeding sites associated with the Elizabeth River and Bleesers Creek, and partially remove several upper tidal tributary breeding sites associated with Bleesers Creek. Overall, the development will only have a minor impact on removing biting midge breeding sites.

The use of low neap tide in-creek bunds to target prime dry season upper tidal tributary breeding sites has the potential to reduce *C. ornatus* breeding and provide some reduction to pest problems. However full scientific studies would be required to evaluate their effectiveness in reducing biting midge breeding.

Personal protection from biting midge bites, either through avoidance of problem times, use of personal repellents, mosquito coils or lanterns, and use of long sleeved shirts and trousers is likely to be the best form of protection from biting midges. The use of insecticide treated vegetation barriers on individual lots could also reduce localised adult biting midge levels.

Recommendations

Mosquitoes

All mosquito breeding sites created by past development should be rectified during the expansion project. This would include filling or draining the two large paperbark swamps/depressions nearby to the wharf, and the two large remnant ponding areas of Mud Pond A. Other mosquito breeding sites such as ground depressions on the cleared land nearby to the wharf (Sections 5421 and 6117) should be rectified by filling and grading. Further open drains are required within Sections 5421 and 6117 to allow complete drainage of the site. All other ground depressions at the East Arm Port Area and adjacent areas should be filled to prevent the breeding of pest and potential disease vector mosquitoes.

Small sediment ponds located in Sections 5421 and 6117 are appreciable mosquito breeding sites, and should be rectified to be free draining, or be completely cleared of vegetation and be modified to have steep sites (1V:2H or steeper) and contain deep water (>1m). The large mud ponds are not currently productive mosquito breeding sites, but should be rectified by filling and contouring to prevent ponding and mosquito breeding. Most open drains at East Arm have issues with ponding, and therefore should be upgraded with concrete low flow inverts to suitable end points.

The rectification of existing mosquito breeding sites at the East Arm Port Area and adjacent areas should be a matter of priority, due to the potential public health issue to workers and passengers at the nearby rail terminal, and the potential quarantine issues in regards to the International Health Regulations. If breeding sites are not rectified in the 2011 dry season, landholders should be required to control mosquito breeding on their respective land until the breeding sites are removed. This includes the construction of drainage and the removal and management of artificial receptacles on vacant land, the wharf and private business by the relevant landholder.

There should be no repeat of the mosquito breeding sites created during the previous development of the East Arm wharf. Specific recommendations in this report in regards to fill borrow areas and site clearing/reclaiming, stormwater drainage, sediment ponds, mud ponds, Water Sensitive Urban Design and other activities that could lead to the creation of water ponding should be adhered to, along with information from relevant Medical Entomology guidelines mentioned in this report. Preventing the creation of mosquito breeding sites during construction would prevent the need for costly and time consuming mosquito larval control programs, and prevent potential public pressure on government to control or rectify the artificially created mosquito breeding sites.

Biting midges

If possible, more of the upper tidal tributaries of Bleesers Creek should be removed as part of the current proposed development. Alternatively biting midge problems at East Arm could possibly be alleviated by the use of tidal bunds across the upper tidal tributaries of Bleesers Creek, and Hudson Creek. The use of tidal bunds however is speculative and would require intensive field trials to determine their effectiveness.

The use of insecticide 'hedge' barriers by individual landholders could provide effective localised control of adult biting midges. However, any insecticide control option would require ongoing evaluation to determine if insecticide resistance is occurring. Any adult biting midge control program would also need to be funded and carried out by the relevant landholder.

All lots should have a notification on titles mentioning the high biting midge pest problems that occur at the East Arm Port Area and adjacent areas between the wharf and Hudson Creek east of Berrimah Rd.

1.0 Introduction

The Northern Territory Department of Planning and Infrastructure (DPI) propose to expand the area around East Arm Port for port related infrastructure (Notice of Intent June 2009). As outlined in the Notice of Intent the proposal is to provide the following elements at the East Arm Wharf and adjacent areas:

- a Department of Defence (Defence) hardstand, to be commenced by 2010, as there is a current requirement for this facility to be developed as soon as possible.
- a marine supply base, to be commenced by 2010, as there is a current requirement for this facility to be developed as soon as possible.
- filling of an area to provide land for an additional rail spur into the bulk stockpile area, to be commenced by 2010/2011.
- development of the additional rail spur to the bulk stockpile area and filling of an area north of the existing East Arm Wharf ponds, to be commenced by 2014.
- extension of the existing East Arm Wharf key line, as identified in the Port Masterplan 2030 and to be commenced by 2014.
- Land Development Corporation (LDC) subdivisional works and filling adjacent to the new East Arm Boat Ramp and Muramats Road, to be commenced by 2014 (Although included in this assessment and listed as part of the proposal in the NOI, the Draft Environmental Impact Statement (EIS) for which this report was prepared does not include the LDC subdivisional works and filling adjacent to the new East Arm Boat Ramp and Muramats Road).
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The East Arm area is subject to very high seasonal biting midge pest problems, caused by the mangrove biting midge *Culicoides ornatus* (Warchot and Whelan 2006). Breeding sites would be associated with the nearby Bleasers Creek and Hudson Creek, which surround East Arm.

Due to the known biting insect issues affecting the site, a biting insect investigation was recommended as part of the Environmental Impact Assessment process for the proposed development, to provide an updated assessment of the biting insect issues. Medical Entomology was commissioned by URS Australia Pty Ltd to conduct the following assessment;

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- Provide recommendations on minimising the impact of biting midges on the workforce.

2.0 Aims

2.1 Mosquitoes

Mosquitoes are a serious potential public health issue in the Northern Territory, 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 East Arm area has been an appreciable mosquito breeding area since the development of the port, with major mosquito breeding associated with hill removal, borrow pits and scrapes, cut-off upper tidal mangrove areas, mud ponds and sediment ponds, constructed drainage lines, and shallow ponding on reclaimed land. All of these are artificially created breeding sites, and most could have been avoided by engineering and construction authorities heeding aspects to minimise or avoid the creation of new mosquito breeding sites, by not allowing over excavation of borrow sites, and ensuring a suitable finished surface slope was provided for site drainage. Natural breeding sites at East Arm were previously limited to isolated upper tidal depressions.

Weekly trapping by Medical Entomology for a period of 12 months from February 2009 to February 2010 revealed very high levels of *Ae. vigilax* and *Cx. annulirostris*, and high levels of *Ae. notoscriptus*. The aim of this study is to provide recommendations on reducing mosquito populations and breeding sites, to minimise the mosquito problem in the area.

The last extensive survey of potential mosquito breeding sites at the East Arm area was conducted in 2006 (Warchot and Whelan 2006). Other more localised investigations occurred in

the East Arm mud ponds area in January 2010 (Warchot and Whelan 2010). Part of the aim of the current study is to provide up to date information on the mosquito breeding sites in the area.

Previous development has created major mosquito breeding problems at East Arm. Another aim of this biting insect assessment is to provide recommendations on development processes that could be utilised to rectify existing problems, or prevent the creation of new mosquito breeding sites.

2.2 Biting midges

Biting midges can be considerable pests within a few kilometres of the coast in the Northern Territory (Whelan 1991a), with highest abundance occurring up to 1.5km from the mangrove margin (Shivas and Whelan 2001). Biting midges can cause problems due to painful bites, while some people experience secondary effects such as intense itching and skin infections from scratching, with a loss of sense of well being. Biting midges however are not known to transmit human disease in Australia.

The mangrove biting midge *Culicoides ornatus* is the most serious pest biting midge in coastal areas of the Northern Territory (Shivas and Whelan 2001, Whelan 2003). Peak season numbers generally occur in the months of August to November. An aim of the study was to identify peak season *C. ornatus* abundance at East Arm, and utilise existing information about this species in Darwin harbour to determine the seasonal pattern of abundance and localised problem areas likely to be encountered at East Arm.

3.0 Methods

3.1 Trapping

A total of 6 traps were set around the East Arm Port area on the 23rd and 24th of October 2010, which was one night before the full moon and on the night of the full moon. The trap sites were chosen to provide an even coverage of the East Arm Peninsular. The trap locations were recorded using a hand held GPS, and marked with flagging tape to aid in future re-location of the sites. Trap sites are shown in Figure 1.

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. Traps were set in the afternoon at least one hour before sundown and collected the following morning at least an hour after sunrise. The traps were designed to collect both biting midges and mosquitoes at the same time.

3.2 Mosquito processing

Collected mosquitoes were stored in a petri dish in a freezer (-10°C) on the day of collection for later identification. For collections of up to 300 mosquitoes, all adult mosquitoes were identified with the aid of light microscopes and various taxonomic keys (Lee et al 1944, 1982, 1984, 1987

and 1989, Marks and Reye 1982, Russell 1996). For collections of over 300 mosquitoes, a sub-sample of 300 mosquitoes was taken from the bulk sample and all mosquitoes identified, with the sub-sample and bulk samples individually weighed to calculate a multiplication factor. The multiplication factor was then applied to the sub-sample to calculate final mosquito numbers. The bulk sample was scanned for extra species not located in the sub-sample. All species and totals for each individual collection were then entered into a database for evaluation.

3.3 Mosquito field surveys and evaluations

Field surveys for potential mosquito breeding sites were conducted on the 11th of October 2010 and 31st of December 2010. The first field survey in October was conducted two days after the highest tide in the 2010 build up period (7.8m Australian Chart Datum (AHD), and was also the morning after heavy rainfall. The December survey was conducted 5 days after the largest daily rainfall event from the first monsoon event of the wet season. The main target mosquito in October was the northern salt marsh mosquito *Aedes vigilax*, although ponding areas were also assessed for the potential to breed other mosquitoes such as the common banded mosquito *Culex annulirostris*. In December, the main target mosquitoes were *Ae. vigilax* and *Cx. annulirostris*. Larvae were sampled using a 350ml/vol ladle dipper. All sites were marked on a GPS for future survey purposes and for plotting on a map (Figures 2A - 2C), while some sites were photographed to provide a visual aspect of the breeding site, with photos shown in Figures 2A-2C.

3.4 Biting midge processing

Collected biting midges were stored in a freezer (-10°C), then separated from the mosquitoes using a fine sieve. Midges were then stored in 70% alcohol. 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 and Dyce et al 2007). 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 evaluation.

3.5 Biting midge breeding site evaluation

Potential *C. ornatus* breeding sites were deduced by examining high resolution aerial photography, and referral to existing information on the breeding sites for this species (Shivas 1999, Whelan 2003). Sites of interest were upper tidal mangrove tributaries and foreshore mangrove areas of Blesers Creek, Hudson Creek and the Elizabeth River.

4.0 Results

4.1 Larval mosquito survey 11th October 2010

The larval mosquito survey on the 11th of October 2010 revealed many actual and potential mosquito breeding sites. Areas of ponding water were associated with drainage lines, sediment

ponds, and depressions caused by vehicle disturbance, fill stockpiling, site clearing or access track construction. Each class of breeding site is discussed below. Site locations and photos are shown in Figures 2a-2c, with the results of the survey shown in Table 1.

The survey was primarily aimed at tide breeding sites, but due to heavy rainfall the night before the survey, many ground depressions that were not tide influenced or above the October tide level were flooded and therefore included in the survey. The survey was slightly too early to find peak breeding for ground pool mosquitoes that lay eggs on damp ground, such as *Ae. vigilax*, however *Ae. vigilax* had hatched at some sites, and therefore the survey still provided a good indication of their preferred breeding sites at East Arm.

4.1.1 Drainage lines

Drainage lines that were actual or potential mosquito breeding sites were Sites 8, 20, 24, 26, and 34-36. Site 8 was the roadside table drain opposite Section 5421, which had *Typha* sp. growth and considerable ponding. Mosquito larvae collected at Site 8 were the common banded mosquito *Culex annulirostris*, with this drain also being a potential breeding site for the northern salt marsh mosquito *Aedes vigilax*. Site 20 was also a roadside drain, which contained considerable ponding and is a probable breeding site for *Ae. vigilax* and *Cx. annulirostris*. The paperbark lined informal drainage lines (Sites 24, 26) are potential *Ae. vigilax* and *Cx. annulirostris* breeding sites, with Site 24 breeding the brackish water mosquito *Verrallina funerea*.

Sites 34-36 were open unlined drains. All were ponding water, although no mosquito larvae were located. The Site 34 drain ended at the paperbark swamp area about 40m upstream of the landward mangrove margin, with the paperbark swamp a potential breeding site for *Ae. vigilax* and *Cx. annulirostris*, and the drain a potential *Cx. annulirostris* breeding site due to semi-aquatic vegetation growth. The Site 35 drain was a tidally affected drain ending at the mangrove margin, with major ponding due to silt deposition and semi-aquatic reed growth. The Site 35 drain is a potential breeding site for *Ae. vigilax* and *Cx. annulirostris*. Site 36 was the open drain adjacent to the railway terminal, with semi-aquatic reed growth (*Typha* sp.) in the drain. This drain is a potential *Cx. annulirostris* breeding site in the upper reaches, and potential *Ae. vigilax* breeding site in the lower reaches. The Site 32 Open Unlined Drain (OUD) does not appear to be a likely mosquito breeding site, due to the relatively low invert level that allows regular tidal flows and fish movement.

The drain near the wharf guard house has been found breeding mosquitoes in high densities on several occasions including *Ae. vigilax* and *Cx. annulirostris* (Warchot and Whelan 2006, Warchot and Whelan 2009). The shallow outflow drain receiving flows from the fuel terminal and Northern Cement open drains has been found breeding *Ae. vigilax*, in an isolated pool caused by silt deposition (Warchot and Whelan 2009). The open drains within Northern Cement and the fuel terminal were not inspected, although the drains are unlined and are potential *Ae. vigilax* and *Cx. annulirostris* breeding sites if ponding occurs within the drains.

Other open drains in East Arm are potential mosquito breeding sites. These include the several drains from the railway embankment to tidal mangrove areas of Bleasers Creek, and the two large open drains opposite Darwin Business Park leading into the upper mangroves of Hudson Creek. The large open drain between Darwin Business Park and the railway (Figure 2b) has been programmed by the Land Development Corporation to be upgraded with a concrete invert to the railway culvert, and therefore will no longer be a *Cx. annulirostris* breeding site.

4.1.2 Ground pools

Some of the most productive mosquito breeding sites at East Arm in October 2010 were shallow depressions located throughout the undeveloped disturbed areas of East Arm. In particular some ground depressions in Section 5421 and 6117 were high productivity *Ae. vigilax* breeding sites. Other ground depressions in Section 5421 and 6117 were not breeding at the time of the survey, but were also likely to be high productivity *Ae. vigilax* breeding sites. Most depressions were vegetated with grass, and therefore are likely to be high productivity *Cx. annulirostris* breeding sites in the wet season. Other notable ground depressions likely to breed *Ae. vigilax* and *Cx. annulirostris* were located in Sections 5420, 5163 and 5720. Most ground pools were a result of site clearing, vehicle or machinery disturbance, and stockpiling associated with the general absence of a suitable surface slope for drainage.

Areas cut off by road embankments were also major or potential mosquito breeding sites. Site 9, colonised by paperbark trees and *Eleocharis* sp. reeds, was a large and very productive *Ae. vigilax* breeding site, and potential wet season *Cx. annulirostris* breeding site. Larval Site 6, a large paperbark area embanked by an access track near the tidal margin, was dry at the time of the survey but is a potentially very large and productive *Ae. vigilax* breeding site.

An examination of aerial photography indicated the presence of tidal grassy pools associated with the upper tidal flowline in the eastern corner of Section 5633 (Site 33). These grassy pools are potentially productive *Ae. vigilax* breeding sites after tide and rain flooding.

4.1.3 Mud ponds and sediment ponds

The large mud ponds between the East Arm wharf and Northern Cement were not breeding mosquitoes during the October 2010 larval mosquito survey. Mud Pond A South West and Mud Pond C have previously been found breeding low levels of *Ae. vigilax* (Warchot and Whelan 2010), while Mud Pond B has also been found breeding low levels of *Ae. vigilax* (Warchot and Whelan 2006). Mud Pond D has not been found breeding mosquitoes except in an isolated plunge pool, but was similar in nature to Mud Pond B and is therefore a potential low level *Ae. vigilax* breeding site (Warchot and Whelan 2010). Mud Pond A South West was a remnant area of the now mostly filled Mud Pond A, and was shallow and contains relatively dense grass and semi-aquatic reeds, therefore is likely to be one of the most productive mosquito breeding sites at East Arm. Mud Pond A between Territory Resources and Berrimah Rd was a very large area colonised with grass and semi-aquatic reeds, and is likely to be the largest and most productive *Ae. vigilax* and *Cx. annulirostris* breeding site at East Arm. The large mud ponds with deep water and no semi-aquatic vegetation are unlikely to be mosquito breeding sites.

The small sediment ponds scattered around East Arm were all actual or potential mosquito breeding sites. Site 23 was colonised by *Eleocharis* reeds and was a high productivity *Ae. vigilax* breeding site, and potential *Cx. annulirostris* breeding site. Site 19 was colonised with *Typha* sp. reeds and is a potential *Cx. annulirostris* and *Ae. vigilax* breeding site. The several small sediment ponds associated with the OM Manganese stockpile and Territory Iron stockpile have been identified as potential *Ae. vigilax* breeding sites (Warchot and Whelan 2010).

4.2 Larval mosquito survey 31 December 2010

A larval mosquito survey was conducted on the 31st of December 2010, several days after appreciable monsoon rainfall. The main focus of the survey was the mud ponds area and the wharf. Survey points and photos are shown in Figures 2a and 2c, with results in Table 1.

Mud Pond A between Territory Resources and Berrimah road was found breeding high levels of *Cx. annulirostris* and *Ae. vigilax*. *Culex annulirostris* larvae were relatively widespread in the depression, amongst vegetation such as *Typha* reeds and grass. *Aedes vigilax* pupae and some 4th instar larvae were found schooling in very high numbers in water between the access road across the depression and Berrimah Road. The presence of large numbers of 4th instar *Cx. annulirostris* and pupae indicated the area had been previously flooded to some extent for an extended period, at least for more than one week.

Mud Pond C was almost completely drained, with only minor ponding towards the outlet. Mud Pond A south west was flooded over a large area, with no mosquito larvae found at the western edge of the depression. There was likely to have been appreciable *Ae. vigilax* breeding in Mud Pond A south west in the weeks prior to the survey. *Typha* and grass growth indicated the potential for *Cx. annulirostris* breeding, at least in the late wet season when vegetation growth would be greatest.

Mud Pond B had some *Typha* growth at the northern margin, indicating the potential for localised *Cx. annulirostris* and *Ae. vigilax* breeding, while the remainder of the pond was relatively vegetation free and windswept, and therefore not likely to be a major breeding site. Mud Pond D was also windswept and had minimal semi-aquatic vegetation, with the plunge pool the only likely appreciable breeding site associated with the pond.

The Larval Site 6 Paperbark Swamp was flooded with dark nutrient rich water. Brief sampling failed to reveal any mosquito larvae, but it is likely that *Ae. vigilax* pupae were in some areas of this swamp similar to Mud Pond A between Territory Resources and Berrimah Rd. This swamp was likely to have been flooded to some extent in the weeks prior to the survey.

Sampling of several ground pools within Section 5421 (Sites 37-39) failed to reveal mosquito larvae, with any hatch of *Ae. vigilax* larvae likely to have occurred in the weeks prior to the survey. *Culex annulirostris* larvae were absent, although breeding appeared likely to occur in the latter wet season when grass growth in and around the edges of the depressions would have been denser. The remainder of Section 5421 was not surveyed, although it is likely that there would have been more flooded depressions compared to the October survey.

The large drain near the railway terminal (Site 36) was again ponding large amounts of water, with semi-aquatic reed growth present. No mosquito larvae were located, although the upper reaches of the drain is a probable *Cx. annulirostris* breeding site, with the lower reaches a probable *Ae. vigilax* breeding site. The grassed drain from the railway terminal (Site 40) was damp, and had silt deposition downstream of the road culvert, indicating the potential for ponding within the upstream reaches of the drain and possible *Ae. vigilax* and *Cx. annulirostris* breeding.

Site 41, located between Berrimah Rd and Section 5674, was a relatively flat, vehicle disturbed area that partially drained to a letterbox pit, with large areas of ponding but no mosquito breeding. This site is a potential *Ae. vigilax* and *Cx. annulirostris* breeding site.

Potential mosquito breeding sites were also located on the wharf. Ground depressions near the rock stockpile on the eastern edge of the wharf (Site 42), and a Casuarina tree lined swale drain (Site 43) are likely *Ae. vigilax* breeding sites. Potential *Ae. vigilax* breeding sites were also found near the wharf sediment pond (Sites 44 and 45). Receptacles ponding water such as used tyres were present in the holding yard near Site 43. The large water tank near Site 43 appeared to be receptive to mosquito breeding, as there were no screens on the outlet and the inspection lid did not appear to be completely sealing. Other water tanks on the wharf may also have been similarly receptive to mosquito breeding.

4.3 Previous larval surveys

Previous larval surveys have been conducted at East Arm, in particular in 2006 (Warchot and Whelan 2006), in 2009 (Warchot and Whelan 2009), and in 2010 (Warchot and Whelan 2010). Further information regarding these surveys can be found in associated reports.

In summary, the previous results at the East Arm wharf area were similar to current surveys, with ponding in ground depressions, drains and small sediment ponds being the major breeding sites, with occasional low level breeding in the large mud ponds, in particular Mud Ponds B and C.

Investigations of breeding sites outside of East Arm Peninsular have revealed potential *Ae. vigilax* breeding sites associated with upper tidal drainage lines and depressions associated with Bleesers Creek and Hudson Creek, and also the very large Hidden Valley paperbark swamp (Warchot and Whelan 2009).

4.4 Mosquitoes

It should be noted that some traps that were set did not record data due to failure. In Tables 2 and 3, this has been noted as the number “1” in both the No. of males and No. of female column boxes under the Species name ‘*Trap failure mosquitoes*’, with the corresponding row and column total left blank. Trap fails were a result of motor failure, which allowed trapped insects to fly out of the catch container.

4.4.1 Mosquito trapping 23rd and 24th October 2010

The results of the October trapping are shown in Tables 2 and 3. The most predominant mosquito was the northern salt marsh mosquito *Aedes vigilax*, with very high numbers collected at Sites 1, 2, 4 and 6 on the 23rd of October, and very high numbers collected at all sites on the 24th of October. *Culex sitiens* was the next most abundant mosquito, with low numbers collected at Sites 2, 4 and 6 on the 23rd of October, with moderate numbers at Site 6 on the 24th of October and low numbers at the other sites on the 24th of October.

Verrallina funerea was collected in low numbers at Site 1 and 6 on the 23rd of October, and low numbers at Site 6 on the 24th of October. *Culex annulirostris* was collected in low numbers at Site

6, and minor numbers at all other sites on the 24th of October. Minor *Cx. annulirostris* numbers were collected at Sites 1, 4 and 6 on the 23rd of October.

The most productive trap site for *Ae. vigilax* on the 23rd of October was Site 2, with 5,459 *Ae. vigilax* collected. Sites 1, 4 and 6 collected between 3000 and 4000 *Ae. vigilax*. The most productive trap site for *Ae. vigilax* on the 24th of October was Site 6 (4631), closely followed by Site 3 (4107). Site 1 recorded 3628 adult female *Ae. vigilax*, with the remaining sites collecting between around 1500 to 2900 adult female *Ae. vigilax*.

The presence of high numbers of adult *Ae. vigilax* in all traps was due to the breeding that occurred following heavy rainfall that occurred on the 10th of October, the night before the larval mosquito survey. This rain triggered breeding in depressions at East Arm, and would have also caused breeding adjacent to East Arm. The source of *Cx. sitiens* would have been extended rain or tide ponding in the same breeding sites as *Ae. vigilax*, possibly in stormwater drains or sediment ponds. The presence of low numbers of *Cx. annulirostris* indicated extended freshwater ponding, likely to be associated with stormwater drains with low flows, sediment ponds (Site 19 and 23) and potentially the waste water ponds at the cattle holding yard on Wishart Rd.

4.4.2 East Arm Port routine weekly mosquito trapping February 2009 to February 2010

A trap site at the old East Arm boat ramp was included in the Medical Entomology routine weekly adult mosquito monitoring program from February 2009 to February 2010. The results of this trapping for seven selected important mosquito species are shown in Figure 3, with the site location shown in Figure 1.

The northern salt marsh mosquito *Aedes vigilax* was recorded in seasonally very high numbers during the wet season months of December and January. These results indicate that wet season depressions are the most important breeding sites affecting East Arm, as opposed to natural areas where seasonal peaks are associated with monthly high tides as well as early wet season rain.

The common banded mosquito *Cx. annulirostris* was recorded in very high numbers in January, March and April, and high numbers in February. Most *Ae. vigilax* breeding sites would also have been *Cx. annulirostris* breeding sites, with breeding occurring once prolonged flooding of over 7 days occurs, which would have been after each monsoon event. The largest peak in April would have been due to maximum seasonal vegetation growth in depressions providing ideal breeding and harbourage areas for *Cx. annulirostris* larvae.

The receptacle mosquito *Aedes notoscriptus* was recorded in relatively high numbers during the wet season, particularly February to April. This species breeds in wet season flooded receptacles such as tree holes, and breeds in artificial receptacles such as used tyres, buckets, drums, plastic sheeting, machinery items and building material such as U pipes, metal beams and tin sheeting. The presence of high numbers indicated a large number of artificial receptacles nearby to the trap site. The yards close to the old boat ramp, and adjacent to the wharf guardhouse contained potential artificial receptacles.

4.5 Biting midges

It should be noted that some traps that were set did not record data due to failure. In Tables 4 and 5, this has been noted as the number “1” in both the No. of males and No. of female column boxes under the Species name ‘*Trap failure biting midges*’, with the corresponding row and column total left blank. Trap fails were a result of motor failure, which allowed trapped insects to fly out of the catch container.

4.5.1 Biting midge trapping 23rd and 24th October 2010

The results of the biting midge trapping in October 2010 are shown in Tables 4 and 5. The most abundant biting midge was the mangrove biting midge *Culicoides ornatus*, which accounted for the vast majority of all biting midges collected. Other biting midges were collected in very low numbers, and are of little importance as human pest therefore will not be discussed further.

The most productive trap site for *C. ornatus* on the 23rd of October was Site 2, which recorded 21,000 adult females. Sites 1 and 6 were the next most productive trap sites, recording 4800 and 5000 adult female *C. ornatus* respectively, while Site 4 recorded 630 adult female *C. ornatus*.

The most productive trap site on the 24th of October was Site 3, with 11000 adult female *C. ornatus* collected. Site 6 recorded similar numbers, with 10780 adult females collected, followed by Site 2 with 6860. Site 5 recorded 3800 *C. ornatus* and Site 1 recorded 2000 *C. ornatus*, with Site 4 the least productive with 336 *C. ornatus*.

4.5.2 Previous trapping

Previous trapping in 2006 revealed very high numbers of *C. ornatus* in the western half of East Arm (Warchot and Whelan 2006). Traps were not set in the eastern half of East Arm in 2006. The trap results in 2006 and 2010 provide a clear indication that all areas of East Arm peninsular will be subject to seasonally appreciable levels of *C. ornatus*.

4.5.3 Biting midge breeding sites affecting East Arm

The actual breeding sites for the major pest biting midge *C. ornatus* were not located during this investigation. However, actual breeding sites and their characteristics have been located during extensive surveying of tidal mangrove areas in other areas of Darwin (Shivas 1999). Three distinct breeding sites for *C. ornatus* were discovered by Shivas (1999); two were associated with the upper reaches of small mangrove tidal tributaries, while the third larval habitat was at the seaward mangrove foreshore (*Sonneratia*) zone (Shivas 1999). The main upper tidal tributary breeding sites are located in the neap tide zone starting where the canopy begins to close over the creek line, up to the point where the creek channel diminishes. The other tidal tributary breeding sites of lower productivity occurs at the back edge of the creek bank forest in the *Ceriops* zone. These breeding site characteristics are applicable to other tidal mangrove areas in the Northern Territory, and other similar tidal mangrove areas in other parts of Northern Australia, and can be deduced by examining high resolution aerial photography.

The major *C. ornatus* breeding sites affecting East Arm would be the upper tidal tributaries associated with Blessers Creek (Figure 1). Blessers Creek contains numerous upper tidal tributaries that would produce enormous numbers of adult *C. ornatus* to most of East Arm

Peninsular. The upper tidal tributaries of Hudson Creek, to the east of Darwin Business Park, would also be major *C. ornatus* breeding sites that would affect the eastern section of East Arm Peninsular. Breeding sites of lower productivity would occur in the wide foreshore mangrove zone of the Elizabeth River between the port and mouth of Hudson Creek, at the mouth of Blesers Creek and also in the section of Hudson Creek between the Muramats Rd industrial area and the Hudson Creek industrial park.

5.0 Discussion

5.1 Mosquitoes

5.1.1 Species present

The most important mosquito species collected of public health importance at East Arm were the northern salt marsh mosquito *Aedes vigilax* and the common banded mosquito *Culex annulirostris*. Other mosquito species of potential significance, either as disease vectors or pest mosquitoes, included the receptacle mosquito *Aedes notoscriptus*, the golden mosquito *Coquillettidia xanthogaster*, the brackish water mosquito *Verrallina funerea* and the salt water *Culex* mosquito *Culex sitiens*.

Aedes vigilax is an important mosquito due to its considerable pest potential and the potential to transmit disease causing arboviruses. *Culex annulirostris* can be an appreciable pest mosquito and is the vector of a number of mosquito borne diseases in the Northern Territory including Ross River virus and the potentially fatal Murray Valley encephalitis. Certain *Anopheles* mosquitoes can potentially transmit malaria, while *Ae. notoscriptus* and *Ve. funerea* are potential arbovirus vectors. *Culex sitiens* can be appreciable pest mosquitoes but is only of minor importance for potential arbovirus transmission.

5.1.1.1 *Aedes vigilax* (northern salt marsh mosquito)

Breeding sites

Typical breeding sites for *Ae. vigilax* include salt marshes, brackish water reed swamps, coastal interdune depressions, poorly draining upper tidal mangrove areas, tidally affected stormwater drains and disturbed upper tidal areas (Whelan 1997a). Eggs are laid in damp mud or near plant stems in suitable upper tidal areas. Actual and potential breeding sites for this species at East Arm are shown in Figures 2a-2c, and have been discussed in Section 4.1 of this report, with further discussions in other previously mentioned East Arm biting insect reports. In natural breeding sites, extensive breeding occurs after high tides of about 7.4m and higher in Darwin Harbour and rainfall events over 25mm in the upper tidal zone, from around 7.4m Australian Chart Datum (ACD) to just above the 8m ACD (maximum high tide) level. Breeding also occurs in coastal depressions at elevations above 4m Australian Height Datum (AHD), such as on reclaimed land. Actual breeding sites for *Ae. vigilax* at East Arm were extensive, and are discussed below.

Ground pools

The numerous ground pools caused by site clearing, reclaiming, the construction of road embankments and general site disturbance were all actual or likely breeding sites for *Ae. vigilax*. The majority were above tidal influence. The ground pools would generally be most productive during the early to mid wet season (October to January) when transient ponding occurs after rainfall over 20mm. During the latter wet season most pools would stay flooded for extended periods and prevent appreciable egg laying. The artificial ground pools are major breeding sites, especially those with grass or reed growth.

Natural upper tidal ground pool breeding sites for *Ae. vigilax* would be located in Section 5633, associated with the upper tidal flowline in the eastern portion of Section 5633 above the mangrove

margin (Site 33, Figure 2A). Grassy pools would be present that would breed *Ae. vigilax* after high tides and rainfall in the late dry to early wet season. Towards the mid wet season groundwater seepage and runoff would keep the upper tidal area flooded and prevent *Ae. vigilax* egg laying. Tidally influenced ground pools at East Arm would be *Ae. vigilax* breeding sites after tides greater than around 7.4m and rain over 20mm in the months of August to January. Tidally influenced ground pools appear to be minimal at East Arm.

Stormwater drains and drainage lines

Most drainage lines at East Arm are likely to be breeding sites for *Ae. vigilax*, with tidally affected stormwater drains leading into the mangroves, roadside swale drains and paperbark lined drainage paths present in the area. Stormwater drains leading into the mangroves are likely to be breeding sites after high tides of around 7.4m and over during August to December, as well as after rainfall of over 15mm in this period. Un-formalised drains subject to tidal influence tend to be productive breeding sites when silt, erosion and vegetation growth promotes tide or rain ponding within the drain. In particular Larval Site 35 was a likely major breeding site for *Ae. vigilax*, due to silt deposition at the mangrove margin preventing the free flow of water.

Roadside swale drains are also *Ae. vigilax* breeding sites at East Arm, mainly due to unsuitable grades to prevent ponding, and a lack of maintenance. The paperbark lined drainage paths are not appropriately graded, and hence pond large amounts of water and are likely *Ae. vigilax* breeding sites during the early wet season. The drainage lines are major breeding sites.

Mud ponds and sediment ponds

The large relatively bare Mud Pond B has been found to be a low productivity breeding site for *Ae. vigilax*, with Mud Pond D also a possible low level breeding site (Warchot and Whelan 2010). Productivity is generally expected to be low in Mud Ponds B and D due to reduced harbourage for mosquito larvae and the effect of wave action across the large ponds. However due to the large size of the ponds, low productivity breeding may still produce appreciable numbers of adult mosquitoes. Productivity will increase when vegetation such as salt bush, reeds and grasses increase in density, which is occurring at the northern end of Mud Pond B. Breeding would generally occur in the early to mid wet season when flooding rains occur.

Mud Pond A South West and Mud Pond A between Territory Resources and Berrimah Rd have high vegetation growth and would be productive *Ae. vigilax* breeding sites. Mud Pond A between Territory Resources and Berrimah Rd in particular is probably the largest and most productive *Ae. vigilax* breeding site at East Arm, while Mud Pond A South West will also be a major breeding site. Both of these sites are remnant areas of Mud Pond A, which has since been mostly developed, leaving these two productive mosquito breeding areas behind. Mud Pond C has generally been found to drain relatively quickly after rainfall ceases, although during extended monsoon rainfall periods low productivity breeding has been located when flooding occurs for long enough to allow completion of the aquatic life stages (Warchot and Whelan 2010). Breeding in the mud ponds and remnant mud ponds would generally occur in the early to mid wet season (October to January) when flooding rains occur.

The small sediment ponds adjacent to the manganese and iron stockpiles could be low productivity *Ae. vigilax* breeding sites in the early wet season. The Sediment Pond in Section 6117 was a high productivity *Ae. vigilax* breeding site in October 2010 after early wet season rainfall.

This sediment pond would be a high productivity *Ae. vigilax* breeding site in the months of October to December. Similarly the sediment pond in Section 5421 is also likely to be a productive *Ae. vigilax* breeding site during October to December.

Breeding Sites adjacent to East Arm

Due to the flight range of this mosquito, there is likely to be dispersal from breeding sites outside of East Arm Peninsular. These actual or potential breeding sites were identified in a recent study (Warchot and Whelan 2009). Potential breeding sites included drainage lines leading into the landward mangrove margin of Bleasers and Hudson Creek, as well as the Hidden Valley Paperbark Swamp.

Seasonal abundance

In the Top End of the Northern Territory, *Ae. vigilax* is most abundant from September to January (Whelan 1997a). The magnitude of high tides in Darwin Harbour increases during the late dry season, which results in progressively greater flooding of upper tidal areas that had dried since the end of the previous wet season. High tides greater than 7.4m in these months generally cause appreciable flooding and breeding in coastal areas around Darwin. Early wet season rainfall also floods previously dry depressions, which can result in extensive breeding and high adult mosquito abundance. During the mid to late wet season, tidal breeding sites become seasonally flooded and remain flooded for the duration of the wet season which minimises egg laying. Thus, numbers of *Ae. vigilax* during the mid to late wet season are generally very low. Minor population peaks can occur during the early to mid dry seasons in some years, when monthly high tides of over 7.4m flood upper tidal areas that had dried or partially dried after the wet season, but before there has been a population build up and the subsequent store of eggs in the habitats. Heavy rainfall in May in some years can also lead to appreciable breeding.

The baseline trapping from February 2009 to February 2010 revealed highest numbers in December and January. This is consistent with the majority of breeding sites at East Arm being rain breeding sites only, located on cleared or reclaimed land. However the 2009 late dry season had lower than average monthly high tides, therefore higher abundance from September to November can be expected in years with the average or higher than average monthly high tides.

The October 2010 trapping revealed very high numbers, due to the above average October rainfall. The above average September 2010 rainfall would also have promoted appreciable breeding. In most years, peak numbers at East Arm can be expected from November to January, with high numbers in September and October in years with heavy late dry season rainfall, and in February in years when there is a late start to heavy rainfall. High tides are not expected to produce the very high widespread numbers associated with rainfall events, although *Ae. vigilax* is still likely to be present in appreciable levels at East Arm starting 9 days after high tides from August to December, from breeding in tidal drains and localised upper tidal depressions.

Spatial abundance

Aedes vigilax has a very long flight range, capable of flying up to 200km, although highest numbers are usually encountered within 5km of breeding sites (Whelan 1997a). Baseline trapping at Murrumujuk on the Gunn Point Peninsular indicated there was very little reduction in *Ae. vigilax* numbers up to 3km from breeding sites through unaltered forest (Whelan 1991). An investigation

in 1982 indicated that *Ae. vigilax* was dispersing at least 9.5km from Howard Swamp to Palmerston (Liehne 1985).

The October 2010 trapping over two nights revealed very high numbers in all areas of East Arm. The appreciable breeding sites closer to the Port are likely to have provided the majority of *Ae. vigilax* to most of East Arm, with the breeding sites nearby to East Arm adding to the numbers in the area. Trap catches varied at some sites from one day to the next in October, generally with such high abundance *Ae. vigilax* trap catches are probably more related to the location of the traps (ie nearby to suitable harbourage areas), rather than proximity of breeding sites. The October results indicate all areas of East Arm peninsular would be subject to seasonally very high *Ae. vigilax* levels.

Localised pest problems would also occur adjacent to breeding sites during minor early wet season rainfall, when only small hatches of *Ae. vigilax* occur. As mentioned above, suitable harbourage areas such as heavily shaded sites can expect the greatest numbers.

Pest numbers

Aedes vigilax will be the most important pest mosquito affecting East Arm. *Aedes vigilax* is an aggressive biter and will bite during the daytime in shaded areas as well as at night, and is usually the cause of most of the mosquito pest problems in urban Darwin and Palmerston. Pest levels for *Ae. vigilax* are generally indicated at around 50 per trap in a trap set in the buffer between the breeding sites and residential area, and 20 per trap for traps set within residential areas.

The trap results in October 2010, and the baseline results from February 2009 to February 2010 revealed very high numbers, from 2,500 up to 5,500 per night in some traps. This represents a potentially very high pest problem to exposed workers at East Arm. In most years, widespread very high pest problems would occur in December and January, with very high pest problems also likely in October and November during years of heavy early wet season rain, as occurred in 2010. Periodic pest problems may also occur from September to December due to monthly high tides.

5.1.1.2 *Culex annulirostris* (common banded mosquito)

Breeding sites

Potential breeding sites for this mosquito were examined during the October and December 2010 field survey. October is not usually a peak month for *Cx. annulirostris* breeding and the timing of the October survey was too soon after rainfall to find *Cx. annulirostris* breeding, nevertheless areas of ponding water were examined for the habitat indicators that point towards *Cx. annulirostris* breeding. Many sites examined in October and December were potential *Cx. annulirostris* breeding sites. Potential areas of *Cx. annulirostris* breeding included all shallow ponding areas with grass and/or semi-aquatic reeds, drains with semi-aquatic vegetation, and Mud Ponds and sediment ponds with semi-aquatic vegetation. Potential breeding sites are indicated in Figures 2a – 2c. The 2009-2010 baseline trapping results revealed *Cx. annulirostris* breeding sites were moderate to highly productive throughout the wet season.

Grassy depressions

The shallow grassy depressions throughout the cleared/reclaimed areas nearby to the port are likely to be seasonally productive *Cx. annulirostris* breeding sites. Breeding would occur after prolonged flooding caused by the first monsoon spell, and at the end of the wet season when greatest semi-aquatic vegetation growth is present. Initial breeding densities would be high until aquatic predators colonise the depressions and provide bio-control, although heavily vegetated depressions would maintain appreciable levels of breeding, due to the vegetation restricting predator access to larvae.

Some breeding is also likely to occur in seepage areas and natural ground pools, such as at Larval Site 33 and in the paperbark flooded area downstream of the Site 34 stormwater drain. These sites are usually low productivity breeding areas in other areas of Darwin, unless high nutrient ponding occurs.

Stormwater drains

Stormwater drains with vegetation, such as the Site 34, 35 and 36 drains would be *Cx. annulirostris* breeding sites during the early wet season when isolated ponding occurs, and in the late wet season when prolonged ponding occurs. Any drains with dry season low flows would be particularly productive, due to high nutrient levels. *Culex annulirostris* was also found breeding in the Site 8 roadside drain, and has been found in the Wharf Guardhouse drain, indicating roadside drains with ponding and vegetation would also be wet season *Cx. annulirostris* breeding sites.

New development also has the potential to create new breeding sites for this species, particularly if wetlands with semi-aquatic reeds are utilised for stormwater treatment. New breeding sites could also be created if dry season stormwater drain low flows are not appropriately discharged to a daily flushed tidal area or a suitable water retention structure with an appropriate management plan.

Sediment ponds

Mud Pond A between Territory Resources and Berrimah Rd is heavily vegetated with grass and semi-aquatic reeds. This site is probably the largest *Cx. annulirostris* breeding site at East Arm, and would be a breeding site throughout the wet season, with greatest breeding likely to occur after initial flooding, and during the late wet season when vegetation growth is greatest. Mud Pond A south-west is also a *Cx. annulirostris* breeding site due to the presence of grass and semi-aquatic reeds. Mud Ponds B and D were generally devoid of appreciable semi-aquatic vegetation and grass, while Mud Pond C drains fairly quickly once rainfall ceases, therefore these ponds are unlikely to be appreciable *Cx. annulirostris* breeding sites.

The small sediment ponds in Sections 6117 and 5421 are also likely to be wet season *Cx. annulirostris* breeding sites, due to the presence of semi-aquatic reeds. The sediment ponds adjacent to the manganese stockpile had minimal semi-aquatic vegetation, therefore are not likely to be appreciable breeding sites for this mosquito unless vegetation growth increases.

Breeding sites adjacent to East Arm

Adjacent breeding sites that could affect East Arm include nearby stormwater drains, and potentially the wastewater ponds at the cattle storage yard and the Hudson Creek sewage ponds (Figure 2b). The Hidden Valley paperbark swamp is a probable breeding site for *Cx. annulirostris*, and may be a source of some *Cx. annulirostris* to the East Arm peninsular.

Seasonal abundance

Culex annulirostris is most abundant from January to August in the Top End of the Northern Territory (Whelan 1997), in which there is usually two peaks in abundance, a short early/mid wet season peak and an extended late wet-mid dry season peak, depending on the characteristics of nearby breeding sites.

The 2009-2010 baseline trapping results at the old East Arm boat ramp revealed a distinct wet season abundance, with the largest peak in the late wet season month of April but high abundance throughout the January to April period. This trend is likely to continue at East Arm as long as the breeding sites remain.

Spatial abundance

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

The October 2010 trapping was not conducted at a peak period for *Cx. annulirostris* abundance. Baseline trapping in 2009-10 revealed very high abundance, indicating most of the East Arm peninsular would be affected by this mosquito. Highest numbers can be expected closer to the major breeding sites, which occur in the western side of the East Arm peninsular.

Pest numbers

Culex annulirostris only bites after sundown at night, and is less aggressive than *Ae. vigilax*. Generally a higher CO2 trap count is required to indicate potential pest problems. In the Darwin Northern Suburbs, a trap catch of 600 per trap in a trap set between residential areas and breeding sites generally indicates a potential pest problem for the residential area (Whelan 1997a). This pest threshold was exceeded during the months of January to April, and it is these months in every year that appreciable pest problems can be expected. The April 2009 results (Figure 3) indicate a potentially very high pest problem, with the other wet season months recording numbers likely to cause high pest problems to exposed workers after sundown.

5.1.1.3 *Aedes notoscriptus* (receptacle breeding mosquito)

This mosquito breeds in natural tree holes in undeveloped areas, and in almost any artificial receptacle in urbanised areas. Levels in natural areas are usually low, with urban areas providing the greatest abundance of breeding sites. This mosquito has a limited flight range and does not fly far from their breeding sites. The indicative pest level for this mosquito is 30 per CO2 trap per

night, with levels recorded at the old East Arm boat ramp greatly exceeding this level, with nightly catches up to 300 recorded (Figure 3). As a receptacle breeding mosquito, this mosquito generally has a wet season abundance and will be present in areas of East Arm adjacent to artificial receptacles during the wet season, such as in the yards near the old boat ramp and opposite the guardhouse. Pest problems, when they occur, would be mainly in the evening.

5.1.1.4 Other mosquito species

Anopheles mosquitoes, which include some species that are potential malaria vectors, were recorded in minor numbers during baseline trapping at the old East Arm boat ramp. Large reed swamps and billabongs are generally the favoured natural habitat for *Anopheles* mosquitoes. Potential breeding sites at East Arm include the semi-aquatic reed vegetated small sediment ponds, the Site 9 *Eleocharis* and paperbark area near Berrimah Rd, Mud Pond A between Territory Resources and Berrimah Rd and Mud Pond A south west.

Mosquito species such as *Ve. funerea* and *Cx. sitiens* generally do not fly far from their breeding sites, but can be appreciable pest mosquitoes near to their respective brackish and saline water breeding sites. *Verrallina funerea* would mainly be found breeding in brackish water paperbark depressions, tidally affected stormwater drains and any upper tidal mangrove depressions around East Arm. *Culex sitiens* is a saline water breeding mosquito, and may breed in Mud ponds B and D, sediment ponds adjacent to tidal areas (particularly Site 23), upper tidal depressions, and tidally affected drains at East Arm.

5.1.2 Mosquito borne disease

5.1.2.1 Ross River virus disease

Ross River virus (RRV) is responsible for the most common arboviral disease in Australia (Russell and Kay 2004), and is the most common mosquito borne disease transmitted by mosquitoes in the Northern Territory (Whelan et al 2008). Symptoms can be debilitating and include joint pain, fever, lethargy, rash, headache and swollen glands, and can last for up to 12 months in some cases, although generally most people will have a severe illness from two weeks to three months (CDC Factsheet April 2003).

The principal potential RRV vectors *Ae. vigilax*, *Cx. annulirostris* and *Ae. notoscriptus* were recorded in appreciable numbers at East Arm. The main risk months for RRV transmission are December to June, with a January to February peak, although transmission can occur in all months (Whelan 1997b). The humid months of December to March will increase the life span of vector mosquitoes, increasing the chance of vector mosquitoes living long enough to obtain a virus from a vertebrate host (presumed to be wallabies in the Top End of the Northern Territory) and pass it on to a human.

Based on the likely abundance of the vector mosquitoes at East Arm, *Ae. vigilax* will pose a very high risk of RRV transmission in December and January. This species may also pose an appreciable risk in other months such as October and November depending on seasonal rainfall, or high tides. *Culex annulirostris* will pose a moderate to very high risk during the wet season months of January to April. *Aedes notoscriptus* will pose a relatively high localised risk during the

wet season months, with work areas nearby to accumulations of exposed building and rubbish items at most risk.

5.1.2.2 Barmah Forest virus

Barmah Forest virus (BFV) causes similar symptoms to RRV, but symptoms are generally milder and BFV is not as common as RRV (CDC Factsheet May 2006). The principal potential vectors of BFV recorded at the proposed development site were *Ae. vigilax*, *Cx. annulirostris* and *Ae. notoscriptus*. Main risk months for BFV transmission are the months of October to July, with a peak in January to March, although transmission can occur during all months (Whelan 1997b). The risk for BFV transmission will be similar to the RRV transmission risk at East Arm.

5.1.2.3 Murray Valley encephalitis virus

Murray Valley encephalitis virus (MVEV) can cause a potentially fatal inflammation of the brain tissue (CDC Factsheet April 2004). Symptoms include high fever, severe headache, seizures or fits (especially in young children), neck stiffness, drowsiness, confusion and progression to delirium and coma in severe cases (CDC Factsheet April 2004). The principal potential vector of MVEV recorded at East Arm was *Cx. annulirostris*. Main risk months for MVEV transmission are January to July with a peak in March to May (Whelan 1997b). Based on the likely abundance of *Cx. annulirostris* at East Arm, the risk of MVEV transmission for an unprotected person is likely to be moderate to very high during January to March. Only 1 in around 1000 people bitten by an infected mosquito is likely to develop disease symptoms, therefore the risk of contracting this disease is much lower compared to RRV and BFV.

5.1.2.4 Kunjin virus

Kunjin virus (KUNV) can potentially cause a fatal inflammation of the brain, but this is much rarer than with MVE disease (Russell and Kay 2004). KUNV typically causes a milder syndrome of severe headaches and fever and has not been responsible for fatalities in the Northern Territory (Russell and Kay 2004). The KUNV risk at East Arm would be similar to the MVEV risk.

5.1.2.5 Malaria

Endemic malaria is no longer present in the Northern Territory, but there is always a risk of limited local transmission from people returning from overseas countries with malaria.

There are three sibling species of *Anopheles farauti* s.l. in the Northern Territory, which are morphologically identical. The brackish water species *An. farauti* s.s. is a known vector of malaria in Vanuatu, Solomon Islands and PNG (Russell and Kay 2004), and is regarded as a potential vector of malaria in tropical Australia. It is the principal potential vector in the Top End of the Northern Territory (Whelan 1983). However, Russell (1987) showed that one of the *An. annulipes* species in south-east Australia was relatively long lived, and *An. annulipes* s.l. in the Northern Territory must be considered a potential vector of malaria where sufficient numbers occur. *Anopheles annulipes* was the probable vector of malaria epidemics in some areas of the Northern Territory prior to 1962, when the last malaria case was recorded (Whelan 1995). *Anopheles hilli*, *An. bancroftii* and *An. amictus* must also be regarded as potential vectors, although *An. bancroftii* may not pose an appreciable risk as it is not as long lived as the other species (Russell 1987). Malaria was isolated from *An. farauti* s.l. and *An. hilli* during the 1942 epidemic in Cairns (Russell

et al 2007), and both can be seasonally present in relatively high numbers in the Darwin area, so these species probably pose the greatest risk in the Darwin area.

Anopheles species mosquitoes at East Arm were generally recorded in low numbers, although there is potential breeding habitat that could provide appreciable localised breeding sites for this mosquito. *Anopheles bancroftii* did reach levels likely to pose a low potential malaria risk during late wet season in 2010 (Figure 3), while *Anopheles hilli* reached levels just above the risk threshold in the wet season. If more than 10 individuals of *An. farauti* s.l. or one of the other *Anopheles* 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 *Anopheles* mosquitoes have bitten the malarious person, a high degree of personal exposure occurs, and there is a lack of effective vector control operations by health authorities. All of these factors are rarely present together in Darwin, and the likely low *Anopheles* mosquito abundance in most areas of East Arm indicates malaria transmission is potentially very unlikely.

In the Northern Territory, similar to the rest of Australia, malaria is a notifiable disease. Each imported case in the Northern Territory is assessed and treated by a health professional, and monitored by Medical Entomology for the potential to cause local malaria transmission. Any risk of local malaria transmission results in Medical Entomology conducting fogging operations at the edges of adjacent swamps and mosquito harbourage areas to minimise the risk of local malaria transmission. It is highly unlikely that local malaria transmission will occur in the proposed development area, as long as prevention measures remain in place and new *Anopheles* breeding sites are not created by development.

5.1.3 Mosquito breeding and development aspects

5.1.3.1 Stormwater drainage

The final discharge sites for stormwater will be critical to prevent the creation of new mosquito breeding sites. Discharge of dry season flows into creeklines or low lying areas will lead to increased mosquito breeding. This type of discharge has created many of the historic mosquito breeding problems affecting Darwin, which was recognised by the Department of Health and Families and various local authorities and subsequently rectified (Task Force Review 1989). Stormwater drainage in East Arm should be discharged to a daily flushed tidal area (ie 3m AHD) via suitable drains with low flow provisions such as a concrete invert. Guidance on stormwater design to prevent mosquito breeding can be found in the Medical Entomology guideline 'Guidelines for preventing biting insect problems for urban residential developments or subdivisions in the Top End of the Northern Territory'.

The installation of stormwater pits with sumps for sediment and rubbish collection has the potential to create cryptic mosquito breeding sites for pest mosquitoes, and act as potential breeding sites for exotic dengue mosquitoes should an incursion or introduction occur. Typically sumps are associated with Gross Pollutant Traps (GPT's), Side Entry Pits (SEP's), Grated Inlet Pits (GIP's) and Letterbox Pits. Due to the mosquito breeding potential of stormwater sumps, and the fact they are unlikely to be managed sufficiently to prevent mosquito breeding, all sumps that retain water should be avoided. This is particularly important for East Arm, where there is a risk of exotic dengue mosquito importation from the adjacent wharf.

Culverts for roads and associated drainage should always be installed flush with the upstream invert of the creekline/flowline, to prevent the upstream impoundment of water and the subsequent mosquito breeding. If some culverts are installed higher than the upstream surface level to allow for future reclaiming, then there should be appropriately sized drainage provisions provided to prevent upstream water ponding until the area is reclaimed. Culverts should be installed with a slight 'V' invert to match the invert of any upstream and downstream drains, to prevent water ponding and minimise silt deposition in the culvert. Upstream and downstream open drains should also have V inverts.

Roadside drains and swales should have concrete low flow inverts, especially for those drains that have minimal fall and are likely to have seepage or dry season low flows. All roadside drains and swales should discharge to a suitable stormwater drainage system or directly to the sea. Major open drains should have concrete low flow inverts to the mangrove margin, and a free draining channel below the mangrove margin. All drains should be placed on an annual inspection and maintenance program.

5.1.3.2 Water Sensitive Urban Design

Preventing the creation of mosquito breeding should be an integral aspect of any Water Sensitive Urban Design (WSUD) strategy in order to minimise the creation of health risks from pest and disease carrying mosquitoes. Guidance on constructed wetlands can be found in the Medical Entomology Guideline 'Constructed Wetlands in the Northern Territory – Guidelines to prevent mosquito breeding'.

The proposed use of WSUD at East Arm will pose some potential mosquito breeding issues. The presence of very high mosquito breeding in the Site 33 sediment pond, as well as shallow flooded sites like Mud Pond A between Territory Resources and Berrimah Rd, indicates and creation of prolonged shallow ponding combined with semi-aquatic vegetation is likely to create appreciable mosquito breeding. Any other WSUD structure that would pond shallow water for periods greater than 3 days would also become mosquito breeding sites. Therefore any constructed wetlands should avoid having shallow vegetated components that will pond water for greater than three days. Wetlands with steep sites (45°) and deep water ($>1\text{m}$) are the preferred design for preventing mosquito breeding issues, while drains leading into and out of wetlands should convey water without ponding. Further information can be found in the above mentioned guideline.

Bioretention basins and swales should also be designed to be free draining structures, taking into account the need to convey low flows without creating surface ponding. Low flows, either the continual wet season seepage that occurs from stormwater pipe systems, or dry season low flows, has the potential to promote algae and weed growth on the bioretention basin or bioretention swale surface, and subsequently lead to ponding. Diverting low flows under the surface of the bioretention basin or bioretention swale could mitigate this potential problem.

All WSUD designs should be submitted to Medical Entomology for comment and approval before construction commences. A management plan will also be required for any WSUD structure, which outlines the responsibility of managing authorities to ensure mosquito breeding is prevented. The final management authority for any WSUD should have an appropriately funded maintenance program in place before construction commences.

5.1.3.5 Construction in and adjacent to tidal areas

Construction in tidal areas or on sites with some saline soil generally has the most potential to create productive mosquito breeding sites. Mosquitoes such as *Ae. vigilax* and *Cx. sitiens* will breed in very high numbers in disturbed upper tidal areas such as those created through site disturbance or the embankment of tide water. Inappropriate site clearing and grading adjacent to tidal areas will create *Ae. vigilax* and *Cx. annulirostris* problems. All construction activities in tidal areas should therefore be carefully considered in the planning stage, and any previous or resultant disturbed areas appropriately rehabilitated upon completion of development. Further information can be found in the Medical Entomology guideline 'Construction practice near tidal areas in the Northern Territory - Guidelines to prevent mosquito breeding'. Many examples of mosquito breeding created by construction activities in and adjacent to tidal areas are evident near East Arm Port. In particular aspects to consider during the construction phase include;

1) New mud ponds should include provisions for altering water levels or providing complete drainage. This would be important for those mud ponds likely to be subject to shallow water ponding. If complete drainage is desired, new mud ponds could be progressively filled starting from the furthest side from the outlet, to allow surface water flows to drain towards the outlet and prevent the creation of isolated areas of ponding. Mud Pond C is an example of a pond that drains relatively quickly after rainfall ceases, although during extended periods of heavy rainfall the pond does not drain quick enough to prevent *Ae. vigilax* breeding (Warchot and Whelan 2010), therefore it remains a seasonal breeding site during monsoon periods and may require a larger outlet culvert.

Preventing mosquito breeding by maintaining mud ponds with deep water (>1m) and no semi-aquatic or margin vegetation is another management option. Deep ponds with bare margins are unlikely to experience appreciable mosquito breeding issues, due to natural control by aquatic predators and wave action. Culverts could be fitted with a suitable device to allow the adjustment of water levels, to assist in water level management to minimise mosquito breeding.

2) Sediment ponds should have provisions to allow complete drainage within 3 days if possible. Alternatively sediment ponds should be steep sided (1V:2H or steeper) and contain deep water (>1m). This would minimise the potential for semi-aquatic vegetation growth and reduce the potential for mosquito breeding. Sediment ponds that pond water could be periodic salt marsh mosquito breeding sites during initial flooding, and therefore would require some management to control breeding. Sediment ponds should be removed once development is complete and sediment runoff would be minimal. All sediment ponds should be maintained free of vegetation.

Sediment fences can impound shallow water when the fence becomes clogged with silt. Therefore regular removal of sediment behind the fences would be required during the construction phase.

3) Site disturbance such as wheel ruts and compacted ground should be rectified upon completion of construction, to prevent these areas from becoming perennial mosquito breeding sites.

4) Borrow pits and earth scrapes or hill levelling areas should be rehabilitated to be completely free draining. This would be required to prevent the creation of another area such as Sections

5421 and 6117, which has extensive shallow ponding as a result of over-excavation, and no subsequent site grading and drainage provisions provided.

5) Reclaimed land should have a suitable surface slope to prevent ponding on the filled surface. Regular wet season monitoring of the site should be conducted, to identify and rectify ponding issues caused by subsidence until the site is developed. Shallow depressions should be rectified as soon as possible, before grass and reeds colonise the depressions and causes greater mosquito breeding productivity.

5.1.4 Mosquito breeding rectification

The existing mosquito breeding sites at East Arm are predominantly artificially created and should all be rectified as part of the port expansion. Rectification of the mosquito breeding sites would result in the East Arm Peninsular having much reduced mosquito problems, thereby reducing the potential for mosquito borne disease transmission.

5.1.4.1 Ground pools

The Larval Site 6 Paperbark Swamp should be rectified by cutting a drain from the lowest point in the swamp to the shoreline, and partially filling under the paperbarks (if required) to remove all ponding. Alternatively the swamp could be filled and appropriately sloped to prevent ponding. The Larval Site 9 Paperbark depression should be rectified by draining the depression to the adjacent roadside drain, or by filling and grading towards the roadside drain.

All other ground depressions highlighted in this report, particularly in Sections 5163, 5420, 5421, 6117 and 5720 should be filled and levelled, with surface runoff directed to the nearest outlet drain. It appears that water will collect at the south-east edge of Section 6117 and north-east edge of Section 5421, therefore along with the filling and levelling of depressions in this area, appropriate collector drains to the nearest outlet drain may be required to assist with drainage of the area.

Ground depressions on the wharf should also be rectified by filling and grading, particularly as these vector breeding sites may pose quarantine issues. Other ground depressions that exist in East Arm that have not been indicated in this report should also be rectified by filling and levelling/grading.

5.1.4.2 Mud Ponds and Sediment Ponds

Mud Pond A between Territory Resources and Berrimah Rd is probably the greatest mosquito breeding site at East Arm. The area should be appropriately filled and graded to drain to a suitable end point, which appears to be the Berrimah Rd table drain. This would be a relatively large job, if permanent rectification is unlikely to occur in the 2011 dry season, in the short term there should be appropriate drains provided and minor filling and grading conducted, to enable as much water as possible to drain to the Berrimah Rd table drain.

Mud Pond A south west is also a large mosquito breeding site. The area partially drains to Mud Pond C via a pipe culvert under the access road. The site should be permanently rectified by filling and grading as soon as possible. If permanent rectification is unlikely to be conducted in the 2011 dry season, short term rectification should be achieved by lowering the current culvert to the lowest point in the depression, and grading the upstream area to drain towards the culvert. Partial filling and grading towards the current pipe culvert could be another short term option to reduce ponding.

Mud Ponds B, C and D. If these ponds are no longer to be used for dredge disposal, they should be filled and suitably graded as soon as possible. In the short term, mosquito breeding in Ponds B and D could be controlled by maintaining the ponds flooded as much as practical during the dry season, to minimise *Ae. vigilax* egg laying and to maintain mosquito predator populations. Semi-aquatic vegetation growth in the northern edge of Mud Pond B should be removed, to remove potential harbourage areas for mosquito larvae. The plunge pool in Mud Pond D, caused by overflows from Mud Pond B, should be rectified by filling and providing appropriate scour protection. In the short term, Mud Pond C may need a larger culvert to achieve faster drainage during periods of persistent heavy rainfall.

Operational sediment ponds such as the OM Manganese Pond (south), Pond 4, DPC stormwater pond and the Territory Iron Pond should be maintained annually to remove vegetation growth and sediment. Wet season ponding should be maintained at a deep level (1m), to allow wave action and minimise semi-aquatic vegetation growth. The sediment ponds on vacant land (Sites 19 and 23) should either be redesigned to contain deep water (1m) and be completely cleared of semi-aquatic vegetation, or be cleared of vegetation and redesigned to completely drain within 3 days.

5.1.4.3 Stormwater drains

The roadside drains nearby to the port and adjacent to the port guardhouse all pond water due to either minimal fall, or limited annual maintenance. All roadside drains with minimal fall should be upgraded with a suitable concrete low flow invert to a suitable end point such as an existing stormwater drain or the sea. This includes the roadside drains opposite the port guardhouse and mud ponds, the fuel terminal, Section 5421 and Section 5720. Site 41 should be rectified by partial filling and regrading towards the adjacent letterbox pit.

The stormwater drain adjacent to the railway terminal ponds water and has *Typha* growth, indicating prolonged ponding occurs within the drain. The drain should be upgraded with a concrete low flow invert from the pipe outfall to the mangrove margin below the last railway culvert.

The drains from Hamaura Rd fall within Development Area 4 (NOI June 2009), therefore should be upgraded to stormwater pipe drains or open drains with concrete low flow inverts. In the meantime two of the drains (Sites 34 and 35) should be desilted to allow the free drainage of water. The open drains from the railway fall within Development Area 1, therefore should be upgraded to stormwater pipe drains or open drains with concrete low flow inverts as part of the development.

The large open drain in Section 5421 should be extended to the coast, similar to the drain in Section 6117, to allow adjacent areas to be graded to drain into this drain. The drainage line between the fuel terminal and railway culvert, as highlighted in the report by Warchot and Whelan (2010), should be desilted on an annual basis to prevent wet season ponding.

The paperbark drainage lines in Sections 6117 and 5633 (Larval Sites 24 and 26) should be regraded to remove the large amount of ponding that currently occurs in both drainage lines.

5.1.4.4 Mosquito breeding sites outside of East Arm

The rectification of breeding sites outside of East Arm that are likely to affect East Arm to some extent are discussed in the Medical Entomology report 'Biting Insect Assessment Berrimah Farm and Prison 2009'. Please refer to this report for further details.

5.1.5 Mosquito monitoring and control

The relevant landholders should be responsible for identifying wet season ponding areas for rectification, and maintaining stormwater drains and sediment ponds to prevent mosquito breeding. Rectification of mosquito breeding sites would prevent the need for larval or adult mosquito control.

If temporary mosquito control is required, the use of methoprene 30 day residual pellets would be the insecticide of choice for most mosquito breeding sites at East Arm. Methoprene 150 day briquettes could also be used, especially in those sites where major extended mosquito breeding occurs, such as Mud Pond A between Territory Resources and Berrimah Rd and Mud Pond A south west, along with the Larval Site 6 and Larval Site 9 Paperbark Swamps, or staked in stormwater drains. The landholder would be required to organise and fund any mosquito control programs on their land.

Landholders should also be responsible for maintaining their respective lots free of receptacle mosquito breeding, by removing unwanted containers, building items and other material that can pond water, or storing them under cover away from rain. Rainwater tanks and other storage tanks should be appropriately screened to prevent mosquito access. This would reduce the risk of dengue mosquito breeding, should an incursion occur from the wharf.

5.1.6 Limitations

Not all areas of East Arm were inspected for potential mosquito breeding issues. Private or fenced lots were not inspected. Some undeveloped lots contain localised depressions that could be mosquito breeding sites. The railway easement was not inspected. Localised depressions and ponding in drainage channels may be present along the railway easement. In this instance it would be up to the landholder to rectify any mosquito breeding sites. Not all wet season depressions have been located by the two larval surveys in 2010, and new sites on vacant land are likely to be constantly created through new disturbance. However the overall aim of new development should be to remove all existing areas of shallow ponding, as they all represent potential mosquito breeding sites.

5.2 Biting midges

5.2.1 Species present

The mangrove biting midge *Culicoides ornatus* accounted for the majority of biting midges collected during trapping at East Arm. All other biting midge species were recorded in low numbers only, or were not of any appreciable human pest significance, and therefore will not be discussed further.

Culicoides ornatus is considered the most significant human pest biting midge species around coastal areas of the Northern Territory (Shivas 1999, Shivas and Whelan 2001), and is also the most common biting midge pest around coastal areas of the Northern Territory (Whelan 2003).

5.2.2 *Culicoides ornatus* breeding sites

Potential breeding sites for *C. ornatus* in the Top End of the Northern Territory are detailed in Appendix 1 'Biting midges or 'sandflies' in the Northern Territory'. The prime breeding sites for *C. ornatus* are the upper tidal tributaries of mangrove creeks around the mean high water neap tide mark, associated with pneumatophores of the mangrove species *Avicennia marina* (Shivas 1999). The highest productivity of *C. ornatus* from upper tidal mangrove tributary breeding sites occurs during the mid to late dry season (Shivas 1999).

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 (Shivas 1999). These breeding sites are usually associated with mud substrates and not sandy substrates (Shivas 1999).

Wet season breeding sites are also found in the *Ceriops* zone at the back of the creek bank forest, where moderate productivity occurs, and the *Rhizophora* zone upstream of the *Sonneratia* foreshore mangrove areas (Shivas 1999, Shivas and Whelan 2001).

East Arm is surrounded by appreciable *C. ornatus* breeding habitat. The extensive network of upper tidal tributaries associated with Bleesers Creek would be the major breeding sites affecting most of East Arm, while numerous upper tidal tributaries associated with Hudson Creek would affect the eastern portion of East Arm. Highest *C. ornatus* numbers collected at Trap Site 2 was indicative of Bleesers Creek containing extensive *C. ornatus* habitat. Foreshore mangrove zones associated with the Elizabeth River, Bleesers Creek and Hudson Creek would also be important breeding sites affecting East Arm, but to a much lesser extent than the upper tidal tributary breeding sites. Potential breeding habitats are indicated in Figure 1.

5.2.3 Spatial abundance and dispersal

Detailed information on the flight activity of *C. ornatus* can be found in Appendix 1. *Culicoides ornatus* actively disperses inland from its mangrove breeding sites (Shivas 1999, Shivas and Whelan 2001), which along with their human biting habits, 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 facing their mangrove breeding areas within 1.5km of the mangrove margin (Shivas and Whelan 2001). A baseline study in Weddell during 1984-85 found *C. ornatus* numbers to be greatest at the 1km mark from the mangrove margin, when trapping was conducted at 400m or 500m intervals from the mangrove margin to 2400m from the mangrove margin (Whelan et al 1988). Other studies have also located highest *C. ornatus* numbers around 1km from the nearest mangrove margin (Liehne 1985, Warchot and Whelan 2008a and 2008b, Warchot and Whelan 2009).

Wet season dispersal and mid dry season dispersal is less than early and late dry season dispersal, with reduced mid dry season dispersal associated with lower temperature, while the reasons for low inland dispersal in the wet season are unknown (Shivas and Whelan 2001), but may be associated with blood meal host availability, dense vegetation growth, lower populations or rain and humidity effects. However, areas within about 500m of the mangrove margin of productive breeding areas can expect substantial levels of midges for most of the year (Shivas and Whelan 2001). Distance trapping by Shivas and Whelan (2001) has indicated appreciable mid dry season dispersal up to 750m-1200m from the mangrove margin.

Much of East Arm is located within 1.5km of the mangrove margin of Bleesers Creek, indicating most of East Arm would be subject to very high numbers arising from Bleesers Creek. The eastern side of East Arm would also be affected by very high numbers originating from the upper tidal tributaries of Hudson Creek. Moderate to high numbers originating from the foreshore mangrove area associated with the Elizabeth River, mouth of Bleesers Creek and mouth of Hudson Creek would also affect most of East Arm. The greatest *C. ornatus* abundance will be encountered in areas of East Arm within 1km of the mangrove margins of Bleesers Creek and Hudson Creek.

Trap Site 4 results were interesting, with only low to moderate levels collected on the 23rd and 24th of October 2010, compared to very high numbers elsewhere. The low numbers at this trap site may be attributed to the buffering effect of industrial land surrounding the trap location, and indicates the inner areas of East Arm buffered by the outer industrial lots are likely to experience lower numbers than the outer edges facing the mangroves. This has been observed in other areas of Darwin, although further investigations would be required to evaluate the benefits of industrial buffers.

5.2.4 Seasonal and monthly abundance

The annual peak in *C. ornatus* adult abundance in the Northern Territory is encountered in the August to November period in the late dry season, with lowest numbers from January to March. Populations start to build up from the end of the wet season (April-May) to a peak in the late dry season, with a slight decrease in the coldest months of June and July (Whelan 2003). Further information on the seasonal abundance of *C. ornatus* can be found in Appendix 1.

Culicoides ornatus occurs in highest numbers over a four day period each month 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 and Whelan 2001). In areas affected by both foreshore mangrove and upper tidal mangrove tributary breeding sites, midge levels can be high 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 mangrove tributary breeding sites (Shivas and Whelan 2001).

Therefore as the breeding sites affecting East Arm include both upper tidal mangrove creek tributaries and foreshore mangrove areas, midge levels are expected to be high over a six day period each fortnight throughout much of East Arm. Very high abundance will occur from August to November, with high abundance in most other months.

5.2.5 Pest problems

The number of bites by *Culicoides* species that will constitute a human 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 (ie workers regularly exposed to biting midge bites) is unacceptable (Whelan et. al. 1997a). For people unaccustomed to biting midge bites, one to five bites per hour may be unbearable. Peak biting times for *C. ornatus* are in the two hours either side of sunset and sunrise (Whelan 2003). This species also bites at relatively low numbers throughout the night (Logan et al 1991). The amount of bites a person receives will be dependant on the amount of skin exposed and length of time spent outdoor in midge prone areas.

Investigations near Darwin have suggested an approximate relationship between the numbers of biting midges collected in a carbon dioxide baited EVS trap and the number of bites that can be expected at the peak biting period. The number of bites in an hour on an exposed leg at the peak biting time around sunset is approximately a quarter of the number collected in a CO₂ trap over one night at the same position (Whelan et. al. 1997a). For example if there were 400 *C. ornatus* in a CO₂ trap this would equate to 100 bites per hour around sunset.

Culicoides species bites can be a significant nuisance and can cause associated health problems. The bites are painful and large numbers of bites can cause a generalised 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. As there is no specific larval control method for *C. ornatus*, affected people would have to rely on reducing midge bites by personal protection measures or treatment of individual properties with a suitable residual barrier insecticide.

The pest problems affecting East Arm will be severe in at least the outer edge of East Arm within 1km of the mangroves of Bleasers Creek and Hudson Creek, and high throughout much of the rest of East Arm during August to November. During other months, high pest problems are likely to affect most of East Arm, particularly within 500m-1km of the nearest mangrove margin.

5.2.6 Biting midge control

The mangrove biting midge *C. ornatus* breeds in mud adjacent to and under dense mangrove canopies. Insecticide control of these sites is not practical, as very large quantities of insecticides would be required to penetrate the canopy and reach the mud below in sufficient amounts to achieve control. This would be unacceptable from an environmental perspective, due to the potential impacts to other organisms. There is also no registered insecticide product in Australia specifically suited to mangrove biting midge larval control.

The only way to effectively reduce *C. ornatus* breeding would be to permanently flood or fill their breeding sites, from the mean high water spring tide mark to below the level of occurrence of

seaward mangrove (Shivas and Whelan 2001). The proposed development (NOI June 2009) will partially remove several upper mangrove tributaries of Bleesers Creek, but the majority of upper tidal tributary breeding sites will remain. The proposed development will have no impact on the Hudson Creek upper tidal tributary breeding sites, but will remove a relatively large portion of the foreshore mangrove breeding sites along the Elizabeth River and mouth of Bleesers Creek. Therefore to have a greater impact on reducing *C. ornatus* abundance, if practical and consistent with future development concepts, more of the upper tidal tributaries of Bleesers Creek should be removed as part of the current proposed development. Removing the upper tidal tributary breeding sites in Hudson Creek would also reduce the pest problem in East Arm.

A lower impact method that may work in reducing peak dry season *C. ornatus* breeding would be to install low level bunds across the upper tidal mangrove tributary breeding sites, such that water is impounded above the mean high water neap tide level and thus flooding the prime creek bank breeding sites. Tidal bunding however would require intensive investigation to determine its effectiveness.

As the current proposed development outlined in the NOI (June 2009) will have minimal impact on removing biting midge breeding sites, some form of adult biting midge control would be the best way to reduce pest problems. The use of barrier insecticide sprays to reduce adult biting midges has been effective in reducing biting midge numbers in residential areas in Hervey Bay, QLD (Standfast et al 2003). In the Hervey Bay trial conducted by Standfast et al (2003), there was a 95%-75% reduction in biting midge numbers in the first month after treatment with the barrier insecticide bifenthrin, indicating appropriately applied barrier treatments by individual landholders could reduce biting midge pest problems. One drawback of this method is that the effectiveness of the barrier spray will require possibly annual or periodic evaluation to ensure there has not been any development of insecticide resistance by the midges. The other drawback is that the barrier is not likely to be effective unless the spray is applied regularly (possibly every 4–8 weeks) and to a suitable substrate such as hedges or fine mesh barrier screens.

Biting midge adult control could be achieved on individual lots, or along the outskirts of East Arm by utilising barrier insecticides such as bifenthrin and alpha-cypermethrin. Further information can be found in the Medical Entomology Handout 'Personal protection from mosquitoes and biting midges in the Northern Territory'. In summary, trap and kill zones such as hedge vegetation could be established between the mangroves and developed areas, or around individual lots, and sprayed with a suitable barrier insecticide. Other potential midge harbourage areas such as under demountables, inside open workshops, and vegetation shaded areas could also be sprayed by the relevant landholder. Ongoing evaluation of any adult biting midge control program would be required to determine if insecticide resistance is occurring.

5.2.7 Biting midges and planning aspects

East Arm is an industrial area therefore urban distance buffers from mangrove breeding sites, as found in some residential areas of Darwin and Palmerston, are not required. However as early morning workers and late evening workers would be particularly affected, as well as the railway passenger terminal during these periods, the biting midge problem should be reduced where practical. As discussed above in Section 5.2.6, breeding sites could be permanently removed by filling the tidal mangrove breeding sites, or potentially reduced by lower impact tidal bunding.

Trap results from October 2010 indicated reduced *C. ornatus* levels inland of the already present industrial lots. With the partial filling of some biting midge breeding sites and subsequent future industrial use, to some extent the inner areas of East Arm would experience lower biting midge numbers. However due to the numerous and very high productivity breeding sites that will remain, pest problems are still likely to be seasonally high in all areas of East Arm until the majority of *C. ornatus* breeding sites are removed or altered to reduce breeding, or until a satisfactory adult biting midge control program is implemented.

In terms of using industrial lots as biting midge buffers, larger lots (>4000m²) are recommended adjacent to the mangroves, to minimise the number of people working in the worst areas for biting midges, and to promote land use such as storage or other activity that results in most of the lots being maintained free of vegetation. All lots in East Arm would require a notification on titles mentioning the high biting midge pest problems that occur throughout East Arm.

5.2.8 Biting midge avoidance and personal protection

Extensive information on midge avoidance and personal protection can be found in Appendix 1 'Biting midges or sandflies in the Northern Territory'. Further information on personal protection can be found in Appendix 2 'Personal protection from mosquitoes and biting midges in the Northern Territory'. Avoiding exposure to biting midges during peak monthly abundance around sunset and sunrise is the best form of personal protection. Other measures include the use of personal repellents and protective clothing such as long trousers with socks and shoes and long sleeve shirts. Yellow or red lights can be used in outdoor areas to minimise attracting biting midges.

6.0 Conclusions

6.1 Mosquitoes

- The main mosquitoes affecting East Arm will be the northern salt marsh mosquito *Aedes vigilax* and the common banded mosquito *Culex annulirostris*. The receptacle mosquito *Aedes notoscriptus* would also be an important mosquito at East Arm.
- *Aedes vigilax* will be present in very high seasonal numbers throughout all of the East Arm peninsular (ie from the wharf to the Hudson Creek mangroves adjacent to Wishart Rd). Its major breeding sites occur in disturbed and reclaimed land, mud ponds and sediment ponds, and stormwater drains around East Arm. Major breeding depressions include Mud Pond A between Territory Resources and Berrimah Rd, Mud Pond A south west, the Site 6 paperbark swamp, the Site 9 paperbark depression, the Site 23 sediment pond, and numerous depressions located in Sections 6117, 5420, 5421 and 5720. Drainage lines such as the Site 35 and 36 stormwater drains, the Site 24 and 26 paperbark drainage lines, and roadside drains near the wharf are also potentially major breeding sites. Breeding sites associated with upper tidal areas and drainage lines outside of East Arm would also be periodic sources of this mosquito to East Arm.
- *Aedes vigilax* is a known vector of Ross River virus (RRV) and Barmah Forest virus (BFV). Greatest abundance will occur in the months of October to January. This species will pose a very high disease risk during these months of increased abundance, although December and January will be the peak months for RRV and BFV transmission by *Ae. vigilax*, due to the increased longevity during these humid months.
- The common banded mosquito *Culex annulirostris* will be the second most common mosquito at East Arm, with seasonally high to very high numbers expected from January to April. This species is a known vector of RRV, BFV, the potentially fatal Murray Valley encephalitis virus (MVEV) and many others. Breeding sites include all actual and potential *Ae. vigilax* sites that are vegetated with grass and semi-aquatic reeds, with the major breeding sites being Mud Pond A between Territory Resources and Berrimah Rd, Mud Pond A south west, the Site 9 paperbark depression, the Sites 19 and 23 sediment pond, as well as grassy ground depressions and stormwater drains with semi-aquatic vegetation.
- The receptacle mosquito *Aedes notoscriptus* was recorded at the old East Arm Boat Ramp in seasonally high numbers during the wet season, with rain water collected in artificial receptacles such as rubbish items, building material and used tyres being potential breeding sites. The storage yards near the old boat ramp and wharf guardhouse were likely to have contained breeding sites for this mosquito. *Aedes notoscriptus* is a potential vector of RRV and BFV. Breeding sites for *Ae. notoscriptus* would act as breeding sites for exotic dengue mosquitoes if an incursion occurs at the nearby wharf.
- Most of the current mosquito breeding sites at East Arm are a result of development. New breeding sites could be created due to the creation of borrow pits and scrapes, sediment ponds, mud ponds, some aspects of Water Sensitive Urban Design, site clearing and reclaiming, stormwater drains and discharge sites, and inappropriate storage of artificial receptacles and materials that could pond water.

- Rectification of mosquito breeding sites would be the best form of mosquito control as East Arm, as it will remove the need for a routine survey and control program.

6.2 Biting midges

- The mangrove biting midge *Culicoides ornatus* is the only species of biting midge likely to cause appreciable human pest problems at East Arm. While biting midges are considered appreciable human pests, they are not known to transmit disease to humans in Australia.
- The upper tidal mangrove tributaries of Bleesers Creek will be the most productive breeding sites affecting all of East Arm, followed by the upper tidal mangrove tributaries of Hudson Creek, and the foreshore mangrove areas of Hudson Creek, Bleesers Creek and the Elizabeth River.
- High pest biting midge numbers will be encountered in all areas of East Arm. Trapping indicated that biting midge numbers inland of areas of industrial development were lower compared to areas adjacent to the mangroves. Overall, high to very high pest problems will occur in all areas of East Arm, with the greatest pest problems in areas adjacent to the mangroves.
- Greatest *Culicoides ornatus* pest problems will occur over a 4 – 6 day period around the full and new moon from August to November. High abundance is also expected in April and May, and to a lesser extent in June and July (Appendix 1). *Culicoides ornatus* abundance during the wet season months of December to March is also likely to be high for most areas of East Arm, particularly those areas closest to the mangroves.
- Pest problems will primarily occur in the two hours either side of sunset and sunrise, with new moon pest problems generally around half the magnitude of full moon pest problems.
- Personal protection from biting midge bites, either through avoidance of problem times, use of personal repellents, mosquito coils or lanterns, and use long sleeved shirts and trousers is likely to be the best form of protection from biting midges.
- The control of mangrove biting midge breeding sites using aerially applied insecticides is not practical or environmentally acceptable, due to dense mangrove canopies, the mud breeding habitat, and the lack of a suitable specific larvacide for mangrove biting midges in Australia. The only long term way to reduce biting midge breeding is to remove or alter their tidal mangrove breeding sites. The proposed development will remove some foreshore mangrove breeding sites associated with the Elizabeth River and Bleesers Creek, and partially remove several upper tidal tributary breeding sites associated with Bleesers Creek. Overall, the development will only have a minor impact on removing biting midge breeding sites.

- The use of low neap tide in-creek bunds to target prime dry season upper tidal tributary breeding sites has the potential to reduce *C. ornatus* breeding and provide some reduction to pest problems. However full scientific studies would be required to evaluate their effectiveness in reducing biting midge breeding.
- To some extent, the addition of more industrial lots would provide a buffer to the inner lots. The use of insecticide treated vegetation barriers, either on individual lots or along the outskirts of East Arm, could also reduce adult biting midge levels.

7.0 Recommendations

7.1 Mosquitoes

- All current mosquito breeding sites at East Arm should be rectified as soon as possible. The most important breeding sites include:
 - a) Mud Pond A between Territory Resources and Berrimah Road. The area should be filled and appropriately graded to drain to Berrimah Rd
 - b) Mud Pond A south west. The area should be filled and drained to Mud Pond C and/or Mud Pond B.
 - c) Site 6 Paperbark Swamp. The swamp should be filled and contoured to be free draining, or be completely drained.
 - d) Site 9 Paperbark depression. The depression should be filled and drained to the adjacent roadside drain.
 - e) Site 23 Sediment Pond. The pond requires the removal of all vegetation, and be modified to be either entirely free draining, or contain deep (>1m) water.
 - f) The major open drain in Section 5421 should be extended to the tidal margin, which would include removing the Site 19 Sediment Pond.
 - g) Ground depressions in Sections 5163, 5420, 5421, 6117 and 5720. All ground depressions should be filled and levelled, with surface flows directed to the nearest open drain. An open drain may be required to drain the south east edge of Section 6117 and north east edge of Section 5421, with the drain linked up with the current major open drains on both lots.
 - h) Site 24 and 26 paperbark drainage lines. Both drainage lines should be regraded to prevent water ponding.
 - i) All roadside drains that pond water during the wet season should be upgraded with concrete low flow inverts.
 - j) Stormwater drains from Hamaura Rd, and from the railway should be upgraded with concrete low flow inverts or stormwater pipes as part of the development of those areas.
 - k) The Site 41 ponding area between Berrimah Rd and Section 5674 should be rectified by filling and grading towards the letterbox pit.
 - l) Mud Pond C should be investigated to determine if a larger outlet pipe is required, as ponding and mosquito breeding does occur during monsoon periods with extended heavy rainfall. Generally Mud Pond C drains relatively quickly after rainfall ceases.
 - m) Mud ponds B and D should eventually be filled and contoured to prevent surface water ponding. In the interim they should be maintained flooded to minimise salt marsh mosquito egg laying and allow wave action to disrupt mosquito breeding. Semi-aquatic reed growth in the northern margin of Mud Pond B should be removed.
 - n) The small sediment ponds associated with the manganese and iron stockpiles should be maintained free of semi-aquatic vegetation, and be maintained with deep water ponding.
 - o) The drainage line between the fuel terminal and the railway culvert should be annually desilted to prevent water ponding.
 - p) The wet season depressions on the wharf should be rectified by filling, while the open drain lined with Casuarina trees should be upgraded with a concrete low flow invert. Water tanks on the wharf should be provided with appropriate insect screening to prevent mosquito access.
- There will be other areas of wet season ponding and mosquito breeding that were not identified in this report, or were created after the field surveys were conducted. Landholders should conduct wet season inspections of their lots to identify wet season ponding areas that require rectification the following dry season.

- Business owners and landholders should annually remove unwanted artificial receptacles and rubbish items that could act as breeding sites for exotic dengue carrying mosquitoes. Building material and other material that could potentially pond water should be stored under cover, or in a manner that prevents ponding and receptacle mosquito breeding.
- Stormwater drainage for the proposed development should be constructed in accordance with the Medical Entomology guideline 'Guidelines for preventing biting insect problems for urban residential developments or subdivisions in the Top End of the Northern Territory'. In particular for East Arm, all new major open stormwater drains should have concrete low flow invert, while roadside drains, swales and other minor drains should have concrete low flow invert when the fall of the drain would not be enough to prevent ponding. All drains should be placed on an annual maintenance program.
- Water Sensitive Urban Design structures such as wetlands and bioretention systems should be designed and maintained in accordance with the Medical Entomology guideline 'Constructed Wetlands in the Northern Territory – Guidelines to prevent mosquito breeding'. All design plans should be submitted to Medical Entomology for informed comment regarding potential mosquito breeding issues.
- Sediment ponds should be designed to be completely free draining, or be designed to have steep sides and contain deep water (>1m). All sediment ponds should be placed on an annual maintenance program.
- Any new mud pond should be constructed to contain deep water (>1m) and have steep sides, to minimise the potential for semi-aquatic vegetation growth and associated mosquito breeding. The installation of a water control device on the outlet culvert may assist in managing water levels in the mud ponds to prevent mosquito breeding. Any new mud pond likely to only contain shallow water should be made free draining, which would include appropriately depositing sludge to minimise the creation of isolated pools and allow surface water to flow to the outlet culvert.
- Any cut off tidal area created during construction should have appropriate temporary drainage provisions provided, to prevent upstream ponding until the upstream area is reclaimed.
- All new reclaimed areas should have a suitable surface profile free from depressions. Borrow pits, scrapes, hill removal and other disturbed areas should be rehabilitated to be free draining.
- There should be no use of stormwater sumps in any roadside or local area drainage within the development site. Gross Pollutant Traps, Side Entry Pits, Letterbox Pits and any other stormwater pit should be free draining to prevent the creation of potential breeding sites for mosquitoes, including exotic dengue mosquitoes.
- If existing mosquito breeding sites at East Arm can not be rectified before the next wet season, all landholders that have lots containing mosquito breeding depressions should be required to control any mosquito breeding. The insecticide of choice would be either Methoprene 30 day pellet or 150 day briquette formulations. Although no residents live at East Arm, *Ae. vigilax* will affect outdoor day workers and railway passengers, while all mosquitoes including *Ae. vigilax* will affect any person outdoors at night.

- Maintenance of stormwater drains and rectifying depressions on private lots, road and rail reserves and undeveloped land should be an ongoing management requirement for respective landholders.

7.2 Biting midges

- If possible, more of the upper tidal tributaries of Bleasers Creek should be removed as part of the current proposed development. Alternatively biting midge problems at East Arm could possibly be alleviated by the use of tidal bunds across upper tidal tributaries of Bleasers Creek, and also Hudson Creek. The use of tidal bunds however is speculative and would require intensive field trials to determine their effectiveness.
- The use of insecticide 'hedge' barriers by individual landholders or along the outskirts of East Arm could provide effective control of adult biting midges. However, any insecticide control option would require ongoing evaluation to determine if insecticide resistance is occurring. Any adult biting midge control program would also need to be funded and carried out by the relevant landholder.
- All lots should have a notification on titles mentioning the high biting midge pest problems that occur at the East Arm Port Area and adjacent areas between the wharf and Hudson Creek east of Berrimah Rd.

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9.0 References

- Communicable Disease Centre (CDC), Department of Health and Community Services Northern Territory Factsheet (April 2003) 'Ross River virus'.
- Communicable Disease Centre (CDC), Department of Health and Community Services Northern Territory Factsheet (April 2004) 'Murray Valley encephalitis virus'.
- Communicable Disease Centre (CDC), Department of Health and Community Services Northern Territory Factsheet (May 2006) 'Mosquitoes'.
- Construction practice near tidal areas in the Northern Territory – Guidelines to prevent mosquito breeding'. Medical Entomology, Northern Territory Department of Health and Families 2009.
- 'Guidelines to minimise mosquito and biting midge problems in new development areas', Queensland Health 2002, Queensland Government.
- 'Guidelines for preventing biting insect problems for urban residential developments or subdivisions in the Top End of the Northern Territory' Medical Entomology, Northern Territory Department of Health and Families 2009.
- Lee, D. J. (1944), 'An Atlas of the Mosquito Larvae of the Australasian Region. Tribes-Megarhinini and Culicini.' Department of Zoology, University of Sydney.
- Lee, D. J. and Woodhill, A. R. (1944), 'The Anopheline Mosquitoes of the Australasian Region.' Publications of the University of Sydney, Department of Zoology. Monograph No. 2.
- Lee, D. J., Hicks, M. M., Griffiths, M., Russell, R. C., and Marks, E. N. (1982), 'The Culicidae of the Australasian Region Vol. 2', Commonwealth Department of Health and Commonwealth Institute of Health incorporating School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.
- Lee, D. J., Hicks, M. M., Griffiths, M., Russell, R. C., and Marks, E. N. (1984), 'The Culicidae of the Australasian Region Vol. 3', Commonwealth Department of Health and Commonwealth Institute of Health incorporating School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.
- Lee, D. J., Hicks, M. M., Griffiths, M., Debenham, M. L., Bryan, J. H., Russell, R. C., Geary, M., and Marks, E. N. (1987), 'The Culicidae of the Australasian Region Vol. 4', Commonwealth Department of Health and School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.

- Lee, D. J., Hicks, M. M., Debenham, M. L., Griffiths, M., Marks, E. N. Bryan, J. H., and Russell, R. C., (1989), 'The Culicidae of the Australasian Region Vol. 7', University of Queensland and University of Sydney in collaboration with Commonwealth Department of Community Services and Health, Monograph Series, Entomology Monograph No. 2.
- Lee, D. J., Hicks, M. M., Griffiths, M., Debenham, M. L., Bryan, J. H., Russell, R. C., Geary, M., and Marks, E. N. (1988), 'The Culicidae of the Australasian Region Vol. 8', Commonwealth Department of Health and School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.
- Lee, D. J., Hicks, M. M., Griffiths, M., Debenham, M. L., Bryan, J. H. and Marks, E. N. (1988a), 'The Culicidae of the Australasian Region Vol. 9', Commonwealth Department of Health and School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.
- Liehne, P. F. in consultation with Medical Entomology Branch (1985), 'Mosquito and Biting Midge Investigations, Palmerston 1982-85', Palmerston Development Authority.
- Logan, D., Kelton, W. and Whelan, P. (1991), 'Bayview Haven Canal Estate Biting Insect Investigation', Medical Entomology Branch, Department of Health and Community Services.
- Marks, E.N. and Reye, E.J, (1982), 'An atlas of common Queensland mosquitoes with a guide to common Queensland biting midges', Queensland Institute of Medical Research.
- Merianos, A., Farland, A. M., Patel, M., Currie, B., Whelan, P. I., Dentith, H. and Smith, D. (1992), 'A concurrent outbreak of Barmah Forest and Ross River virus disease in Nhulunbuy, Northern Territory', *Comm Dis Intel*, vol. 16, no. 6, pp. 110-111.
- National Guidelines for Evaluating Water Sensitive Urban Design (WSUD). BMT WBM Pty Ltd November 2007.
- Russell, R. C., (1986), 'Dispersal of the arbovirus vector *Culex annulirostris* Skuse (Diptera:Culicidae) in the Murray Valley of Australia', *Gen Appl Ent*, 18.
- Russell, R. C., (1987), 'Seasonal abundance, longevity and population age composition of potential malaria vectors in northern and southern Australia.' *Aust. J. Zool.*35:289-306.
- Russell, R. C. (1999), 'Constructed wetlands and mosquitoes: Health hazards and management options – An Australian perspective', *Ecological Engineering* 12 (1999) 107 – 124.

- Russell, R. C. and Kay, B.H. (2004), 'Medical Entomology: changes in the spectrum of mosquito-borne disease in Australia and other vector threats and risks, 1972-2004', *Australian Journal of Entomology* (2004) 43, 271-282.
- Russell, R. C., Currie, B.J., Lindsay, M.D.A., Mackenzie, J.S., Ritchie, S.A., Walker, J.C. and Whelan, P.I. (2007), 'Climate change and vector-borne disease in Australia: what are the real threats from malaria, dengue and endemic arboviruses', A discussion paper prepared for NAMAC.
- Shivas, M., Whelan, P. I., and Webb, C. (1997), 'The characterization of emergence sites of the biting midge *Culicoides ornatus* (Diptera:Ceratopogonidae) in mangroves near Darwin, Northern Territory, Australia', in *Arbovirus Research in Australia*, vol. 7, *Proceedings of the Seventh Arbovirus Research in Australia Symposium, and Second Mosquito Control Association of Australia Conference, 1996*, pp. 275-279.
- Shivas, M. (1999), 'The larval biology of *Culicoides ornatus* Taylor in mangroves near Darwin, Northern Territory.' Faculty of Science, Northern Territory University Darwin. PHD Doctor of Philosophy.
- Shivas, M., and Whelan, P. I. (2001), 'Biting midge research project' (Study undertaken on behalf of Department of Lands, Planning and Environment). Territory Health Services.
- Standfast, H., Fanning, I., Maloney, L., Purdie, D., and Brown, M. (2003), 'Field evaluation of Bistar 80 S.C. as an effective insecticide harbourage treatment for biting midges and mosquitoes infesting peri-domestic situations in an urban environment'. *Bulletin MCAA* vol. 15; 2, pp 19-33.
- Tai, K. S., Whelan, P. I., Patel, M. S. and Currie, B. (1993), 'An outbreak of epidemic polyarthritis (Ross River virus disease) in the Northern Territory during the 1990-1991 wet season. *Medical Journal of Australia*, vol. 158, pp. 522-525.
- Warchot, A. and Whelan, P. (2006), 'Biting insect assessment East Arm Condensate Processing Facility', Medical Entomology, Northern Territory Department of Health and Community Services.
- Warchot, A. and Whelan, P. (2008a), 'Muirhead Biting Insect Assessment'. Medical Entomology Section, Northern Territory Department of Health and Community Services.
- Warchot, A. and Whelan, P. (2008b), 'Palmerston Eastern Suburbs Biting Insect Assessment'. Medical Entomology Section, Northern Territory Department of Health and Community Services.

- Warchot, A. and Whelan, P. (2008c), 'Constructed Wetlands in the Northern Territory – Guidelines to prevent mosquito breeding'. Medical Entomology, Northern Territory Department of Health and Community Services.
- Warchot, A. and Whelan, P. (2009), 'Biting insect assessment Berrimah Farm and Prison'. Medical Entomology, Northern Territory Department of Health and Families.
- Warchot, A. and Whelan, P. (2010), 'Mosquito breeding sites East Arm Port sediment ponds area January 2010', Medical Entomology, Northern Territory Department of Health and Families.
- Whelan, P. I. (1991), 'Biting midge investigations near Darwin and their implications for urban planning', in *Proc. Nat. Conf. on Biting Midges*, Surfers Paradise, Qld, 8-9 Feb, 1990, pp. 39-50.
- Whelan, P. I. (1994), 'Construction practice near tidal areas in the Northern Territory', *Bulletin of the Mosquito Control Association of Australia*, Vol. 6, No. 1, pp. 18-39.
- Whelan, P. I. (1995), 'Malaria and the receptive area of the Northern Territory', Medical Entomology Branch, Northern Territory Department of Health and Community Services.
- Whelan, P.I. (1997a), 'Problem mosquito species in the Top End of the Northern Territory – Pest and vector status, habitat and breeding sites', Medical Entomology Branch, Northern Territory Department of Health and Community Services.
- Whelan, P.I. (1997b), 'Arbovirus disease risk periods in the Northern Territory', Medical Entomology Branch, Northern Territory Department of Health and Community Services.
- Whelan, P. I. (2003), 'Biting midges or "sand flies" in the Northern Territory.' *Northern Territory Disease Control Bulletin* Vol. 10, No.3, pp. 1-9, September 2003.
- Whelan, P.I. (2004a), 'Common mosquito species in the Top End of the Northern Territory – Their biology and disease significance', Medical Entomology Branch, Northern Territory Department of Health and Community Services.
- Whelan, P.I. (2004b), 'Summary of the biology of selected *Culicoides* species in the Top End of the Northern Territory and Seasonal prevalence of selected *Culicoides* species in the Top End of the Northern Territory', Medical Entomology Branch, Northern Territory Department of Health and Community Services.
- Whelan, P.I. (2009), 'Personal protection from mosquitoes and biting midges in the Northern Territory', Medical Entomology, Northern Territory Department of Health and Families.

- Whelan, P.I., Booth, D. and Kelton, W. (1988), 'Biting insects in the proposed Newtown (Weddell) development, Darwin', Medical Entomology Branch, Northern Territory Department of Health and Community Services.
- Whelan, P. I. and Hayes, G.A. (1992). Arbovirus Outbreak Nhulunbuy Northern Territory 1992 - Medical Entomology Aspects. December to March 1992, Medical Entomology Branch, Northern Territory Department of Health and Community Services.
- Whelan, P.I., and Hayes, G.A., (1993), 'Biting insect investigations Darwin South, Stage I' (Study undertaken on behalf of the Department of Lands, Housing and Local Government), Northern Territory Department of Health and Community Services.
- Whelan, P. I., Merianos, A., Patel, M., Tai, K. S. and Currie, B. (1993), 'The epidemiology of arbovirus infection in the Northern Territory 1980-92', *Arbovirus Research in Australia*, vol. 6, *Proc. of the 6th Arbovirus Conference, 1993*.
- Whelan, P. I. and Weir, R. P. (1993), 'The isolation of alpha and flavi viruses from mosquitoes in the Northern Territory 1982-1992', *Arbovirus Research in Australia*, vol. 6, *Proceedings of the 6th Arbovirus Conference, 1992*.
- Whelan, P. I., Montgomery, B.L., Hayes, G.A., Nowland, R.A. and Love, B.L. (1994), 'Biting insect investigations Darwin South Stage II. Twelve month baseline study of species, abundance and distribution of biting insects in the Darwin South area', Medical Entomology Branch report.
- Whelan, P. I., Hayes, G., Montgomery, B. L. (1997a), 'Biting midge surveillance in Darwin Harbour, *Culicoides ornatus* (Diptera:Ceratopogonidae) abundance and dispersal', in *Arbovirus Research in Australia*, vol. 7, *Proceedings of the Seventh Arbovirus Research in Australia, and Second Mosquito Control Association of Australia Conference, 1996*, pp. 326-336.
- Whelan, P. I., Merianos, A., Hayes, G., and Krause, V. (1997b), 'Ross River virus transmission in Darwin, Northern Territory, Australia', in *Arbovirus Research in Australia*, vol. 7, *Proceedings of the Seventh Arbovirus Research in Australia Symposium, and Second Mosquito Control Association of Australia Conference, 1996*, pp. 337-345.
- WHO. 2002. Report of the fifth WHOPES working group meeting: review of Olyset Net and Bifenthrin 10%WP. WHO/CDS/WHOPES/2001.4.
- Wirth, W., and Hubert, A. (1989), '*Culicoides* of South East Asia.' The American Entomological Institute, Florida U.S.A.

Figures

Figure 1 East Arm Port Expansion Project biting insect assessment. Location of adult biting insect trap sites and potential biting midge (C. ornatus) breeding sites



Figure 2A - Larval mosquito survey 11 October and 31 December 2010. Actual and potential mosquito breeding sites.



Legend

- larval mosquito survey 31 Dec 2010
- larval mosquito survey 11 Oct 2010
- potential mosquito breeding area *

*Note: potential mosquito breeding area as defined during limited early wet season surveys. Not likely to be accurate extent of true ponding area.

Scale 1:6,000

0 100 200 300 400 500 Meters

Map Source: NT Government 2010 June All rights Reserved



Stormwater drains. Potential mosquito breeding.

Cattle yard wastewater ponds

Sewage ponds

033

032

034

035

11 Oct 2010

11 Oct 2010

11 Oct 2010

11 Oct 2010

- larval mosquito survey 31 Dec 2010
- potential mosquito breeding area *

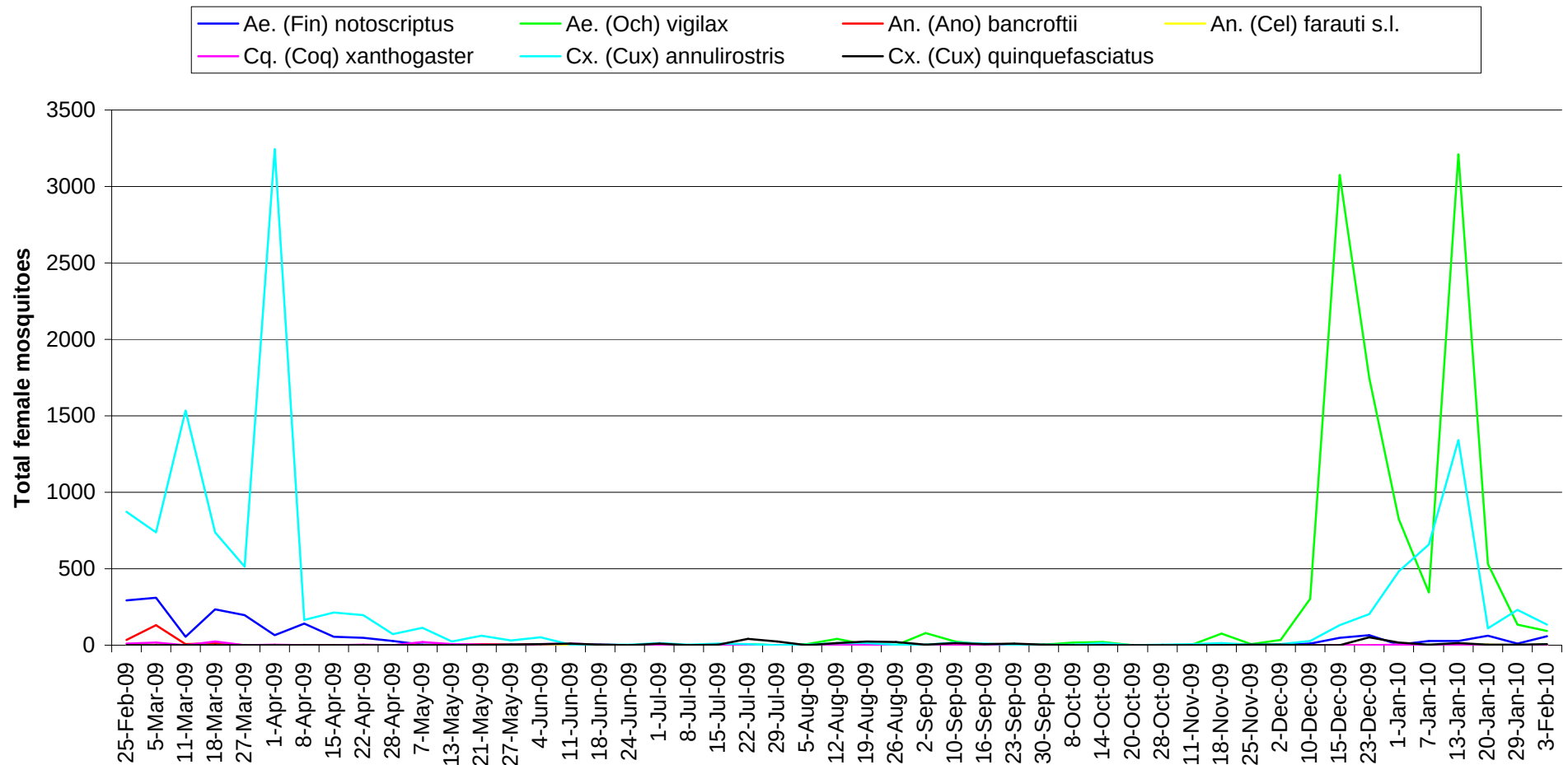
Map Source:
NT Government 2010 June
All rights Reserved

Figure 2C - Larval mosquito survey 31 December 2010. Actual and potential mosquito breeding sites.



Figure 3

DM26 East Arm between old boat ramp and wharf guardhouse (see Figure 1). Total numbers of seven select mosquito species collected during weekly routine CO2 trapping February 2009 to February 2010. Single trap set once per week.





Tables

Table 1 Larval mosquito survey East Arm Port Expansion 11th October and 31 December 2010												
Date collected	Trap Location	Water presence	Water area	Breeding	No. of dips	Ave per dip	Species	1st instar	2nd instar	3rd instar	4th instar	Pupae
11-Oct-10	Larval 1 & 2 East Arm Port 2010 - storage yard adjacent to old boat ramp	Pooling	80	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 3 East Arm Port 2010 - depressions in vacant lot Sec 5420	Pooling	80	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 4 East Arm Port 2010 - wheel ruts near mangrove margin Sec 5421 South edge	Pooling	10	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 5 East Arm Port 2010 - small mangrove depression Sec 5421 South edge	Pooling	5	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 6 & 7 East Arm Port 2010 - wheel ruts and paperbark depression, Sec 5421 south edge	Pooling	60	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 8 East Arm Port 2010 - roadside drain Berrimah Rd adj to Sec 5421	Pooling	100	Yes	2	5	<i>Cx. (Cux) annulirostris</i>	0	0	1	1	1
11-Oct-10	Larval 9 East Arm Port 2010 - paperbark depression adj to Berrimah Rd Sec 5421	Pooling	300	Yes	2	10	<i>Ae. (Muc) alternans</i> <i>Ae. (Och) vigilax</i>	1 4	0 0	0 0	0 0	0 0
11-Oct-10	Larval 10 East Arm Port 2010- depressions Sec 5421	Pooling	100	Yes	2	20	<i>Ae. (Och) vigilax</i>	7	0	0	0	0
11-Oct-10	Larval 11 East Arm Port 2010 - depressions Sec 5421	Pooling	60	No	6	N/C	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 12 & 13 East Arm Port 2010 - depressions Sec 5421	Pooling	600	Yes	6	0.5	<i>Ae. (Muc) alternans</i>	1	0	0	0	0
11-Oct-10	Larval 14 East Arm Port 2010 - depressions Sec 6117	Pooling	N/C	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 15 East Arm Port 2010 - depressions Sec 5421	Pooling	N/C	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 16 East Arm Port 2010 - depressions Sec 6117	Pooling	N/C	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0

Table 1 Larval mosquito survey East Arm Port Expansion 11th October and 31 December 2010												
Date collected	Trap Location	Water presence	Water area	Breeding	No. of dips	Ave per dip	Species	1st instar	2nd instar	3rd instar	4th instar	Pupae
11-Oct-10	Larval 17 East Arm Port 2010 - depressions Sec 6117	Pooling	N/C	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 18 East Arm Port 2010 - depressions Sec 5421	Pooling	N/C	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 19 East Arm Port 2010 - Sediment pond and adjacent depressions Sec 5421	Pooling	300	No	10	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 20 East Arm Port 2010 - roadside drain opposite fuel terminal	Pooling	400	No	10	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 21 East Arm Port 2010 - depressions around fill stockpiles Sec 6117	Pooling	400	No	10	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 22 East Arm Port 2010 - depressions around fill stockpiles Sec 6117	Pooling	N/C	No	10	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 23 East Arm Port 2010 - sediment pond Sec 6117	Pooling	300	Yes	2	10	<i>Ae. (Och) vigilax</i>	2	1	0	0	0
							<i>Ae. (Muc) alternans</i>	0	1	0	0	0
11-Oct-10	Larval 24 East Arm Port 2010 - paperbark drainage line Sec 6117	Pooling	200	Yes	10	0.2	<i>Ve. (Ver) funerea</i>	1	0	0	0	0
11-Oct-10	Larval 25 East Arm Port 2010 - paperbark drainage line end point Sec 6117	Pooling	3	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 26 East Arm Port 2010 - paperbark drainage Sec 5633	Pooling	400	No	10	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 27-29 East Arm Port 2010 - large depressions Sec 5720 and road reserve	Pooling	600	No	20	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 30 East Arm Port 2010 - small depressions Sec 5633	Pooling	10	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 31 East Arm Port 2010 - small depressions Sec 5633	Pooling	N/C	No	4	0	<i>Nil mosquitoes</i>	0	0	0	0	0

Table 1 Larval mosquito survey East Arm Port Expansion 11th October and 31 December 2010												
Date collected	Trap Location	Water presence	Water area	Breeding	No. of dips	Ave per dip	Species	1st instar	2nd instar	3rd instar	4th instar	Pupae
11-Oct-10	Larval 32 East Arm Port 2010 - Hamaura Rd drain opp Sec 5366	Pooling	200	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 33 East Arm Port 2010 - upper tidal depressions Sec 5633	N/C	N/C	No	N/C	N/C	<i>N/A mosquito</i>	1	0	0	0	0
11-Oct-10	Larval 34 East Arm Port 2010 - Hamaura Rd drain opp Sec 4980	Pooling	N/C	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 35 East Arm Port 2010 - Hamaura Rd drain opp Sec 5106	Pooling	N/C	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	Larval 36 East Arm Port 2010 - railway terminal drain	Pooling	200	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	East Arm industrial zone - sediment pond south of Northern Cement Mud Pond B	Pooling	50000	No	15	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	East Arm Industrial area - Mud Pond A south west	Pooling	1000	No	10	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	East Arm Industrial area - Mud Pond A between Territory Resources and Berrimah Rd	Damp	0	No	0	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	East Arm industrial area - second sediment pond south of Northern Cement Mud Pond D	Flooded	N/C	No	10	0	<i>Nil mosquitoes</i>	0	0	0	0	0
11-Oct-10	East Arm Industrial area - Mud Pond C	Damp	0	No	0	0	<i>Nil mosquitoes</i>	0	0	0	0	0
31-Dec-10	Larval 37-39 East Arm Port 2010- depressions Sec 5420, south of drain	Pooling	N/C	No	15	0	<i>Nil mosquitoes</i>	0	0	0	0	0
31-Dec-10	Larval 40 East Arm Port 2010 - swale drain from railway terminal	Damp	0	No	0	0	<i>Nil mosquitoes</i>	0	0	0	0	0
31-Dec-10	Larval 36 East Arm Port 2010 - railway terminal drain	Pooling	N/C	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0
31-Dec-10	Larval 41 East Arm Port 2010 - depressions in road reserve between Berrimah Rd and Sec 5674	Pooling	150	No	15	0	<i>Nil mosquitoes</i>	0	0	0	0	0

Table 1 Larval mosquito survey East Arm Port Expansion 11th October and 31 December 2010												
Date collected	Trap Location	Water presence	Water area	Breeding	No. of dips	Ave per dip	Species	1st instar	2nd instar	3rd instar	4th instar	Pupae
31-Dec-10	Larval 42 East Arm Port 2010 - depressions in rock stockpile area East Arm Wharf	Pooling	N/C	No	N/C	N/C	<i>N/A mosquito</i>	1	0	0	0	0
31-Dec-10	Larval 43 East Arm Port 2010 - Casuarina lined drainage line East Arm Wharf	Pooling	N/C	No	2	0	<i>Nil mosquitoes</i>	0	0	0	0	0
31-Dec-10	Larval 44 East Arm Port 2010 - depressions near pipelines East Arm Wharf	Pooling	N/C	No	N/C	N/C	<i>N/A mosquito</i>	1	0	0	0	0
31-Dec-10	Larval 45 East Arm Port 2010 - shallow depressions adj to wharf pond	Pooling	N/C	No	N/C	N/C	<i>N/A mosquito</i>	1	0	0	0	0
31-Dec-10	East Arm Industrial area - Mud Pond A between Territory Resources and Berrimah Rd	Flooded	6000	Yes	5	10	<i>Ae. (Och) vigilax</i>	0	0	0	4	16
							<i>Cx. (Cux) annulirostris</i>	0	2	3	5	2
31-Dec-10	East Arm Industrial area - Mud Pond A south west	Flooded	N/C	No	20	0	<i>Nil mosquitoes</i>	0	0	0	0	0
31-Dec-10	East Arm industrial zone - sediment pond south of Northern Cement Mud Pond B	Flooded	N/C	No	N/C	N/C	<i>N/A mosquito</i>	1	0	0	0	0
31-Dec-10	Larval 6 & 7 East Arm Port 2010 - wheel ruts and paperbark depression, Sec 5421 south edge	Flooded	N/C	No	5	0	<i>Nil mosquitoes</i>	0	0	0	0	0
31-Dec-10	East Arm Industrial area - Mud Pond C	Flowing	10	No	N/C	N/C	<i>N/A mosquito</i>	1	0	0	0	0

EAST ARM PORT EXPANSION PROJECT MOSQUITO RESULTS 23 OCTOBER 2010

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EAST ARM PORT EXPANSION PROJECT MOSQUITO RESULTS 23 OCTOBER 2010

Medical Entomology DHF 14/01/2011

EAST ARM PORT EXPANSION PROJECT BITING MIDGE RESULTS 23 OCTOBER 2010

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EAST ARM PORT EXPANSION PROJECT BITING MIDGE RESULTS 24 OCTOBER 2010

Medical Entomology Branch DHCS 14/01/2011

Appendix 1 'Biting midges or sandflies in the Northern Territory'.



**Northern
Territory
Government**

Department of Health
and Community Services

BITING MIDGES OR “SANDBLIES” IN THE NT

**PETER WHELAN
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DARWIN
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July 2003**

The Northern Territory Disease Control Bulletin Vol 10, No. 3, September 2003

For more information contact:

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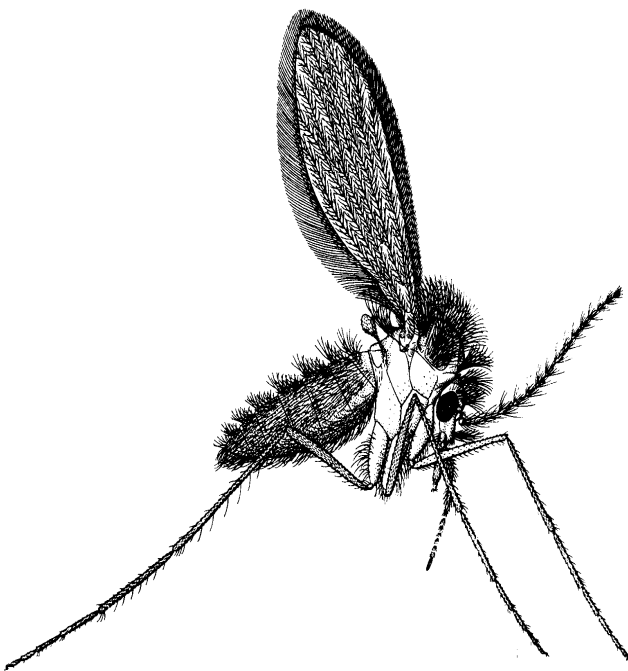
Telephone: 08 89228333
Fax: 08 89228820
Email: peter.whelan@nt.gov.au

Biting Midges or 'Sandflies' in the Northern Territory

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

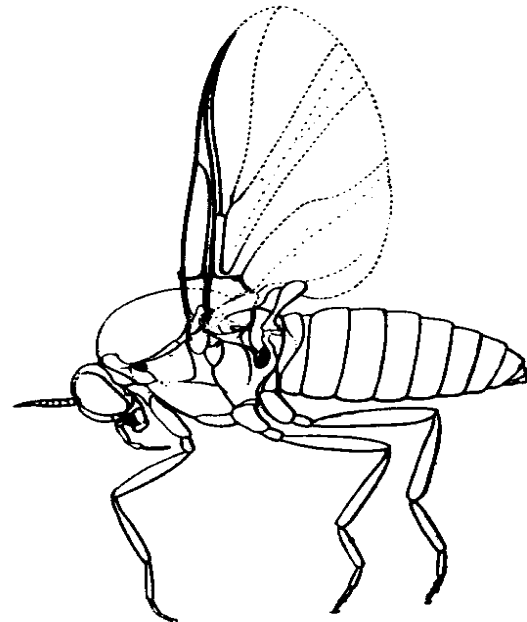
1.0 Introduction

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



Phlebotomus – a female "Sand Fly"

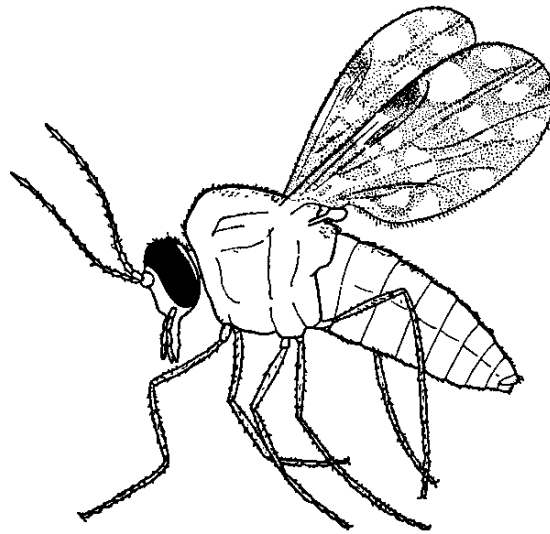
Insects of Medical Importance
British Museum 1956



Simulium – a female "Black Fly"

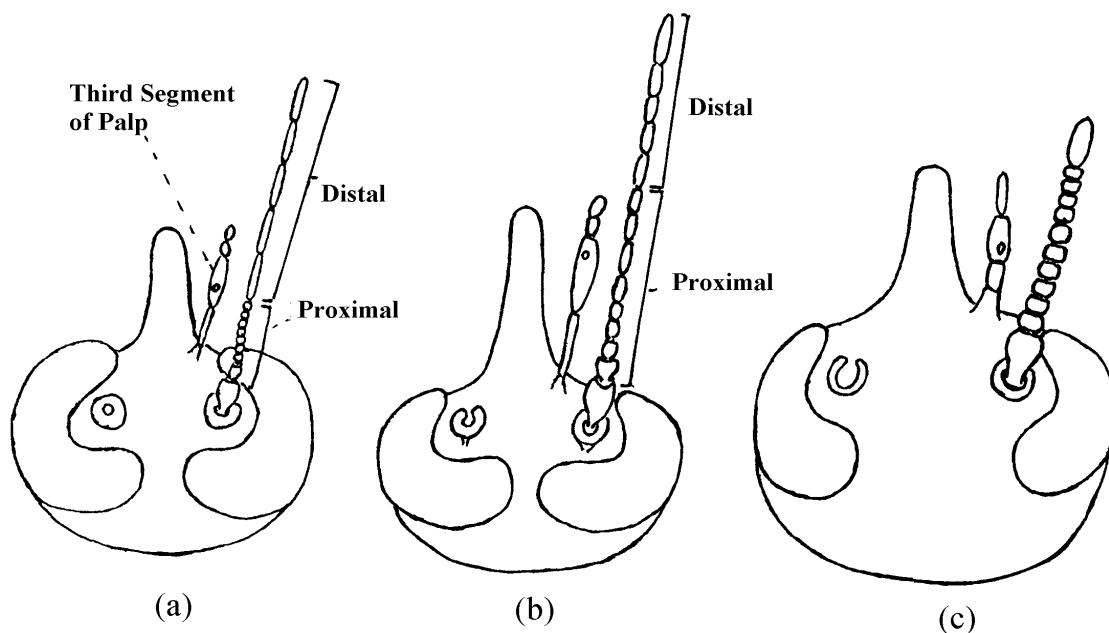
Insects of Medical Importance.
British Museum 1956

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



Culicoides – a female “Biting Midge”

Entomology for Students of Medicine. Blackwell Scientific Ltd. 1962



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

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

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

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

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

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

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

2.0 Bites of Biting Midges

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

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

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

3.0 Treatment of Bites

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

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

4.0 Breeding Sites of *Culicoides ornatus*

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

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

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

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

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

5.0 The Flight Activity of *Culicoides ornatus*

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

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

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

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

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

6.0 Seasonal Abundance of *Culicoides ornatus*

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

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

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

7.0 Protection from Bites of *Culicoides ornatus*

7.1 Avoidance

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

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

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

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

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

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

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

7.2 Clothing and Netting

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

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

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

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

7.3 Repellents

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

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

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

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

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

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

There is an urban myth that taking Vitamin B1 or thiamin can act as a repellent. There is no scientific evidence that Vitamin B1 acts as a repellent, or helps to reduce the reaction to insect bites by developing some immunity to the bites.¹³ Other topical applications such as a 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.¹¹

7.5 The reduction of vegetation

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

7.6 The use of attractant traps

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

8.0 Evaluation of Biting Midge Problems

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

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

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

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

9.0 Control of *Culicoides ornatus*

9.1 Insecticide fogging for Adult Midges

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

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

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

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

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

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

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

9.2 *Barrier spraying*

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

9.3 *Insecticide Control of Larval Habitats*

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

9.4 *Elimination of Breeding Habitats*

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

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

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

9.5 *Buffer zones*

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

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

10.0 Planning Guidelines To Prevent Biting Insect Problems

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

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

Good urban planning is required to;

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

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

Selected References

1. Marks, E.M. (1982), "An atlas of common Queensland mosquitoes" by Elizabeth Marks with "A guide to common Queensland biting midges" by Eric Reye, ", Q.I.M.R. Revised edition.
2. Whelan, P.I. (1991a), "Biting midge investigations near Darwin and their implications for urban planning", In Proc. Nat. Conf. on Biting Midge, Surfers Paradise, Qld., 8-9 Feb, 1990.
3. Whelan, P.I., Hayes, G., Montgomery, B.L. (1997), "Biting midge surveillance in Darwin Harbor, *Culicoides ornatus* (Diptera: Ceratopogonidae) abundance and dispersal", *Arbovirus Research in Australia*, vol. 7, pp.326-336.
4. Shivas M. (2000) "The Larval Biology of *Culicoides ornatus* Taylor in mangroves near Darwin, NT. PHD. Faculty of Science NTU Darwin Feb 2000.
5. Whelan, P.I., Booth, D. and Kelton, W. (1988), "Biting insect investigations and comment on the proposed Newtown (Weddell) Development, Darwin, N.T.", Department of Health and Community Services, Darwin NT.
6. Whelan, P.I. and Hayes, G.A. (1993), "Biting Insect Investigation Darwin South Stage I", Department of Health and Community Services, Darwin NT.
7. Whelan, P.I. (1995), "Biting insect investigation Darwin South Stage II", Department of Health and Community Services, Darwin NT.

8. Lee D.J. (1975), "Arthropod bites and stings and other injurious effects". SPHTM, Inst. of Public Health, Uni. of Sydney.
9. Shivas, M., Whelan, P.I., & Webb, C. (1997), "The characterization of emergence sites of the biting midge *Culicoides ornatus* (Diptera: Ceratopogonidae) in mangroves near Darwin, NT, Australia", in *Arbovirus Research in Australia*, vol. 7.
10. Wightman, G.M. (1989), "Mangroves of the Northern Territory", Northern Territory Botanical Bulletin, No.7 Conservation Commission, Palmerston, N.T.
11. Shivas M and Whelan P.I. (2001), "Biting midge research project March 1999-March 2001". Study for DLP&E, Darwin NT on dispersal biology and effect of lights and vegetation. Department of Health and Community Services, Darwin NT.
12. Leihne, P.F. in association with Medical Entomology Branch DHCS (1985), "Mosquito and biting midge investigations, Palmerston 1982-85", Palmerston Development Authority.
13. Khan A.A., Maibach H.I., Strauss W.G. et al. "Vitamin B1 is not a systemic mosquito repellent in man". Trans St John Hosp Derm Soc 1969;55:99-102
14. Standfast H., Fanning I. Maloney L., Purdie D. and Brown M. "Field evaluation of Bistar 80SC as an effective insecticide treatment for biting midges (*Culicoides*) and mosquitoes infesting peri-domestic situations in an urban environment" Bulletin Mos Cont Assoc Aust Vol 15 (2) July 2003.

Appendix 2 'Personal protection from mosquitoes and biting midges in the Northern Territory'.



Northern
Territory
Government

DEPARTMENT OF HEALTH AND FAMILIES

Personal protection from mosquitoes & biting midges in the NT

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October 2010

Personal protection from mosquitoes & biting midges in the NT

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1.0 MOSQUITOES AND 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 enter 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 small capillaries in 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 histamine like 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 northern salt marsh mosquitoes *Aedes vigilax* and various other pest mosquitoes. 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 appreciable rain. Salt marsh mosquito and midge pest calendars are available from the health website http://www.health.nt.gov.au/Medical_Entomology/index.aspx

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 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 with small dendritic creeks or estuarine areas with muddy banks are potential sources of mangrove 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, drums, fallen palm fronds, pot plant drip trays, plant striking buckets, animal water, garden equipment, plastic sheeting, 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. Disused fish ponds or ponds used for frogs can be rectified by the addition of a few fish.

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, deltamethrin, bifenthrin, or alpha-cypermethrin 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. Tents can be made more mosquito effective by spraying them inside and out with bifenthrin or alpha-cypermethrin.

4.0 MOSQUITO NETS

Mosquito nets are useful in temporary camps or in unscreened houses near biting insect breeding areas. In general 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 dipping impregnation with permethrin (Lines et al. 1985) or by spraying them inside and out with bifenthrin, lambda-cyhalothrin or alpha-cypermethrin.

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, loose fitting long sleeved shirts and full-length trousers are recommended. Dark clothing such as dark blue denim or black clothing is much more attractive to salt marsh mosquitoes than white clothing. Many mosquitoes including salt marsh mosquitoes or *Anopheles bancroftii* will bite through tight fitting shirts or pants. 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 good protection, with DEET based repellents the best. Many botanical based products do not offer sufficient protection. Some specific repellent products, such as standard Aerogard, which are formulated to repel flies, are generally not efficient against mosquitoes or biting midges. Brands with higher concentrations of DEET such as Rid, Tropical Strength Aerogard, Bushman's, and Muskol, or products with higher concentrations of picaridin such as Repel 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 concentrations of DEET greater than 20%. Protection from mosquito penetration through open weave or close fitting 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 gels are best and creams usually last longer than the aerosol formulations. Repellents can prevent bites from 1 to 4 hours, depending on the repellents, the species of biting insect, or the physical activity of the wearer. In general aerosol alcohol based repellents will

only give one hour protection in the tropics so reapplication is necessary. Products labelled low irritant generally mean that they contain less active ingredient.

There are some new metofluthrin vapour active pyrethroid spatial repellents on the market where there is passive evaporation from impregnated strips or pads. These have been shown to be very effective in preventing landing or biting of many species of mosquitoes and midges, even in outdoor situations within a close surround of the devices, or within rooms in more enclosed areas.

Mosquito vapour lanterns (candle operated) or mosquito vapour repellent devices (butane gas operated) that use flame to heat pads impregnated with the synthetic pyrethroid allethrin offer excellent protection from mosquitoes and biting midges in outdoor situations. Mosquito lanterns (various brands) or the gas operated (eg Thermacell) devices are cost effective for events such as barbeques or congregations of people, with two or more dispersed around the group to cater for breeze direction. Since these products are flame operated, they should be placed out of reach of children and well away from fuel sources or flammable objects. They work best in still or light breeze conditions. Insecticide impregnated mosquito coils can offer good protection in relatively wind protected areas such as patios and verandas. Mosquito vapour lanterns, gas operated mosquito vapour repellent devices, and mosquito coils are available from supermarkets, hardware stores and some outdoor/fishing stores.

Electronic insect repellents 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 repellents 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 white light. This can cause pest problems in unscreened houses or when camping. The use of yellow or even better 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 or house or premises they can be knocked down with hand held 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.

There are automatic wall mounted dispensers of aerosol for killing adult mosquitoes or flies that dispense mainly pyrethrins. These are registered for use either indoors or outdoors so care is needed in reading the labels. Generally these dispense aerosol in short bursts every 20 to 40 seconds and can last up to 40 hours before refilling. Outdoors devices need to be in wind protected areas such as verandas and patios.

Other devices that can be effective at killing and/or repelling biting insects include mosquito lanterns and gas operated mosquito vapour repellent devices (Alten 2003; Collier 2006), mosquito coils (Charlwood & Jolley 1984) and electric plug in insecticide pads. The mosquito lanterns generally last about 4 hours for both the candle and the pad effectiveness, so replacement candles and pads are required. The butane powered vapour pads generally last about 4 hours and replacement pads are required, as well as replacement butane burners after 12 hours. The plug in pad devices are very effective inside buildings but care is needed in reading the labels. These devices are more effective in relatively protected or closed areas such as patios, inside buildings, or where there are only slight breezes. Use of vapour lanterns, mosquito vapour repellent devices or coils in outdoor or unscreened areas should be backed up with other measures such as suitable protective clothing or repellents in case of accidental damage or heat method expiry of the devices.

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 malathion, bioresmethrin or pyrethrum. 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 may 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.

The best protection can be obtained by residual synthetic pyrethroids such as bifenthrin, lambda-cyhalothrin and alpha-cypermethrin using barrier sprays around houses or buildings and can provide excellent mosquito protection for up to 6 weeks (Standfast et al 2003, Li et al 2010). These residual insecticides are available as water-based formulations and can be applied (according to label recommendations) with the aid of a garden pressure sprayer or by back pack mechanical misters onto outside walls, fences, solid surfaces and low thick vegetation and shrub areas around houses in a band 1.5 to 2 m high. If there is no vegetation screen around buildings, black weed matting or shade cloth 1.5-2 m high all around fence lines close to the building can substitute for vegetation as the application surface. Application should be at label rates and made to the point of just before runoff. When applying the insecticide to vegetation such as clumps of plants or bushes, it should be applied under leaves as well as on leaves and surfaces. Use of these insecticides can give immediate relief from salt marsh mosquito plagues on a house block scale and the effect should last at least 4 weeks under Darwin conditions.

Barrier applications can be done by householders with appropriate equipment after familiarisation with the chemical and provisions and safeguards for use, although generally it is advisable for motorised back pack applications to be done by a licensed pesticide company.

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.

Bifenthrin based insecticide for barrier applications is available in a 2 litre premixed and ready to use container in the pest control section of supermarkets and hardware stores, while concentrated products containing bifenthrin, lambda-cyhalothrin and alpha-cypermethrin are available from suppliers of agricultural and pest control chemicals.

10.0 INSECTOCUTORS AND INSECT TRAPS

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

11.0 TREATMENT OF BITES

Relief from bites and prevention of secondary infection can be obtained by the application of various products, either to the skin or internally. The effectiveness of various products is variable, depending on individual reaction. Skin application products include proprietary products such as Eurax, Stingose, Medicreme, Katers lotion, Dermocaine and Paraderm crème and topical antihistamine products, and

non-proprietary products such as paw paw ointment, tea tree oil, eucalyptus oil, aloe vera gel, ice, or methylated spirits.

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

Some people have had good results from the application of paw paw ointment following bite reactions in the reducing the itching and aiding the healing process.

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

12.0 EMERGENCY BITING INSECT PROTECTION

There are a number of emergency measures that can be taken when exposed to biting insects with no protection. Sheltering downwind next to smoky fires can offer considerable protection. Burning dung or aromatic and oil producing foliage from plants such as *Hyptis* (horehound), *Vitex* (black plum), *Calytrix* (Turkey bush), *Melaleuca* species (Paper bark) and *Eucalyptus* species (gum trees) can make the smoke more effective. A small native plant *Pterocaulon serrulatum* (warnulpu) has sticky strongly aromatic leaves, and branches are burnt or the moist leaves are rubbed on the skin by Aborigines in the Katherine district to repel mosquitoes (Aborigines of the NT 1988). Another useful widespread Top End native repellent plant, the native cherry (*Exocarpos latifolius*) is used by burning the wood or leaves (Top End Native Plants 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, warnulpu, 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.

References

Aborigines of the Northern Territory of Australia (1988) Traditional Bush Medicines, An Aboriginal Pharmacopoeia, Greenhouse Publications pp 184-185.

Alten, B., Caglar, S., Simsek, F., Kaynas, S., & Perich, M. (2003), 'Field evaluation of an area repellent system (Thermacell) against *Phlebotomus papatasi* (Diptera: Psychodidae) and *Ochlerotatus caspius* (Diptera: Culicidae) in Sanliurfa Province, Turkey'. *J. Med Ento*, 40(6); 930-934.

Brock J. 1988. 'Top End Native Plants'.

Burgess, N., Carter, S., Dodd, G., & Shirley, C. (1988), 'Permethrin fabric treatment for the protection of personnel from biting insect and other arthropod attack', *International Pest Control*, vol. 30, no. 6.

Charlwood, J. D., & Jolley, D., (1984), 'The coil works (against mosquitoes in Papua New Guinea), *Trans Roy Soc Trop Med Hyg*, vol. 78.

Collier, B., Perich, M., Boquin, G., Harrington, S. and Francis, M. (2006), 'Field evaluation of mosquito control devices in southern Louisiana', *Journal of the American Mosquito Control Association*, 22(3); 444-450.

Curtis, C. F. (1986), 'Fact and fiction in mosquito attraction and repulsion', *Parasitology Today*, vol. 2, no. 11.

Helson, B. & Surgeoner, G. (1983), 'Permethrin as a residual lawn spray for adult mosquito control', *Mosquito News*, vol. 43, no. 2.

Jacups S, Kurucz N, Whelan PI and Carter JM (2009) 'A comparison of *Aedes vigilax* larval population densities and associated vegetation categories in a coastal wetland, Northern Territory, Australia' *J. Vector Ecology* 34(2), pp. 311-316. (Dec09).

Jacups S, Whelan PI and Currie B. 2008. 'Ross River virus and Barmah Forest virus infections: a review of history, ecology and predictive models, with implications for tropical northern Australia' *Vector Borne and Zoonotic Diseases* 8:2; 283-97.

Kurucz N, Whelan PI, Carter JM and Jacups S (2009) 'A geospatial evaluation of *Aedes vigilax* larval control efforts across a coastal swampland, Northern Territory, Australia' *J. Vector Ecology* 34(2), pp. 317-323. (Dec09)

Kurucz N, Whelan PI, Jacups SP, Broom A, Melville LF. 2005. 'Rainfall, Mosquito Vector Numbers and Seroconversions in Sentinel Chickens to Murray Valley Encephalitis Virus in the Northern Territory'. *Arbovirus Research In Australia*. 9:188-192.

Lee, D. J. (1975), 'Arthropod bites and stings and other injurious effects', *School of Public Health & Tropical Medicine, University of Sydney*.

Li C. X., Wang Z. M., Dong Y. D., Yan T., Zhang Y. M., Guo X. X., Wu M. Y., Zhao T. Y., Xue R. D (2010). 'Evaluation of lambda cyhalothrin barrier spray on vegetation for control of *Aedes albopictus*'. *Journal of the American Mosquito Control Association*, vol. 26, no. 3, pp. 345-348.

Lines, J. D., Curtis, C. F., Myamba, J., Njau, R. (1985), 'Tests of repellent or insecticide impregnated curtains, bednets and anklets against malaria vectors in Tanzania', *WHO VBC/85.920*.

Matsuda, B. M., Surgeoner, G. A., Heal, J. D., Tucker, A. O., Maciarelo, M. J. (1996), 'Essential oil analysis and field evaluation of the citrosa plant *Pelargonium citrosum* as a repellent against populations of *Aedes* mosquitoes', *Journal of the American Mosquito Control Association*, vol. 12, no. 1, pp. 69-74.

Mitchell, L. (1992), 'Mythical mosquito control', *Wing Beats*, vol. 3, no. 2, Florida Mosquito Control Association.

Russell, R. C. (1995), 'Arboviruses and their vectors in Australia: an update on the ecology and epidemiology of mosquito borne viruses', *Review of Medical Veterinary Entomology*, vol. 83, no. 4.

Schreck, C. E., Haile, D. G., Kline, D. L. (1984), 'The effectiveness of permethrin and deet alone or in combination for protection against *Aedes taeniorhynchus* ', *Am J Trop Med Hyg*, vol. 33, no. 4.

Standfast H., Fanning I. Maloney L., Purdie D. and Brown M. "Field evaluation of Bistar 80SC as an effective insecticide treatment for biting midges (Culicoides) and mosquitoes infesting peri-domestic situations in an urban environment" Bulletin Mos Cont Assoc Aust Vol 15 ;2 2003.

Whelan, P. I. (1990), 'Biting midge investigations near Darwin and their implications for urban planning', *Proceedings of the National Conference on Biting Midge, Surfers Paradise*, February 1990.

Whelan, P. I., Hayes, G., Montgomery, B. L.(1997), 'Biting midge surveillance in Darwin harbour, *Culicoides ornatus* (Diptera: Ceratopogonidae) abundance and dispersal', *Proceedings of the Seventh Symposium "Arbovirus Research in Australia", Second Conference Mosquito Control Association of Australia*, Surfers Paradise.

Whelan PI. 2003. 'Biting Midges or "Sand Flies" in the NT' 2003'. *The Northern Territory Disease Control Bulletin*. 10:3:1-9.

Whelan PI, Jacups SP, Melville L, Broom AK, Currie BJ, Krause VL, Brogan B, Smith F. and Porigneaux P. 2003. 'Rainfall and vector mosquito numbers as risk indicators

for mosquito borne disease in Central Australia'. *Communicable Disease Intelligence*. 27:1:110-116.

Whelan PI, Van Den Hurk A. 2003. 'Medically important insects in the Northern Territory and how disasters may affect them'. *The Northern Territory Disease Control Bulletin*. 10:1:27-38.

Whelan PI. 2005. 'Bites and stings in the Top End and how to avoid them'. *Northern Territory Disease Control Bulletin*. 12:3:20-27.

Whelan PI. 2007. 'Mosquito Control in Leanyer Swamp'. *Northern Territory Disease Control Bulletin*. 14:2:19-20.

Whelan PI. 2007. 'Mosquito Vector Control in the Northern Territory'. *Northern Territory Disease Control Bulletin*. 14:2:12-18.

Whelan, P. I., Merianos, A., Hayes, G., & Krause, V.(1997) , 'Ross River virus transmission in Darwin, Northern Territory, Australia', *Proceedings of the Seventh Symposium "Arbovirus Research in Australia", Second Conference Mosquito Control Association of Australia*, Surfers Paradise.

Whelan P I 2008. 'Personal mosquito protection while overseas' *Northern Territory Disease Control Bulletin*. 15:1:18-19.

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