

Appendix G

Biting Insect Survey and Assessment Blacktip Project June 2004 prepared by Northern Territory Medical Entomology



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**Northern
Territory
Government**

Department of Health
and Community Services

Biting Insect Survey and Assessment

BlacktipProject

June 2004

13 July 2001

Study undertaken on behalf of EcOZ Environmental Services
for
Woodside Energy Ltd

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Synopsis

Background

The Blacktip Project consists of both offshore and onshore components. The onshore components include the construction and operation of an onshore processing plant, construction and operation of 3km of buried onshore pipeline, and the construction of access roads and construction camp. There were potential biting insect concerns associated with these onshore components of the Blacktip Project.

EcOZ Environmental Services was commissioned by Woodside Energy Limited (Woodside) to assist in the preparation of a Draft Environmental Impact Statement (EIS) for the Blacktip Project. EcOZ Environmental Services then commissioned the Medical Entomology Branch of the Department of Health and Community Services to provide information on biting insects likely to affect the Blacktip Project.

The Medical Entomology Branch (MEB) of the Department of Health and Community Services (DHCS) was commissioned to;

- Conduct field surveys to locate actual and potential freshwater, brackish and salt marsh water mosquito breeding sites likely to affect the development area.
- Conduct adult biting insect trapping to indicate species and relative numbers of biting insects likely to affect the development area.
- Conduct a desktop study to indicate potential pest *Culicoides ornatus* biting midge breeding sites.
- Identify any risk areas where the construction of the gas pipeline and onshore gas processing facility may lead to the creation of mosquito breeding sites.
- Provide information on mitigation measures to ensure the construction of the gas pipeline and onshore gas processing facility does not lead to the creation of new mosquito breeding sites and to prevent the importation of exotic mosquito species.
- Provide information on mitigation measures to reduce the negative health impacts associated with biting insects.

Survey and report

A field survey was conducted in June 2004 to locate actual and potential freshwater and brackish water mosquito breeding sites. Adult biting insect trapping was conducted one night before the full moon in June 2004 to indicate the post wet season relative numbers of *Anopheles*, *Culex*, *Coquillettidia* and *Mansonia* mosquito species, and the monthly peak of the human pest mangrove biting midge species *Culicoides ornatus*. The following report outlines the findings of the June 2004 adult biting insect trapping and field survey. Further biting insect trapping will be conducted in September 2004 to indicate peak season pest biting midge numbers, and in November 2004 to indicate peak season salt marsh mosquito numbers, with additional field surveys to locate further potential mosquito breeding sites.

A desktop assessment was made using aerial photography to indicate potential human pest biting midge breeding sites.

Findings

The major findings from the June 2004 survey and assessment were:

Biting midges

a) Species

- *Culicoides ornatus* was the principal species of biting midge collected, representing 87.4% of all biting midges recovered

b) Source

- The largest biting midge breeding sites likely to affect the Blacktip Project area are the upper tidal creek mangrove areas associated with Swamp 2, which is located approximately 3km south-west of the onshore gas processing plant. Minor breeding sites may be the *Sonneratia* mangrove foreshores adjacent to the onshore pipeline crossing. Minor breeding sites may also be located in the small mangrove tidal creek area associated with Swamp 1, approximately 2km north of the onshore gas processing plant.

c) Pest problem

- *Culicoides ornatus* will be the principal biting midge pest species in the Blacktip Project development area.
- *Culicoides ornatus* may cause minor pest problems in the Blacktip Project development area in the months of August to November. It is unlikely that pest numbers of this species will affect the development area during other periods of the year.
- Highest numbers will be present in those areas of the development nearest to Swamp 2.
- Pest problems, when they occur, will be greatest for three or four days around the full moon and new moon periods in the months of August to November, with numbers being greater during full moon periods. Pest problems are likely to be greatest one hour either side of sunset, and one hour either side of sunrise.
- Adult biting midge trapping in September 2004 around the time of the full moon will be conducted to indicate actual peak season numbers of *C. ornatus* affecting the Blacktip Project area.

d) Mitigation measures

- The development will not reduce or affect the *C. ornatus* breeding sites likely to affect the Blacktip Project area.
- High use personnel areas such as accommodation, mess and recreation areas should be screened and landscaped to allow effective insecticide barrier control of midges. Yellow or red lights should be used in outdoor personnel areas, as well as light proof curtains for personnel buildings, to prevent attracting biting midges.
- The use of white or UV lights in non-personnel areas can be used to divert biting midges away from personnel areas.
- It is unlikely that *C. ornatus* will reach numbers sufficient to warrant fogging with insecticides in the development area, due to the considerable buffer distance of the development area from Swamp 2.

- The elimination of biting midge breeding sites is not feasible. It would require the filling of a considerable portion of the upper tidal creek mangrove areas in Swamp 1 and 2, and the filling of the entire *Sonneratia* mangrove foreshores adjacent to the onshore pipeline crossing.
- The workforce and visitors should be notified of a potential minor biting midge pest problem in the months of August to November, and they need to take appropriate personal protection precautions.
- The NT Government will not be responsible for any biting midge monitoring or control operations at the development site and within the vicinity of the development.

Mosquitoes

a) Species

- The species occurring in highest numbers during June 2004 were, in decreasing order of prevalence, *An. farauti* s.l. (the Australian malaria mosquito), *Cx. annulirostris* (the common banded mosquito), *Cq. xanthogaster* (the golden mosquito), *Cx. sitiens* (the salt water *Culex* mosquito) and *Oc. vigilax* (the salt marsh mosquito).
- *Anopheles farauti* s.l., *Cx. annulirostris* and *Oc. vigilax* will be the most important mosquito species affecting the Blacktip Project development area.

b) Source

- By far the major source of mosquitoes to the Blacktip Project area will be Swamp 1, a tidal and rainwater influenced swamp located approximately 1.5km north of the onshore gas processing plant. This swamp will be a breeding ground for extreme numbers of *Oc. vigilax*, very high numbers of *An. farauti* s.l. and high to very high numbers of *Cx. annulirostris*. This swamp will also be a breeding ground for non-disease transmitting pest mosquito species such as *Cq. xanthogaster*, *An. bancroftii* and *Ma. uniformis*.
- Swamp 2, a tidal and rainwater influenced swamp located approximately 3km south-west of the onshore gas processing plant, will also provide pest numbers of *Oc. vigilax* to the development sites. The interdunal areas adjacent to the coastal vine thicket to the south (referred to as 'Southern Coastal Vine Thicket') of the onshore gas pipeline crossing is also a likely significant *Oc. vigilax* breeding site.

c) Pest and potential disease problem

- *Ochlerotatus vigilax* will pose the greatest pest problem. Severe pest problems may occur for up to 10 days per month from September to January inclusive. Low to moderate pest problems may occur in February. Pest numbers will appear from 9 days after significant rainfall or monthly high tides in the months of September to February.
- *Ochlerotatus vigilax* will pose a high risk for Ross River Virus (RRV) and Barmah Forest Virus (BFV) transmission in the October to January period.
- *Culex annulirostris* were trapped in moderate pest numbers. A moderate pest problem from this species is likely to occur in the mid to late wet season months of January, February and March, with high to very high pest problems in the post wet season months of April, May and June. This species will pose a high risk for RRV and BFV transmission in January to March and a high risk for MVEV transmission from January to June.
- *Anopheles farauti* s.l. will pose a very high risk of local malaria transmission at the Blacktip Project development site, should a person with the infective stages of malaria be present in the

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development area from April to June. High risk areas are located near Swamp 1 and the northern section of the onshore gas processing plant.

- Other mosquito species including *Cq. xanthogater* and *An. bancroftii* will cause pest problems only, mainly in the post wet season months of April, May and June.

d) Mitigation measures

- Advice should be given to all employees and visitors by the Blacktip Project Environmental Officer on the need for periodic personal protection measures against mosquitoes at the Blacktip Project area, to reduce pest problems and reduce exposure to mosquito borne diseases. Potential problem areas and problem periods should be pointed out to workers.
- Any mosquito complaint should be forwarded to the Blacktip Project Environmental Officer, who can then take remedial action by advising appropriate personal protection and advising other workers or visitors of problem periods or areas during the construction phase.
- Possible malaria cases should be reported as soon as possible to a doctor and health authorities, and mitigation measures put in place to ensure potential and actual cases are kept away from mosquitoes. This is to prevent the infection of local populations of *Anopheles* mosquitoes and subsequent local transmission. Employees recently arrived or returning from overseas should receive malaria awareness material.
- During the construction phase, any vessels and cargo capable of holding small amounts of water, such as machinery, used tyres etc from overseas or North Queensland should be inspected as per DHCS guidelines (Appendix 8) by the Blacktip Project Environmental Officer. This is to prevent the introduction of exotic dengue transmitting mosquitoes (*Ae. aegypti* and *Ae. albopictus*). Any road transport and cargo from North Queensland and Tennant Creek should also be inspected by the Blacktip Project Environmental Officer as per DHCS guidelines (Appendix 8), to prevent the introduction of *Ae. aegypti*. Any larvae found should be sent to the MEB laboratory in Darwin for analysis, with appropriate remedial action advised or coordinated by MEB.
- Artificial receptacles such as tyres, drums etc should be disposed of by landfill, holed or stored away from rainfall. If this is not possible, ongoing sanitation measures such as treatment with a chlorine solution or residual insecticide would be required to prevent mosquito breeding. Monthly inspections of artificial receptacles holding rainwater by the Blacktip Project Environmental Officer for mosquito breeding should be conducted during the construction phase, and a final inspection should be conducted upon the completion of construction, with appropriate treatment applied when necessary. Any larvae found should be sent to the MEB laboratory in Darwin for analysis, with appropriate remedial action advised by MEB.
- Swamps 1 & 2 should be burned annually as soon as possible after the swamps dry out each wet season. Burning reduces shelter for mosquito larvae, which allows predator access to larvae. The Blacktip Project Environmental officer should conduct inspections in late June or July to observe if the swamps are dry enough to burn.
- A mosquito larval control program for Swamp 1 should be established and conducted by the proponents and under the duties of the Blacktip Project Environmental Officer, to detect and control salt marsh mosquitoes during the construction phase. Helicopter larval control should be carried out at least in the productive reed areas of the swamp. The MEB will delineate the potentially most productive salt marsh mosquito breeding areas in September 2004 and provide this information to the proponents. The larvicide of choice would be a methoprene 30 day residual pellet formulation. The residual pellets should be applied at Swamp 1 before the October monthly high tide, and reapplied after every 30 days of water inundation in the breeding site until the end

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of January. The Medical Entomology Branch should be consulted on any mosquito larval survey and control program.

- Stormwater drains throughout the development should have erosion control structures where appropriate. Drains with the likelihood of dry season low flows should be formalised with impervious linings and low flow facilities. All drains would need to be maintained annually to remove excess silt and vegetation. Drains should discharge to a suitable end point where water can not pool in downstream areas and cause mosquito breeding. Drains should not discharge water to Swamp 1, as this could exacerbate mosquito breeding in this swamp. Drains should be monitored monthly for mosquito breeding during the construction phase by the Blacktip Project Environmental Officer, with samples sent to the MEB laboratory in Darwin for analysis and advice on rectification measures.
- The processed water settling ponds should be deep and constructed with steep sides (1:2, 1:3 or 1:4 slope) to discourage marginal vegetation growth. A slightly sloping floor should be constructed so that during low water periods all of the water is contained in one area. Provisions should be allowed to ensure overflow water does not pool in any downstream areas, which could exacerbate mosquito breeding. The processed water ponds should be checked monthly for mosquito breeding by the Blacktip Project Environmental Officer during the construction phase, with any larvae found sent to the MEB laboratory in Darwin for analysis and control recommendations.
- The bunded drains, washdown area, condensate and fuel bunded areas, as well as any other bunded area should contain provisions that ensures that water does not pool for more than five days in these structures, to prevent mosquito breeding. It may be necessary to drain these areas into the processed water settling ponds on a weekly basis in the wet season, and whenever necessary to prevent mosquito breeding in the dry season. These areas should be formalised to prevent the establishment of vegetation and consequent mosquito breeding. These areas should be monitored monthly for mosquito breeding by the Blacktip Project Environmental Officer during the construction phase, with any larvae found sent to the MEB laboratory in Darwin for analysis advice.
- Construction activities should be monitored by the Blacktip Project Environmental Officer, to ensure activities such as machinery disturbance does not lead to the creation of new mosquito breeding sites. This would include monthly inspections for mosquito breeding during the wet season, with samples sent to the MEB laboratory in Darwin for analysis and advice.
- Sewage treatment facilities should dispose of effluent through sprinkler irrigation to designated areas or dispose of effluent to regularly flushed tidal areas. Disposal to regularly flushed tidal areas is the preferred option in regard to preventing mosquito breeding.
- Any high use personnel area for the onshore gas processing plant should be sited on the southern section of the onshore gas processing plant, as far away from Swamp 1 as possible. This is to create a greater buffer distance between personnel areas and the extensive mosquito breeding sources of Swamp 1.
- White or UV lights should be sited away from personnel areas, to divert mosquitoes to some extent away from personnel areas. Outdoor personnel areas should be fitted with yellow or red lights, and have light proof curtains fitted to prevent inside lights from attracting mosquitoes.
- The barrier spray bifenthrin should be utilised around personnel areas, to control adult mosquito numbers. The benefits of this product will be enhanced by planting shrub type vegetation or constructing a fence with dark shade matting around personnel areas, which can then be treated with the product. The shrub type vegetation or dark fencing will be attractive resting places for

mosquitoes (as well as biting midges), and they will receive a dose of the chemical when they rest on the treated surface. Bifenthrin can also be sprayed on insect screens and any other likely mosquito resting place.

- The laying of the underground pipeline must not result in the impediment of the natural flow of surface water. The finished surface must be level with the surrounding land. Any upstream embankment of water could lead to the creation of mosquito breeding sites. Any leftover spoil should not result in the embankment of water.
- Soil erosion, silt deposition and pooling of rain in excavations will need to be prevented to reduce the potential to create new mosquito breeding sites. Any disturbance caused by machinery should be rectified as soon as possible.
- Any sand or gravel pit in the Blacktip Project area and within 1.5km of the Blacktip Project area or Port Keats residential area should be filled or made free draining. No borrow pits should be constructed in an area with high wet season water tables to prevent new surface water features.
- Access roads should be fitted with culverts where necessary, to prevent the upstream ponding of water that can lead to mosquito breeding.

Recommendations

The major recommendations arising from the findings of the study are:

Biting midges

- The use of bifenthrin barrier treatments around personnel areas should be implemented to reduce adult biting midge numbers that could affect the workforce.
- The workforce and visitors should be notified of a potential minor biting midge pest problem in the development area in the months of August to November.

Mosquitoes

- There will be a requirement for periodic personal protection against mosquitoes at the Blacktip Project area to reduce pest problems and exposure to mosquito borne disease.
- Possible malaria cases should be reported as soon as possible to health authorities, and mitigation measures put in place to ensure potential and actual cases are kept away from mosquitoes.
- High use personnel areas should be sites as far away as possible from Swamp 1.
- Any vessels and cargo such as machinery or other receptacles capable of holding small amounts of water from overseas or Queensland, and road transport cargo from Queensland or Tennant Creek should be inspected as per DHCS guidelines to prevent the introduction of the dengue mosquito.
- Mosquito larval control with methoprene 30 day residual pellets is recommended for Swamp 1, to control salt marsh mosquitoes. This is recommended for the construction phase.
- Swamps 1 & 2 should be burned annually during the construction phase when the swamps dry after the wet season.
- Stormwater drains should be constructed in a manner that does not lead to the creation of new mosquito breeding sites.

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- The processed water settling ponds should be constructed in a manner that does not lead to the creation of mosquito breeding sites. Hardy native fish species should be stocked in the settling ponds.
- Bunded areas should be managed to prevent mosquito breeding.
- Artificial receptacles should be managed to prevent mosquito breeding.
- Sewage treatment facilities should dispose of effluent through sprinkler irrigation or disposal to a regularly flushed tidal area. Disposal to a regularly flushed tidal area is the preferred option.
- Bifenthrin barrier treatment should be used around high use personnel areas, to reduce adult mosquito populations in these areas.
- The laying of the underground pipeline must not result in the ponding of water or impediment of the natural flow of surface water.
- Construction activities should be monitored, to ensure activities such as machinery disturbance does not lead to the creation of new mosquito breeding sites.
- The construction of borrow pits must not lead to the creation of mosquito breeding sites, and should be avoided within 1.5km of personnel areas and 1.5km of Port Keats residential areas.
- Access roads should be fitted with culverts where necessary, to prevent the upstream ponding of water that can lead to mosquito breeding.

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1.0 Introduction

1.1 Background

The Blacktip Project consists of both offshore and onshore components. The onshore components include the construction and operation of an onshore processing plant, construction and operation of 3km of buried onshore pipeline, and the construction of access roads and construction camp. There were potential biting insect concerns associated with these onshore components of the Blacktip Project.

EcOZ Environmental Services was commissioned by Woodside Energy Limited (Woodside) to assist in the preparation of a Draft Environmental Impact Statement (EIS) for the Blacktip Project. EcOZ Environmental Services then commissioned the Medical Entomology Branch of the Department of Health and Community Services to provide information on biting insects likely to affect the Blacktip Project.

The Medical Entomology Branch (MEB) of the Department of Health and Community Services (DHCS) was commissioned to;

- Conduct field surveys to locate actual and potential freshwater, brackish and salt marsh water mosquito breeding sites likely to affect the development area.
- Conduct adult biting insect trapping to indicate species and relative numbers of biting insects likely to affect the development area.
- Conduct a desktop study to indicate potential pest *Culicoides ornatus* biting midge breeding sites.
- Identify any risk areas where the construction of the gas pipeline and onshore gas processing facility may lead to the creation of mosquito breeding sites.
- Provide information on mitigation measures to ensure the construction of the gas pipeline and onshore gas processing facility does not lead to the creation of new mosquito breeding sites and to prevent the importation of exotic mosquito species.
- Provide information on mitigation measures to reduce the negative health impacts associated with biting insects.

1.2 Survey and report

A field survey was conducted in June 2004 to locate actual and potential freshwater and brackish water mosquito breeding sites. Adult biting insect trapping was conducted one night before the full moon in June 2004 to indicate the post wet season relative numbers in *Anopheles*, *Culex*, *Coquillettidia* and *Mansonia* mosquito species, and the monthly peak of the human pest mangrove biting midge species *Culicoides ornatus*. The following report outlines the findings of the June 2004 adult biting insect trapping and field survey. Further biting insect trapping will be conducted in September 2004 to indicate peak season pest biting midge numbers, and in November 2004 to indicate peak season salt marsh mosquito numbers, with additional field surveys to locate further potential mosquito breeding sites.

A desktop assessment was made using aerial photography to indicate potential human pest biting midge breeding sites.

1.3 Acknowledgments

We wish to acknowledge the assistance of Kylie Harvey of EcOZ Environmental Services who provided background information and aerial photography of the Blacktip Project.

We wish to acknowledge Ceri Morgan from Woodside Energy Ltd for on-site field co-ordination with the NLC, and Des Stones from Woodside Energy Ltd who provided MEB with a satellite phone for safety purposes.

We wish to acknowledge Popeye Briston and other NLC staff for assistance in navigation to the various survey sites.

MEB officer Jane Carter identified the mosquitoes. MEB officers Jane Carter and Allan Warchot identified the biting midges.

Figures were prepared by Jane Carter. Tables by Jane Carter and Allan Warchot. Text by Allan Warchot and Peter Whelan.

2. Project Aims

2.1 Aims

The aims were to;

- Conduct adult biting insect trapping at locations around the development area to locate likely biting insect problem areas.
- Conduct field surveys to locate actual and potential mosquito breeding sites
- Identify potential biting insect issues in regard to the development of the onshore gas pipeline and onshore gas processing plant.
- Provide mitigation strategies to prevent the creation of new mosquito breeding sites during the construction of the gas pipeline and associated facilities.
- Provide mitigation strategies to reduce biting insect pest problems, and to prevent the introduction of exotic mosquito species and mosquito borne disease into the development area.
- Outline potential biting insect health risks and risk periods for the workforce.

2.2 Significance and scope of the project

An evaluation of the Blacktip Project development area for potential biting insect problems is required for the Draft EIS. It is also a requirement to consider the impact of the development on biting insect populations and outline management procedures to reduce the impact of these insects.

Biting midges can be considerable pests within a few kilometres of the coast in the NT (Whelan 1991a). These pests can disrupt the work force by causing direct effects due to their painful bites, and indirect effects due to secondary infection and loss of a sense of well being. Minor biting midge pest problems can also occur near freshwater lakes and streams.

Mosquitoes are a serious potential public health issue in the NT, both as pest insects and as vectors of a number of human diseases including the potentially fatal disease caused by Murray Valley encephalitis virus (MVEV), and a number of other diseases caused by Kunjin virus (KUNV), Ross River virus (RRV) and Barmah Forest virus (BFV).

The onshore gas processing plant development boundary is located approximately 1km from the nearest shoreline, approximately 1.5km south of a tidal and paperbark swamp, and approximately 3km north of a tidal swamp (Figure 2). Preliminary observations of aerial photographs indicated these were potentially significant mosquito breeding sites likely to affect the onshore development. The main mosquito species considered likely to affect the onshore development was the salt marsh mosquito *Ochlerotatus vigilax*, and the common banded mosquito *Culex annulirostris*. Both of these species are vectors for RRV and BFV, with *Cx. annulirostris* also a vector for MVEV. The onshore development was also considered to be subject to biting midge pest problems arising from the mangrove areas associated with these tidal swamps, and from the three mangrove foreshore sites adjacent to the onshore pipeline crossing.

In order to gauge the mosquito problem likely to affect the onshore part of the Blacktip Project, mosquito trapping was proposed to be carried out during the early dry season, to give an indication of the presence and relative numbers of most *Culex*, *Coquillettidia* and *Anopheles* species. Trapping was

also proposed to occur from 10 days after the monthly high tide in November over two nights, to indicate peak numbers of the salt marsh mosquito *Oc. vigilax*.

Trapping for biting midges, and in particular the mangrove biting midge species *C. ornatus* was also planned to occur at the same time as for mosquito trapping, with additional trapping over three nights around the full moon in September to indicate peak numbers of *C. ornatus* likely to affect the onshore element of the Blacktip Project.

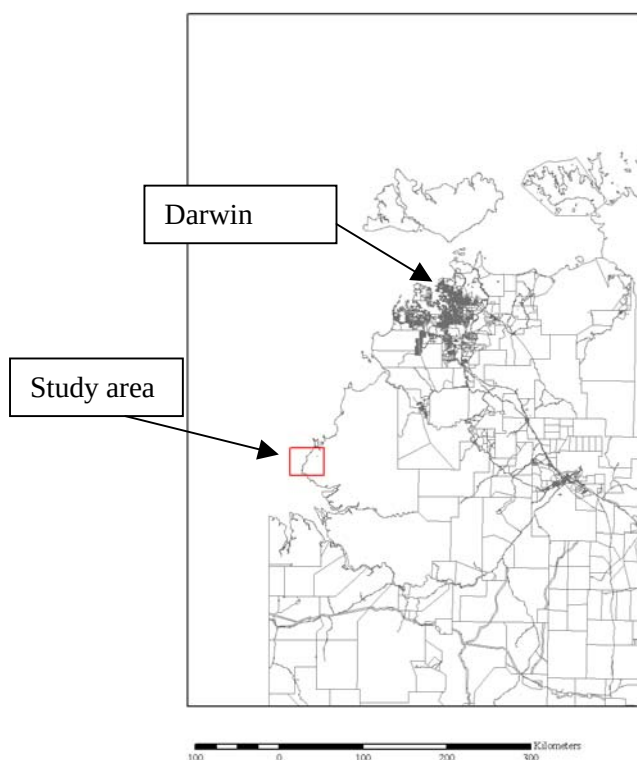
Seasonal trends of biting midges and mosquitoes were to be interpreted from relevant studies around Darwin. Potential biting midge breeding sites were to be assessed from aerial photographs using the biology of the biting midge, in particular *C. ornatus*. *Culex* and *Anopheles* species breeding sites were to be assessed in the early dry season when seasonal pools and swamps were present. Salt marsh mosquito breeding sites were to be assessed from inspections in June, September and November 2004, to locate upper tidal and dunal areas likely to hold tidal and rain water.

The following report highlights the findings of the June 2004 adult biting insect trapping and field surveys, with the associated discussion, conclusions and recommendations.

2.3 Study Site

The Blacktip Project area is near Port Keats on the western coast of the Northern Territory, with gas planned to be piped from the Joseph Bonaparte Gulf to an onshore gas processing plant approximately 8km west of the Port Keats community. The onshore gas facilities are located between two tidal swamps to the north and south, with a paperbark swamp associated with the tidal swamp to the north. The study area in regards to Darwin is outlined in Figure 1 below, with the study area alone further indicated in Figure 2.

Figure 1: Blacktip Project study area



3. Methods

3.1 Field inspection

3.1.1 Habitat inspection

Intensive field inspections of mosquito habitats were carried out during the early dry season on the 3rd of June, 2004. Evaluations of actual and potential mosquito breeding sites were made. Prospective habitats or habitats with water were inspected for the presence of mosquito larvae, aquatic predators, and vegetation. Potential mosquito breeding sites were sampled with a standard 270ml volume ladle dipper. Potential mosquito breeding sites were assessed for potential productivity based on topographical features, localised depressions, the presence of poorly draining areas, and vegetation patterns indicating location and extent of tidal influence or freshwater inundation.

No ground inspections were made for biting midge breeding sites. Assessments of potential *C. ornatus* biting midge breeding sites were made from aerial photographs using the known biology of *C. ornatus*.

Assessments of air photos were made to determine potential mosquito breeding and biting midge breeding sites before ground inspections.

3.1.2 Trap site selection

Assessments of air photos were made to locate likely areas to set adult biting insect monitoring traps. Actual adult biting insect trap sites were selected during initial field inspections on the morning of June 2nd 2004. Trap sites were selected based on proximity to potential breeding sites, to assess the productivity of these sites. This included setting traps near the tidal swamps to the north and south of the proposed development. Trap sites were also set near the onshore gas processing plant boundary, and where the gas pipeline crosses the shoreline, to gauge the biting insect problem likely to affect workers and the likely source of the biting insects.

All the trap sites were marked with flagging tape and referenced using a hand held Garmin GPS unit, to allow for the exact location of these sites during the initial and future trapping. The trap sites are indicated in Figures 2 & 3. Photos of the trap sites are in Appendix 1.

3.2 Survey dates and seasonal timing

Trapping for adult biting insects commenced mid afternoon on 2nd June, with traps collected the following mid-morning. This was designed to collect late afternoon, evening, night and early morning contributions to total midge and mosquito numbers. Trapping start dates and seasonal timing was;

- June 2, 2004 – Early dry season. Trapping one night before the full moon to monitor monthly highs in *C. ornatus* numbers, and post wet season presence and relative numbers of *Coquillettidia*, *Mansonia*, *Culex* and *Anopheles* species originating from nearby wetlands.

Further trapping and field surveys are proposed for;

- September 2004 – Late dry season. Trapping for three nights around the full moon to monitor peak season numbers of *C. ornatus*.
- November 2004 – Early Wet Season. Trapping for two nights starting 10 days after the monthly high tide to monitor peak season numbers of the salt marsh mosquito *Ochlerotatus vigilax*.

Habitat surveys were carried out on the 3rd of June 2004, to evaluate the presence of water and mosquito habitats resulting from the wet season, and the physical nature of the habitats. Surveys were

also conducted to locate potential salt marsh mosquito breeding habitats by locating potential or actual poorly draining areas within the upper tidal zone and coastal areas.

Further habitat surveys of upper tidal and coastal areas are to be conducted in September and November 2004.

3.3 Biting midge trapping

Trapping for the presence and relative abundance of biting midges was carried out overnight using carbon dioxide baited EVS traps (Rohe and Fall 1979). The traps consist 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.

Biting midges were collected from the trapping on the night of June 2, 2004, and will be collected during three nights trapping in September 2004 and two nights trapping in November 2004. Traps in June 2004 were set between 1430 hours and 1600 hours, and collected the following morning between 0800 hours and 1030 hours.

Trap collections were killed by placing the catch containers in an esky with dry ice. The contents were carefully emptied into tissues, and the tissues gently folded and placed into sample containers. The sample containers with the catch contents were then returned to the esky with dry ice to preserve the catch. Trap collections were then transported back to the MEB laboratory in Darwin for processing.

At the MEB laboratory in Darwin, mosquitoes and biting midges were separated using a sieve. The midges were stored in 70% alcohol in individual tubes for each collection. For individual collections of 50 midges or less, all individual midges were identified. For midge collections above 50 individuals but below 1000 individuals, a sub-sample of 50 midges was identified, with the remaining bulk examined for any species not identified in the sub-sample. For collections over 1000 individuals, a sub sample of 50 individuals was identified, with a further sub-sample of 600 individuals scanned for any species not identified in the sub-sample of 50 individuals. Midges were identified with the aid of stereo microscopes using wing photos and taxonomic references (Dyce & Welling 1998, Wirth and Hubert 1989). Total numbers were estimated using a standard volume/number comparison method.

3.4 Biting midge population and seasonal trends

The species and relative numbers of human pest biting midges collected during the biting insect trapping for the Blacktip Project will be compared to the seasonal trend in pest *Culicoides* numbers collected during the Fairway Waters (Palmerston) study (Whelan et al 1998). Biting midge data from trapping in September 2004 will provide an overall picture on the maximum pest biting midge population likely to be experienced in the development area, and allow for comparisons with seasonal data collected for the Fairway Waters study to predict seasonal trends and populations likely to be present at the Blacktip Project development area.

The Fairway Waters study trapping was carried out on the night of the full moon for twelve continuous months, and hence is indicative of maximum seasonal numbers of the pest biting midges *C. ornatus*. *Culicoides ornatus* is the main biting midge species likely to affect the Blacktip Project development area. Seasonal trends in *C. ornatus* numbers in Fairway Waters should be similar to seasonal trends in *C. ornatus* numbers in the Blacktip Project area.

3.5 Mosquito trapping

Mosquitoes were sampled by the same traps used above for biting midge sampling. For mosquito collections under 300 individuals, all mosquitoes were individually identified. For mosquito collections over 300 individuals, a sub-sample of approximately 300 individuals was taken for

identification and weighed, with the remaining bulk sample also weighed. The bulk weight was divided by the sub-sample weight, to determine the multiplication factor for which the sub-sample was multiplied by to determine total numbers. All individuals in the sub-sample were identified, with the remaining bulk scanned for any species not detected in the sub-sample. Any additional species located in the bulk were entered into a database with the species from the sub-sample, but were excluded from multiplication.

3.6 Mosquito population and seasonal trends

An evaluation of the probable maximum numbers and relative numbers of all species of mosquitoes would require monthly trapping for a complete year, combined with trapping 10 days after a monthly high tide or significant rainfall in November or December. Monthly trapping for a complete year will not be conducted for the Blacktip Project.

Trapping in June 2004 for the Blacktip Project allowed for an indication of post wet season numbers of most *Culex*, *Anopheles*, *Coquillettidia* and *Mansonia* species. The unseasonal and above average rainfall in May has meant that mosquito numbers recorded in June are probably good indications of the likely magnitude of the relative numbers of the species. Trapping in November will allow for an indication of likely maximum numbers of the salt marsh mosquito.

The seasonal trend in mosquito populations likely to be encountered at the Blacktip Project development area can be interpreted from an evaluation of the weekly mosquito monitoring trapping at the Holmes Jungle trap site in Darwin. The Holmes Jungle trap site is located nearby to an extensive freshwater and brackish water reed swamp, similar in nature to the freshwater and brackish water reed swamp north of the Blacktip Project onshore gas processing facility. The reed swamp to the north of the Blacktip Project onshore gas processing facility is larger than the Holmes Jungle reed swamp, although there are semi-aquatic vegetation differences that indicate the peaks in mosquito numbers at the Blacktip Project area will occur a number of weeks sooner than at Holmes Jungle.

4. Results

4.1 Habitat survey

The Blacktip Project onshore gas facility is located approximately 1.5km south of a large seasonally inundated reed swamp subject to both tidal and freshwater flooding and a seasonally flooded paperbark swamp adjacent to the reed swamp (Swamp 1, Figure 5a). A small tidal creek is associated with Swamp 1. The facility is also located approximately 3km north of large tidal areas that includes a tidal creek, mudflat and salt-water grass areas (Swamp 2, Figure 5b). The gas pipeline crosses the shore between two large coastal vine thickets, and between three mangrove foreshore areas (Figures 5a & 5b).

The largest potential mosquito breeding site nearby to the development area is Swamp 1, with Swamp 2 also likely to contribute to mosquito populations at the Blacktip Project development area. Poorly draining interdune areas adjacent to the coastal vine thickets are also likely to contribute mosquito numbers at the development area.

Potential biting midge habitats assessed from air photos were present along three foreshore mangrove areas near the gas pipeline shore crossing (Figures 5a & 5b), and at the mangrove areas associated with Swamps 1 & 2 (Figures 5a & 5b).

The results of the field surveys are presented in Table 3, with the results of the larval surveys and salinity samples of some sites shown. Photos of the larval habitats are presented in Appendix 2.

4.1.1 Field survey 2 and 3 June 2004

This initial field survey was carried out to locate trap sites and to identify major post wet season mosquito breeding areas. Surveys of potential late dry, and early to mid wet season mosquito breeding sites were also carried out. Trap location sites are shown in Figures 2 & 3, and photos of trap locations are shown in Appendix 2. Larval collection results and water sample results are shown in Table 3. Larval sample locations are shown in Figures 5a & 5b.

4.1.1.1 Swamp 1

Swamp 1 was a broad area (Approximately 5ha was surveyed or visually located) containing dense green *Eleocharis* reed areas, a large paperbark forest fringing the upper tidal area, large tidal mudflats, *Sporobolus virginicus* tidal grass areas, as well as small mangrove areas and large *Schoenoplectus* reed areas. The entire swamp was not surveyed. The area of swamp surveyed or visually located is highlighted in Figure 5a. Associated photos are provided in Appendix 2.

The swamp was extensively flooded during the time of the survey. The exact extent and vegetation make up of the swamp was not determined, due to access difficulties across the flooded swamp and time constraints. The exact extent and vegetation make up of the swamp will be determined in September 2004, when the swamp is dry and easily accessible. It can be assumed that the swamp drains towards the mangrove creek located north-west of the reed swamp areas.

Between the beachline and the swamp was a high sand dune (approximately 4m high in some sections). The tidal limit of the south-west end of the swamp consisted of dense emergent and lodged *Eleocharis* reeds adjacent to the sand dune, extending along the western side of a mudflat and grading into *Schoenoplectus* reed areas, and a large *Sporobolus* tide grass area (Approximately 5000m²). The mudflat was approximately 5000m². To the east of the mudflat, *Sporobolus* and other tidal grass species bordered an open, green grassy paperbark area that was dry at the time of visit, and appears to be well drained. Standing *Schoenoplectus* reeds were noticed bordering all of the mangrove areas in the south-west end of the swamp. The *Schoenoplectus* and mangrove area downstream of the *Eleocharis* reeds and mudflat was approximately 3500m².

The south-east section of the swamp consisted of a very large area of dense lodged and emergent *Eleocharis* reeds (Approximately 23,000m²), bordering a poorly draining densely vegetated paperbark swamp to the east. Further seaward, emergent *Schoenoplectus* reeds replaced the *Eleocharis* reeds. Dead paperbarks were noticed in the *Eleocharis* reed area bordering the paperbark swamp. Between the south-west and south-east end of the tidal swamp was a large *Schoenoplectus* reed and mangrove area (approximately 17,000m²).

Ochlerotatus vigilax were found breeding in very high numbers at the south-west end of the swamp, which was partially flooded due to recent rainfall and high tides the night before the survey pushing floodwater into previously dry areas. Highest concentrations of larvae were associated with *Eleocharis*, *Sporobolus* and *Schoenoplectus* vegetation, with concentrations of up to 30 *Oc. vigilax* per ladle dip (2nd and 4th instars, pupae present) (Table 3). Lower concentrations of larvae were observed in the flooded, bare mudflat area. Positive areas for *Oc. vigilax* breeding in Swamp 1 were larval sites PKL 2 and PKL 4-7 (Figure 4a, Appendix 2).

Anopheles farauti s.l. larvae were found widespread in low concentrations (less than 1 larvae per ladle dip) in both *Eleocharis* and *Schoenoplectus* reed areas. *Anopheles farauti* s.l. were also found breeding in the paperbark swamp. Positive areas for *An. farauti* s.l. breeding were larval sites PKL 5 & 6 and PKL 8-9 (Figure 5, Table 3, Appendix 2).

Culex annulirostris larvae were found breeding in the *Eleocharis* reed area on the south-west side of the tidal reed swamp only (Larval site PKL 8, Figure 5, Appendix 2), in low concentrations of less than one larvae per ladle dip (Table 3).

4.1.1.2 Swamp 2

Only the northern end of this very large tidal and paperbark swamp area was surveyed, due to the distance of this swamp from the Blacktip Project development area. The larval collection locations are indicated in Figure 5.

The upper tidal limits of the northern end of the swamp consisted of a large, flat, dense grassy area. Small isolated depressions were located throughout this area, with *Ochlerotatus vigilax* found breeding in concentrations of 5 larvae per ladle dip in one area of 20m² (Larval site PKL 12, Table 3).

Further south of PKL 12, the upper tidal area becomes a narrow strip of grass between mangroves and a paperbark swamp. Small depressions in the tidal grass areas and an eroded flowline at the paperbark/grass margin revealed *Oc. vigilax* and *Verrallina funerea* breeding at 3.75 and 1.25 larvae per ladle dip respectively (PKL 11, Table 3, Appendix 2).

Further south of PKL 11 was a large mudflat bordering a tidal grass area (PKL 10). An extensive, shallow depression (Approx. 10,000m²) was present in the upper tidal area of the mudflat, with *Oc. vigilax* larvae found at 0.83 larvae per ladle dip, and *An. farauti* s.l. larvae found at 0.17 larvae per ladle dip (Table 3). Only the western edge of the depression was surveyed.

4.1.1.3 Southern coastal vine thicket

Several interdune areas adjacent to the coastal vine thicket south of the onshore pipeline crossing were surveyed to locate potential salt marsh mosquito breeding sites. Survey sites are indicated as PKL 14 – PKL 17. The interdune area between PKL 14 and PKL 15 was not surveyed, this area will be surveyed in September 2004.

PKL 14 was a small localised low lying area in the sand dunes near the mangrove margin. The evidence of lush green vegetation indicates that rainwater pooling occurs in this site, with the area of flooding likely to be up to 80m². This depression is a likely salt marsh mosquito breeding site after the first flooding rainfall in the early to mid wet season.

PKL 15 was a large depression of approximately 500m², located behind the main beach sand dune and sparsely vegetated with paperbark trees. This site may be a minor *Anopheles* and *Culex* species breeding site after monsoonal rainfall.

PKL 16 consisted of several flowlines from the interdune area to the main beach dune. The invert of the main beach dune was higher than the invert of the flowlines, indicating rainwater pooling is likely to occur in the interdune areas behind the main beach dune after monsoonal rainfall. The edge of the vegetation line was characterised by Beach Hibiscus. Behind the Beach Hibiscus were several large flowlines in the interdune area. These poorly draining flowlines are likely to be large sources of *Oc. vigilax* after monsoonal rainfall.

PKL 17 also consisted of a flowline from the interdune area to the main beach dune. The invert of the main beach dune was higher than the invert of the flowline, indicating probable rainwater pooling in the flowline within the interdune area. This site is likely to be a large source of *Oc. vigilax* after monsoonal rainfall.

4.2 Biting midge trapping

The summary of the biting midge trapping from all nine adult trapping sites are shown in Table 1. Adult biting insect trap locations are shown in Figure 2 & 3.

4.2.1 Species present

A total of 3531 adult female biting midges were collected from the nine adult biting insect traps, representing at least 8 different species (Table 1).

The majority of biting midges collected were *Culicoides ornatus*, representing 87.4% of total biting midges trapped. The next most frequently recovered species were *C. austropalpalis* (3.6%), *C. immaculatus* (3.34%), *C. undescribed sp. No. 6* (2.1%), *C. bundyensis* (1.5%), *C. narrabeenensis* (0.4%), *C. papuensis* (0.31%) and *C. actoni* (0.06%) (Table 1).

Culicoides ornatus was the only major pest human biting midge species trapped. The highest individual collection of female *C. ornatus* was 2,530.

The biology and pest significance of selected *Culicoides* species are provided in Appendix 3.

4.2.2 Spatial abundance

The relative spatial abundance of all species collected from the nine adult biting insect traps is shown in Table 1. The spatial abundance of *C. ornatus* is also shown in Figure 3.

The highest spatial abundance of biting midges was at site 6, accounting for 74.79% of all biting midges collected. The site with the second highest spatial abundance was site 5, with 14.16% of all biting midges trapped.

Culicoides immaculatus was most abundant at site 6 (55), followed by site 4 (26), site 9 (20) and site 8 (15), with minimal to nil numbers at other trap sites.

Culicoides narrabeenensis was most abundant at site 5 (10), with minimal to nil numbers at other trap sites.

Culicoides austropalpalis was most abundant at site 5 (100), followed by site 7 (19), with minimal to nil numbers at other trap sites.

Culicoides bundyensis was most abundant at site 2 (44), with minimal to nil numbers at other trap sites.

Culicoides undescribed sp. No. 6 was most abundant at site 6 (55), with minimal to nil numbers at other trap sites.

Culicoides papuensis was most abundant at site 5 (10), with minimal to nil numbers at other trap sites.

Culicoides actoni was only found in low numbers (2) at site 2.

For individual collections of *C. ornatus*, the highest numbers occurred at site 6 (2530), followed by site 5 (380), site 4 (68), site 2 (52), site 9 (34), site 7 (9), site 8 (8), site 3 (4) and site 1 (1) (Table 1, Figure 3).

4.2.3 Seasonal abundance

The seasonal abundance of the main human pest biting midge species *C. ornatus* is shown in Figure 7, which depicts the results of 12 months trapping on the night of full moon at Fairway Waters in Palmerston. Figure 7 indicates that the seasonal peak in *C. ornatus* numbers occurs during the mid to late dry season months of August, September and October, with low numbers in the wet season, with numbers starting to rise from the early dry season.

Biting midge trapping will be conducted at all nine Blacktip Project trap sites for three nights around the full moon in September 2004, to locate peak season *C. ornatus* numbers at the various locations around the Blacktip Project development site.

4.2.4 Biting midge breeding sites

An assessment of probable *C. ornatus* breeding sites was made from aerial photography and an assessment of the June 2004 trapping results. Probable *C. ornatus* breeding sites are pointed out in Figure 5a & 5b.

The largest *C. ornatus* breeding site appears to be the upper tidal mangrove creek areas associated with the distant Swamp 2 to the south of the Blacktip Project area. High pest numbers were trapped adjacent to Swamp 2. Closer to the Blacktip Project area, the small *Sonneratia* foreshores to the north and south of the onshore pipeline crossing appear to be a source of minor numbers of *C. ornatus*. Swamp 1 may be a small source of *C. ornatus*.

4.3 Mosquito trapping

4.3.1 Species present

There were a total of 6,429 female adult mosquitoes trapped from the nine adult biting insect traps, representing 19 species (Table 2).

Anopheles farauti s.l. was the most abundant species trapped, representing 33.92% of all mosquitoes trapped. The next most abundant species were *Culex annulirostris* (20.28%), *Coquillettidia xanthogaster* (19.66%), *Culex sitiens* (9.52%), *Ochlerotatus vigilax* (5.15%) and *Culex vishnui* grp. (4.09%).

The highest number of females of various species from a single trap was *An. farauti* s.l. (1271), followed by *Cx. annulirostris* (604), *Cq. xanthogaster* (470), *Cx. sitiens* (326), *Cx. vishnui* grp. (167), *Oc. vigilax* (102) and *An. bancrofti* (96).

Culex vishnui grp. includes two undescribed species, *Cx. sp* 32 of marks and *Cx. sp* near *vishnui*. Both species are very difficult to separate morphologically as adults, and are not regarded as human pest species.

Anopheles farauti s.l. is a species complex that includes the species *An. farauti* (brackish water breeder), *An. hinesorum* and *An. torresiensis* (freshwater breeders). These species are impossible to separate morphologically so are combined to form the *An. farauti* s.l. species complex. However, as the major mosquito breeding site Swamp 1 has extensive brackish water areas, the majority of *An. farauti* s.l. collected were likely to be *An. farauti*.

The biology and disease significance of the common mosquito species is described in Appendix 4.

4.3.2 Spatial abundance

The relative spatial abundance of all mosquito species collected from the nine adult biting insect traps is shown in Table 2. The spatial abundance of six selected important mosquito species is shown in Figure 2.

The highest number of mosquitoes were trapped at site 7, representing 30.32% of all mosquitoes trapped, followed by site 1 (24.48%), site 5 (10.61%), site 6 (8.45%), site 3 (8.37%), site 4 (6.07%), site 8 (5.91%), site 2 (3.39%) and site 9 (2.41%).

The highest total number of *An. farauti* s.l. was at site 7 (1271), followed by site 1 (364), site 8 (269), site 2 (121), and site 5 (120), with relatively few or none at the remaining trap sites.

The highest total number of *Cx. annulirostris* was at site 1 (604), followed by site 7 (226), site 6 (124), site 3 (122), site 5 (87) and site 8 (54), with relatively few others at the remaining trap sites.

The highest total number of *Cq. xanthogaster* was at site 1 (470), followed by site 3 (378), site 6 (141), site 7 (113) and site 4 (50), with relatively few others at the remaining trap sites.

The highest total number of *Cx. sitiens* was at site 5 (326), followed by site 4 (98), site 6 (77) and site 7 (71), with relatively few to nil at the remaining trap sites.

The highest total number of *Cx. vishnui* grp. was at site 4 (167), followed by site 5 (68), with relatively few to none at the remaining trap sites.

The highest total number of *An. bancrofti* was at site 1 (96), followed by site 7 (50), with relatively few to none at the remaining trap sites.

The highest total number of *Oc. vigilax* was at site 6 (102), followed by site 7 (100) and site 9 (38), with relatively few at the remaining trap sites.

4.3.3 Seasonal abundance

The seasonal abundance of mosquito species at the Blacktip Project area can be inferred from weekly mosquito monitoring from the Holmes Jungle weekly adult mosquito monitoring results (Figure 6). The Holmes Jungle trap site is situated near to an extensive tidal and rain inundated reed swamp that includes *Eleocharis* and *Schoenoplectus* reeds, making it similar in habitat to Swamp 1. Freshwater mosquito breeding at Swamp 1 is unlikely to extend into the dry season for as long as that encountered at Holmes Jungle, due to Holmes Jungle swamp being fed by dry season flows from a freshwater creekline, which prolongs flooding of the swamp and is indicated by *Typha* sp. at the start of the reed swamp. Swamp 1 does not have this feature. It is likely that high mosquito breeding in Swamp 1 will continue until late June only in wet years, with Swamp 1 expected to be significantly dry by early June in average rainfall years, and be significantly dry before the end of May in dry years.

Ochlerotatus vigilax numbers begin to rise at Holmes Jungle from around late September to a peak in November and December, with low numbers occurring in January. This species is virtually absent for the remaining months of the year, although in some years minor numbers can occur in May, June and July, when high tides push floodwaters into recently dried areas of the reed swamp, or

uncharacteristically late significant rainfall occurs. It should be noted that much higher numbers of *Oc. vigilax* would be sourced from the Holmes Jungle reed swamp if aerial control of *Oc. vigilax* larvae was not carried out by MEB, so the numbers depicted in Figure 6 is a much reduced indication of the true numbers that would normally arise from the swamp. Numbers of this species at Swamp 1 are likely to follow similar seasonal trends.

Culex annulirostris numbers generally show two peaks during the year at Holmes Jungle, with a mid wet season peak in January and February, and post wet season peak from April to August. The post wet season peak is generally the larger and more extended of the two peaks, due to more favourable dense reed habitat areas with restricted predator access during the post wet season months. Numbers are minor for the remaining months of the year. At Swamp 1, peak *Cx. annulirostris* abundance is likely to be similar to Holmes Jungle, except the post wet season peak is likely to be expected between April and June.

Anopheles farauti s.l. numbers at Holmes Jungle generally peak for a short period during the post wet season months of April to June, with numbers relatively low to absent for the remaining months of the year. Numbers of this species is likely to show a similar trend at Swamp 1.

Anopheles bancroftii numbers at Holmes Jungle generally peak in the post wet season months of April to August, with moderate numbers in the mid to late wet season months of January, February and March. This species is generally absent for the remaining months of the year. Numbers of this species at Swamp 1 are likely to follow this trend, except for post wet season breeding to finish by the end of June in average rainfall years.

Coquillettidia xanthogaster numbers at Holmes Jungle peak in the post wet season months of May to August, with a minor peak in the mid wet season months of January and February. Numbers of this species are generally low or absent for the remaining months of the year. Numbers of this species at Swamp 1 are likely to follow this trend, except for post wet season breeding to finish by the end of June.

Another potential pest mosquito species is *Mansonia uniformis*, which was trapped in low numbers during the Blacktip Project trapping in June 2004. *Mansonia uniformis* numbers generally peak in the mid wet season months of January and February, with a minor peak in the post wet season months of May and June, and low to nil numbers for the remaining months of the year. It is possible that elevated numbers of this species will be present at Swamp 1 in January and February.

4.4 Location of various development elements

The development plans were evaluated as a desktop study. The impact of the development on existing biting insect populations and the capacity to create new breeding sites is discussed in Section 5 under the various headings of biting midges or mosquitoes. Suggested measures to reduce mosquito problems are dealt with separately in section 5.2.2.

The development plans available were preliminary. The various elements are presented below.

4.4.1 Shore crossing

The pipeline shore crossing will occur through a beach dunal area between two coastal vine thickets. There is a low lying woodland area behind the dune. The shore crossing is within flight range of various species of mosquitoes likely to originate from the southern coastal vine thicket to the south, and from Swamps 1 & 2. The beach dune is high in elevation and therefore appears well drained.

The shore crossing is close to foreshore *Sonneratia* mangrove areas, and is within flight distance of *C. ornatus* biting midges from Swamp 2.

4.4.2 Onshore Gas Processing Plant and Ancillary Facilities

The onshore gas processing plant and ancillary facilities is located within the flight range of various species of mosquitoes likely to originate from the southern coastal vine thicket to the west and south-west, and from Swamps 1 & 2. Swamp 1 will be by far the major source of mosquitoes for the onshore gas processing plant and ancillary facility areas.

The onshore gas processing plant and ancillary facilities is also located within the flight range of *C. ornatus* from the *Sonneratia* foreshores , and from Swamps 1& 2.

5.0 Discussion

5.1 Biting midges

5.1.1 Species present

Thirty-three (33) species of *Culicoides* have been recorded in the Darwin area (Whelan et al 1997). Eight (8) species of *Culicoides* were collected during the Blacktip Project trapping in June 2004. Of the 8 species trapped, *C. ornatus* is by far the major potential pest species, both in terms of numbers and because this species is considered the most significant pest human biting midge species in the Top End of the NT. The most important or common pest species in Darwin Harbour, their biology, and their season prevalence are summarised in Appendix 3.

More intensive trapping in the Blacktip Project area may reveal more species, although it is unlikely that any other *Culicoides* species trapped would be a major human pest species or be present in numbers high enough to cause a human pest problem.

Culicoides actoni were trapped in very low numbers at one site only. This species has been recorded biting humans (Wirth & Hubert 1989), although it is unlikely to be of any major pest significance. The larval habitat of this species is unknown (With & Hubert 1989).

Culicoides bundyensi and *C. austropalpalis* were trapped in minor numbers and are not regarded as human pest species.

Culicoides papuensis were trapped in very low numbers and breed in similar areas as *C. ornatus* (Shivas 1999). There appears to be no published records of this species biting humans in Australia, and Shivas (1999) also did not record this species biting human bait. It is therefore unlikely that this species is of human pest significance in Australia.

Culicoides narrabeenensis rarely bites people, so it is unlikely to be of any pest significance in the Blacktip Project area. This species breeds at the edge of freshwater.

Culicoides undescribed sp. No. 6 were trapped in low numbers. This species rarely bites humans so are not considered to be of any human pest significance.

Culicoides immaculatus were trapped in minor numbers. This species can be confused with other *Culicoides* species, so those *C. immaculatus* found during the Blacktip Project trapping need their identity confirmed.

5.1.2 Probable breeding sites

Culicoides ornatus will be the most important pest biting midge species affecting the Blacktip Project area.

The actual breeding sites for *C. ornatus* have not been located in the areas surrounding the Blacktip Project. However the breeding sites can be inferred from investigations of breeding sites around Darwin Harbour (Shivas et al 1997, Shivas 1999). Probable breeding sites are pointed out in Figures 5a and 5b.

Investigations of breeding sites in Darwin Harbour have located the breeding sites of *C. ornatus* by adult emergence trapping (Shivas et. al. 1997, Shivas 1999). The midge breeds in the dry season in the mangrove mud in the creek banks of upper tidal tributaries between Mean Low Water Neap (MLWN) and Mean High Water Neap (MHWN). Larval sampling has revealed significant breeding at tidal

elevations of 4.7m ACD to 5.5m ACD at creekbank habitats in Darwin Harbour (Shivas 1999). The prime breeding sites are in a narrow zone in the upper section of narrow creek banks associated with the occurrence of pneumatophores of the mangrove species *Avicennia marina*. The prime dry season breeding site has an upper limit where the *Avicennia* reduces in height and predominance, and a lower limit where the creek opens out from the overhanging *Avicennia* canopy (Shivas 1999, Whelan 2003). Breeding also occurs in a broad band centred around the edge of the vegetation line on the upper part of the creekbank i.e just above MHWN (Shivas 1999, Shivas 2001).

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

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

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

The development will not reduce or significantly affect the major biting midge breeding sites that are currently causing the pest problem. Breeding sites for *C. ornatus* likely to affect the Blacktip Project include the *Sonneratia* foreshores adjacent to the gas pipeline shore crossing, the upper tidal creek mangrove areas to the south of the Blacktip Project site and the upper tidal creek mangrove area to the north of the Blacktip Project site. Preliminary trapping indicates the mangrove creek area to the south of the Blacktip Project site is by far the largest breeding site affecting the development area.

The breeding sites affecting the Blacktip Project are likely to pose only minor biting midge pest problems, due to the absence of nearby extensive areas of foreshore *Sonneratia* mangroves, and the distance of the Blacktip Project from extensive upper tidal creek (dendritic) mangrove areas.

5.1.3 Spatial abundance and dispersal

Collections of *C. ornatus* in Darwin Harbour have been greatest near extensive dendritic areas of mangroves and at the head of tidal creeks, with numbers highest within 1 – 1.5 km of these areas (Shivas & Whelan 2001). High numbers are usually present on the slope of escarpments facing extensive breeding areas. The highest numbers recorded for the Blacktip Project trapping in June 2004 were close to the mangroves at site 6 (Swamp 2), so it is likely that high numbers were also present in the hinterland area up to 1.5 km from the upper tidal creek mangrove areas near site 6.

The development area is at least 3km from the most productive nearby *C. ornatus* breeding site (Upper tidal creek mangrove areas associated with Swamp 2), although minor pest problems may be experienced in the development area, as *C. ornatus* are capable of dispersing in low numbers for at least 3.5km (Shivas & Whelan 2001).

5.1.4 Seasonal fluctuations

Culicoides ornatus numbers reach a yearly peak in the months of August to November (Mid to late dry season) around the time of the full moon, with a smaller peak around the time of the new moon (Figure 8). Numbers are markedly reduced during the wet season months. Numbers begin to rise from the early dry season months of May or June to the August to November peak (Figure 8).

Sampling in June 2004 at the study site revealed *C. ornatus* numbers as they were beginning to rise from the wet season lows. Further sampling in September 2004 around the time of the full moon should reveal peak season maximum numbers likely to affect the Blacktip Project. The seasonal maximum numbers can vary between the months of August to November (Figure 8), although trapping in September will indicate *C. ornatus* populations during the peak season, and likely maximum numbers. At Fairway Waters, peak season numbers in late August were approximately 10 times greater than numbers in June. It is likely that trapping in September 2004 in the study area will reveal a similar trend in seasonal variations of *C. ornatus*.

5.1.5 Limitations

Ideally to fully gauge the *C. ornatus* population affecting the Blacktip Project, sampling would need to be carried out over three nights around the full moon for every month of the year, to cater for the expected maximum peak dispersal. This species has a range of breeding sites, which exhibit different breeding and dispersal characteristics over a three-day period (Shivas 1997, Shivas 1999).

Traps set one day before the full moon in June 2004 were likely to sample peak numbers from creekbank habitats, but were likely to miss peak numbers from the *Sonneratia* foreshore site, due to maximum dispersal from these sites occurring up to four days before peak dispersal from creekbank habitats (Shivas 1999, Shivas & Whelan 2001). There would have been a delay in maximum numbers at the development site compared to maximum numbers at the mangrove site, due to the distance of the development site from the mangrove breeding sites. Traps set near the development area may have missed maximum monthly numbers for June, due to *C. ornatus* possibly not reaching the development area in peak numbers by the night of trapping.

Traps set over a three night period around the full moon in September 2004 will sample peak season numbers, but may not sample peak season maximum numbers, which can occur around the full moon during any of the months of August to November.

5.1.6 Pest problems and public health

Minor biting midge pest problems in the Blacktip Project development area from *C. ornatus* may occur in the August to November period, particularly for three or four days around full moon nights. A minor pest problem may also occur around new moon nights in this period, but will be lower than for full moon nights. There are unlikely to be significant pest problems for the remaining months of the year.

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

Investigations near Darwin have suggested an approximate relationship between the numbers of biting midges collected in a carbon dioxide trap and the number of bites that can be expected at the peak biting period (Whelan et. al. 1997a). The number of bites in an hour on an exposed leg at the peak biting time around sunset is approximately a quarter of the number collected in a 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.

The trapping results indicate that the number of *C. ornatus* in a trap equating to 60 bites per hour (240 *C. ornatus* per trap night) was only exceeded at sites 5 & 6, which were located at least 3km from the Blacktip Project area. Numbers trapped within the vicinity of the Blacktip Project area did not exceed pest numbers, although the low numbers trapped may still cause a minor nuisance to some people. Extended trapping in September 2004 is likely to reveal higher numbers of *C. ornatus*, and give a better indication of abundance in the development area.

An expected minor pest problem will affect construction workers and outdoor workers in the Blacktip Project development area. It is not expected that outdoor activities will be significantly affected by *C. ornatus* pest problems, with particular problems primarily posed to personnel who are particularly sensitive to insect bites. Peak biting times for this species are in the hours either side of sunset and sunrise. It should be noted however that construction workers within 1.5km of Swamp 2, or at or near Port Keats, will be exposed to much higher levels of biting midges.

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

Of other *Culicoides* species collected, *C. immaculatus* bite people readily but are usually found only near their breeding sites at rock-sand or sandy beaches. This species may cause a minor nuisance problem for construction workers at the onshore pipeline crossing site only.

5.1.7 Measures to reduce biting midge pest problems

5.1.7.1 Alteration or removal of breeding habitat

The development is not likely to impact on any of the major pest biting midge breeding sites, because the development will mostly be constructed above the tide margin and not within any mangrove zone where most problem midges breed.

5.1.7.2 Biting midge buffer zones

A biting midge buffer zone can be defined as an area of separation between the biting midge breeding or harbouring areas and the development. An effective buffer width should be a minimum of 1.5km (Liehne 1985, Shivas & Whelan 2001). The onshore gas processing plant and ancillary facilities are approximately 3km from the nearest extensive *C. ornatus* breeding sites (Swamp 2), ensuring an effective buffer distance.

If there are biting midge pest problems for at least some people in the development area, additional measures can be taken to reduce biting midge numbers. The use of UV or white lights in non personnel areas can act as a diversion for biting midges, although the use of lights alone is not likely to provide a useful or effective buffer (Shivas & Whelan 2001).

5.1.7.3 Biting midge larval control by insecticides

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

5.1.7.4 Biting midge adult control

‘Fogging’ or the application of aerosols against adult biting midges can offer some scope for the reduction of biting midge populations. Aerosol application for adult biting midge control poses serious practical problems to achieve an effective measure of control. These include timing of control, the

necessary environmental and weather conditions, access requirements, the non-specificity of most adulticides, and the failure of aerosols to penetrate thick vegetation.

It is unlikely that pest biting midges will reach populations sufficient to warrant adult fogging operations in the Blacktip Project area.

However if there is a need to reduce any pest problems, a new residual insecticide product aimed at adult biting midge and mosquito barrier control (Bistar 80SC, active ingredient 0.1% bifenthrin) has been proven very successful in reducing adult biting midges around residences for up to six weeks in Hervey Bay QLD (Standfast et al 2003, Appendix 7). It is likely to reduce adult biting midge numbers in prepared or landscaped areas and if required, could be used as part of a strategy for biting midge protection. It is recommended that specific landscaping (the use of dense shrub type vegetation) and/or shade cloth fencing be erected around personnel areas to enable enhanced protection by any bifenthrin applications.

5.1.7.5 Personal protection and avoidance

There may be periods when biting midge populations reach levels that warrant personal protection strategies. It is possible that minor pest numbers of *C. ornatus* will affect at least some people in the Blacktip Project area for three or four days around the full and new moon in the months of August to November, with greatest problems occurring around the time of the full moon. Biting midge pest problems are unlikely to occur in the Blacktip Project area at other times of the year. The main pest period will be the hour either side of sunset and sunrise (Whelan & Hayes 1993, Whelan et al 1994).

There are a number of avoidance and personal self-protection measures that can be taken to reduce biting midge pest problems. These include the use of diversionary lights between sources and morning or evening use areas, fine insect screens, light proof curtains, avoidance of areas of pest biting midge activity, avoidance of problem areas or exposure at times of peak biting activity, and personal protective clothing and personal repellents at times or locations of exposure to biting midges (Appendix 5 and 6). If bifenthrin barrier treatments are to be used as mentioned in Section 5.1.7.4 above, then the personnel areas to be protected will need to be specifically landscaped.

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

5.2 Mosquitoes

5.2.1 Species present

Over 100 mosquito species have been recorded in the Northern Territory. Nineteen (19) species were recorded from the June 2004 sampling for the Blacktip Project. The most significant species in terms of abundance was *Anopheles farauti* s.l. The most significant species in terms of disease potential was *Culex annulirostris*. Due to the presence of a nearby extensive coastal reed swamp (Swamp 1), it is predicted that the salt marsh mosquito *Oc. vigilax* will be the most important mosquito species in terms of posing a pest problem.

5.2.2 Mosquito breeding sites

Larval surveys conducted during the June 2004 survey revealed mosquito breeding sites that will cause pest and potential disease problems for the Blacktip Project development site. The mosquito breeding sites are shown in Figure 7. Each of these sites are dealt with separately below.

5.2.2.1 Swamp 1

This site was an extensive reed swamp and paperbark swamp (approximately 5ha was surveyed or visually inspected), with associated mudflats and tidal grass areas. The reed swamp was subject to both tidal and freshwater influence, while the paperbark swamp was subject to freshwater influence. The extent of each mosquito breeding habitat surveyed is roughly delineated in Figure 4a. The full extent of the swamp will be determined in September 2004, when the swamp is dry and easily accessible.

The reed swamp has probably occurred as a result of a barrier between the swamp and the invert of the small tidal creek downstream of the reed swamp, creating an extensive poorly draining area. Much of the swamp was not surveyed. Investigations will be carried out in September when the swamp is dry and easily accessible to determine the exact constitution of the swamp.

The reed swamp was a major source of *Anopheles farauti* s.l., *Culex annulirostris*, and *Ochlerotatus vigilax* larvae during the post wet season. *Coquillettidia xanthogaster* larvae were not located, as the larvae of this species attach themselves to submerged aquatic vegetation, making sampling with standard ladles and buckets very difficult. Numbers of most *Culex*, *Anopheles* and *Coquillettidia* species reach a peak in the post wet season months in reed swamp habitats, due to the presence of dense reed growth and isolated heavily vegetated areas creating ideal habitats with restricted predator access. Most larvae found in the June 2004 survey were located amongst dense vegetation. The location of large numbers of *Oc. vigilax* larvae was a direct result of unseasonably high dry season rainfall in the four or five days prior to the survey, resulting in the re-flooding of previously dry areas of the swamp. Monthly high tides the night before the survey also pushed floodwater into previously dry areas, possibly resulting in further hatches of *Oc. vigilax* larvae.

During the late dry season and early wet season, the reed swamp and associated mudflats, and the tidal creek downstream of the reed swamp are likely to be sources of extreme numbers of the salt marsh mosquito *Oc. vigilax*. Extensive areas of the swamp are likely to be dry by the time of the late dry season, providing vast breeding areas for the salt marsh mosquito, which lays its eggs on damp or drying mud or near plant stems. Eggs hatch after inundation from tidal or rainwater. Peak populations would occur in November and December, and possible early January.

During the early to mid wet season when the swamp becomes permanently flooded, the reed swamp will cease to be a source of *Oc. vigilax* and become a source of pest numbers of *Cx. annulirostris*, *An. bancrofti*, and possibly *Ma. uniformis*. Numbers would be relatively low during the wet season when the reed swamp becomes colonised with aquatic predators of mosquito larvae, but would rise after the wet season when the drying swamp and lodged reeds creates areas with restricted predator access.

5.2.2.2 Swamp 2

The northern section of this swamp consisted of extensive tidal grass and tidal mudflat areas bordering a narrow paperbark swamp, and freshwater creekline to the south. Only the northern section of the swamp was surveyed, due to the distance of the remaining areas of the swamp from the Blacktip Project site being outside the major pest dispersal range for most pest mosquito species (Appendix 4).

The extensive tidal grass areas surveyed contained many shallow poorly draining areas, with a few areas spot surveyed revealing salt marsh mosquito breeding. The large mudflat to the south was also a salt marsh mosquito breeding site. During the late dry and early wet season, it is likely that this swamp will contribute to pest numbers of the salt marsh mosquito to the Blacktip Project development area.

The remaining areas of the swamp (to the south of the freshwater creekline) not surveyed may contain large salt marsh mosquito breeding sites that could contribute to pest numbers at the Blacktip Project area during the late dry season and early wet season.

The paperbark swamp was relatively narrow and appeared to be relatively well drained. *Culex*, *Anopheles* and *Coquillettidia* numbers were lower at the adult trap sites set near this swamp, and at the trap site near the southern boundary of the onshore gas processing plant, compared to the traps set at Swamp 1 and at the northern boundary of the onshore gas processing plant. This indicates that the swamp is a relatively small source for wet season and post wet season mosquito breeding species.

The upper reaches of the tidally influenced creeks associated with this large swamp may also be salt marsh mosquito breeding sites in the late dry season, contributing to pest numbers at the Blacktip Project site.

5.2.2.3 Southern coastal vine thicket

The coastal vine thicket was situated behind a coastal dune just south of the pipeline shore crossing, hence was dry at the time of visit in June 2004. Small areas of the interdune area adjacent to the coastal vine thicket were surveyed, with several potentially large salt marsh mosquito breeding sites located. Further more extensive surveys of the interdune area adjacent to the southern coastal vine thicket will be conducted in September 2004.

Pest salt marsh mosquito problems are likely to arise from the interdune areas after monsoonal rainfall in late December, January and February. Minor numbers of *Anopheles* and *Culex* species may arise from the interdune areas during January and February.

5.2.2.4 Northern coastal vine thicket

The interdune area associated with smaller coastal vine thicket slightly north of the pipeline shore crossing was not surveyed. It will be surveyed in September 2004 to locate potential mosquito breeding sites. It is possible that pest numbers of the salt marsh mosquito may breed in any poorly draining areas that may be present in the coastal vine thicket.

5.2.3 Spatial abundance and dispersal

The current survey indicated that most post wet season mosquitoes likely to affect the development area were originating from Swamp 1. The mosquitoes were dispersing in appreciable numbers to at least the northern boundary of the onshore gas processing plant site. There was a large reduction in *An. farauti* s.l. numbers at the northern boundary of the onshore gas processing site compared to the swamp, although numbers were still high. *Culex annulirostris* and *Cq. xanthogaster* numbers were higher at the northern boundary of the gas processing site compared to the swamp, indicating active dispersal into the nearby woodland areas. Numbers of *Anopheles* and *Culex* species, as well as *Cq. xanthogaster* and potentially *Ma. uniformis* are likely to be higher at the northern section of the onshore gas processing plant site compared to the southern section. Swamp 2 is not expected to be a significant source of mosquitoes in the post wet season.

Both swamp trap sites recorded similar low numbers of the salt marsh mosquito *Oc. vigilax*. These were low season numbers only, with numbers in the late dry season and early wet season likely to be high at both sites, with numbers at Swamp 1 expected to be extreme. This species will be breeding in peak pest numbers after monthly high tides or rainfall in the late dry and early wet season months of October, November, December and early January. This species has a very active dispersal characteristic and will fly at least 3.5km in pest numbers from significant breeding sites. Both of these swamps will contribute significant pest numbers of *Oc. vigilax* to the development site, Swamp 1 being the major source, with numbers likely to be high throughout the development area. Pest numbers of *Oc. vigilax* are likely to arise from at least Swamp 1 in the early dry season, after high tides or unseasonal rainfall.

Mid wet season *Oc. vigilax* breeding in the interdune areas adjacent to the coastal vine thickets in January and/or February, in particular the southern coastal vine thicket, is likely to cause pest problems for the Blacktip Project, although minor compared to the expected pest problem from

Swamp 1 & 2. *Anopheles* and *Culex* species breeding in the coastal vine thickets may cause minor pest problems at the shore crossing, and minor nuisance problems only along the western half of the onshore gas processing plant.

5.2.4 Seasonal fluctuations

After assessing results from the Holmes Jungle reed swamp habitat, it can be assumed that most *Anopheles*, *Culex* and *Coquillettidia* species affecting the Blacktip Project site would reach peak numbers in the post wet season months of April, May and June. *Culex annulirostris* are also likely to have a mid wet season minor peak in January and February. *Anopheles bancroftii* may have a mid to late wet season minor peak in February and March. Large or extended wet season rainfall may see numbers of these species continue until the end of June, while a small wet season may see numbers continue into early June, until the major breeding sites affecting the Blacktip Project site (Swamp 1) dries up to a significant extent.

5.2.5 Pest problems and public health

There are likely to be severe pest problems of *Oc. vigilax* present at the Blacktip Project development area for up to 10 days in the late dry season and early wet season months of October to January. The June 2004 survey results also indicates that pest problems of this mosquito species can occur in the early dry season, dependant on environmental conditions such as unseasonal rainfall or high tides. When present at peak numbers in November and December, pest problems at Swamp 1 are likely to be extreme, with severe pest problems likely for the Blacktip Project development area. High risk periods for Ross River virus (RRV) and Barmah Forest virus (BFV) disease transmission will occur from *Oc. vigilax* when numbers are high in the months of November to January. Macropod (wallaby) hosts for these viruses are present in the general area, increasing the risk of RRV and BFV transmission in the development area.

Anopheles farauti s.l. numbers will be very high in May and June within 500m of Swamp 1, with high numbers up to 1.5km from Swamp 1 (which includes the northern section of the onshore gas processing plant). Moderate to high numbers may also be present in March and April. This species is the most important potential malaria vector, but risk of transmission is dependent on other factors such as the presence of imported cases with infective stages in the blood and degree of exposure during after sundown peak biting periods. All potential workers should be screened for symptoms of malaria before entering the Blacktip Project site.

If potential cases of malaria are present in the Blacktip Project site, the affected person should be kept indoors at night to prevent the potential infection of local *An. farauti* s.l. mosquitoes, until the person has sought medical advice and is cleared or appropriately treated for malaria. If actual cases of malaria are present in the development area and are assessed as risk cases, traps would need to be set to assess the numbers of adult *An. farauti* s.l. If there is a risk of local transmission, fogging will need to be conducted at the nearest breeding ground or harbouring area to the development, which will be Swamp 1, and along at least the northern boundary of the onshore gas processing plant. The success of this fogging in reducing the numbers of *Anopheles* and associated risk will be entirely dependent on wind direction and access, hence unfavourable environmental conditions may not allow adequate risk reduction. This emphasises the need for appropriate screening of workers, and the rapid detection of cases and application of appropriate treatment and precautionary measures, rather than relying on an insecticide solution.

Culex annulirostris were recorded in moderate pest numbers at the northern boundary of the onshore gas processing plant, although due to the size of the *Eleocharis* reed areas in Swamp 1, high to severe pest numbers are expected. Pest numbers of this species can be expected in the early to mid wet season months of January and February, when Swamp 1 is first flooded after heavy rainfall. High to severe pest problems are expected for extended periods during the post wet season months of April, May and June. This species is a vector of RRV and BFV, and will pose a risk of these viruses to workers in the

development area from December to March. *Culex annulirostris* is also a vector of Murray Valley encephalitis virus (MVEV), with the presence of the freshwater reed swamp (Swamp 1) and associated water bird hosts for the virus increasing the risk of MVEV transmission in the development area. The main risk period for MVEV transmission in the development area will be from January to June.

Anopheles bancroftii numbers were low at the time of trapping in June 2004. Due to the presence of an extensive *Eleocharis* reed area, as well as a large paperbark swamp at Swamp 1, it is expected that pest numbers of this species will be present at Swamp 1 in the post wet season months of April and May, with reduced numbers in June, and disperse in pest numbers to the development site. The low numbers collected in June 2004 seems abnormal for this type of habitat. This species is a potential malaria vector, but is not likely to pose an appreciable risk for malaria transmission unless it is present in very high numbers. This species is likely to cause pest problems only.

Coquillettidia xanthogaster will reach moderate to high pest numbers in the vicinity of Swamp 1 and at the Blacktip Project development site in the months of April, May and June. This species is of little consequence as a disease vector, hence is considered a pest problem only.

Mansonia uniformis were collected in very low numbers. Highest numbers have been recorded in the mid wet season months of January and February at Holmes Jungle, so it is possible that pest numbers of this species may be present in the vicinity of Swamp 1, however this species disperses less than other mosquito species and may not disperse in appreciable pest numbers to the development site. This species is of little consequence as a disease vector, hence is considered a pest problem only.

5.3 Potential mosquito borne diseases

5.3.1 Arboviruses

The most important potential endemic mosquito borne diseases in this area are those caused by Murray Valley encephalitis virus (MVEV), Ross River virus (RRV) and Barmah Forest virus (BFV) (Mackenzie et al 1994; Russell 1995, Whelan et al 1992). As there is no vaccine against these diseases, the best method of prevention is self-protection from mosquito bites (Appendix 5).

The greatest period of risk for Murray Valley encephalitis virus disease at the Blacktip Project development site is when *Culex annulirostris* numbers are elevated in the mid wet season to early dry season months of January to June. *Culex annulirostris* is also a vector of RRV and BFV, with the greatest risk period of RRV and BFV transmission from this species also being in the January to March period.

Ochlerotatus vigilax is a vector of RRV and BFV. The vector status of this species is enhanced due to its persistent and day biting habits. High to severe numbers of this species will occur in the Blacktip Project area in the months of September to early January, with low to moderate pest numbers likely in late January and February. The greatest risk period of RRV and BFV transmission from this species will be from October to January.

The dengue mosquito species *Aedes aegypti* and *Aedes albopictus* were not trapped, and are not likely to be present in the Blacktip Project area. *Aedes aegypti* is currently endemic to North Queensland, and a population has recently been detected in Tennant Creek. *Aedes albopictus* is not present in Australia. These two mosquito species breed in artificial receptacles, with *Ae. aegypti* usually only found in association with human residences (Lee et al 1987). There is a risk of importation of these species into Port Keats and the Blacktip Project area from artificial receptacles sourced from vessels from overseas and Queensland. Road transport from Queensland and Tennant Creek may also introduce *Ae. aegypti* into the Port Keats and Blacktip Project area. Any cargo from overseas, and from Queensland and Tennant Creek should be inspected and treated if necessary, as per DHCS

guidelines (Whelan 1988, Appendix 8) to prevent the introduction of exotic mosquito species into the area.

5.3.2 Malaria

Malaria is no longer present in the Northern Territory, but there is always a risk of re-introduction, if a proportion of the workforce is mobile and sourced from countries where malaria is present. Cases of imported malaria may not be rapidly detected in isolated areas with reduced medical services and may subsequently infect the local species of *Anopheles* mosquitoes.

The primary potential vector species for malaria in Australia is generally considered to be *Anopheles farauti* s.l. because of its known association with the disease in Papua New Guinea, and because it was shown to be a vector in an epidemic in Cairns in 1942 (Russel 1987). It is the principal potential vector in the Top End of the NT (Whelan 1981). However, Russel (1987) showed that *An. annulipes* in south-east Australia was relatively long lived and therefore *An. annulipes* in the NT must also be considered a probable potential vector of malaria. *Anopheles annulipes* was the probable vector of malaria epidemics on some areas of the NT prior to 1962. *Anopheles hilli*, *An. bancroftii* and *An. amictus* must also be regarded as potential vectors, although *An. bancroftii* may not pose a significant risk as it is not as long lived as the other species (Russel 1987).

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

If malaria cases occur in the Blacktip Project area, the individual should be kept indoors at night away from mosquito bites until a risk assessment is made by MEB. It is important for the individual to receive appropriate treatment to eliminate the parasite in their blood, before the patient is exposed to mosquitoes. Patients should avoid spending evenings and nights close to Swamp 1, which includes the northern section of the onshore gas processing plant. Any accommodation and personnel facilities should be sited in the southern section of the onshore gas processing plant.

Any personnel that have returned from overseas malarious areas and experience a sudden onset of fever should be considered as possibly having malaria. Only patients exposed after sundown would be at risk of spreading malaria, as *Anopheles* species bite only after dusk. Suspected malaria patients should be advised to seek medical advice.

In the present development, *An. annulipes* and *An. amictus* are not likely to be present in relatively high numbers. *Anopheles hilli* (brackish to saltwater breeder) may be present in moderate to high pest numbers in the post wet season months of April, May and June. Numbers of *An. bancroftii* may be present in moderate to high pest numbers in the period of April to June.

Anopheles farauti s.l. were recorded at very high levels in June. High to very high numbers of *An. farauti* s.l. will be present in the months of April, May and June. Numbers of *An. farauti* s.l. are not likely to be significant after June. There is a very high risk of local malaria transmission in the months of April to June if a malaria patient is present in the development area and within 2km of Swamp 1. The greatest risk area will be those areas within 1km of Swamp 1, with significant risks for the northern section of the onshore gas processing plant.

The finding of very high numbers of *An farauti* s.l. near the Blacktip Project area has considerable implications on what can be defined as high risk areas for malaria transmission in the Northern Territory. The Blacktip Project trapping results indicate potentially significant malaria risk areas exist along coastal and sub-coastal areas on the western edge of the NT as far west as the Port Keats vicinity. Limited trapping in late May at Treachery Bay in 1882 (Whelan 1982), located on the coast

approximately 25km south of the Blacktip Project area failed to reveal any *An. farauti s.l.* adults, and *An. farauti s.l.* is generally absent from Western Australia. This indicates that the Port Keats and the Blacktip Project vicinity is perhaps near the western limit of the *An. farauti s.l.* and the potential malaria high risk zone in the Northern Territory. The numbers trapped at Swamp 1 are comparable to *An. farauti s.l.* numbers around brackish swamps near Darwin, indicating that a very high risk for malaria transmission exists for the Blacktip Project development and surrounding areas near Swamp 1, comparable to some of the higher risk localities in the rest of the NT.

5.4 Evaluation of development plans and suggested mosquito control measures

5.4.1 General considerations

5.4.1.1 Internal drainage

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

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

5.4.1.2 Containment bunding

It is likely that fuel and condensate storage tanks will require containment bunding. There is a potential for containment bunding to collect rain water and breed mosquitoes. All containment bunding should have drainage facilities so that they can be completely drained on a weekly basis during the wet season. Bunded areas should be formalised to prevent vegetation growth and mosquito breeding.

5.4.1.3 Water storage features

Any water storage pond has a great capacity to become a new mosquito breeding sites. The capacity of the water storage pond or dam to breed mosquitoes will depend on salinity, vegetation growth, the presence of fish, and the rate of draw down of water. A stable freshwater pond level will encourage *Eleocharis* and *Typha* reed growth around the margins and promote mosquito breeding. Brackish water storage will enable *Shoenopectus* reeds to establish around the margins. All water storage ponds should be at least 1.8m deep with steep sloping sides.

Any pond should be maintained to ensure native fish are present and can be maintained permanently in the feature. The floor of the ponds should slope slightly towards the water entry point, to form a sink area when water levels are low, to minimise the formation of isolated pools when water is drawn down to low levels. If there is high dry season leakage from a freshwater pond, an appreciable permanent freshwater habitat will develop downstream that could become a large source of mosquitoes. Dry season leakage from water storage ponds should be prevented. Any wet season overflow from water storage ponds should be formalised and discharge to a well drained area, where the water does not end up pooling and causing mosquito breeding. Regular maintenance would be required to ensure any water storage pond is free of vegetation.

Any rainwater tanks and septic tanks should be completely sealed to prevent mosquito breeding. Any sewage treatment ponds should have concrete edges and effluent discharge should be sprinkler dispersed or discharge to the sea, with discharge to the sea the preferred option in regards to preventing mosquito breeding. Any sewage treatment facility requires approval by the NT Department of Health and Community Services.

5.4.1.4 Borrow pits or depressions

Borrow pits can be large sources of *Cx. annulirostris* and *Anopheles* species. Any sand or gravel pit in the Blacktip Project area and within 1.5km of the Blacktip Project area or Port Keats residential area should be filled or made free draining. No borrow pits should be constructed in an area with high wet season water tables to prevent the creation of new surface water features.

5.4.1.5 Artificial receptacles

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

Any machinery and other equipment supplies from North Queensland, Tennant Creek or overseas can introduce exotic mosquito species into the development area. Appropriate inspection and sanitation procedures are required to ensure that any machinery and other equipment capable of holding water do not introduce exotic mosquitoes into the development area or Port Keats. This will include searching for the presence of water and mosquito larvae, and emptying and treating any water holding, or potential water holding receptacles with a chlorine solution or a residual insecticide to kill any mosquito larvae or eggs that may be present (Appendix 8).

5.4.2 Development elements

5.4.2.1 Onshore gas pipeline

The laying of the gas pipeline has the potential to create new mosquito breeding sites. From the onshore beach crossing to the onshore gas processing plant, the construction of the pipeline must not lead to the impoundment of water. The pipeline should be buried and soil re-compacted to match the existing ground surface level. Any discrepancy in the finished level of the buried pipeline may lead to either the upstream impoundment of water if the finished level is higher than the natural surface level, or lead to pooling on top of the buried pipeline if the finished level is below natural surface level. Care must be taken to ensure the remaining spoil from the digging of the pipeline trench is stored in a manner to prevent the impoundment of water. Any disturbance to the ground caused by machinery should be rectified as soon as possible.

5.4.2.2 Onshore gas processing plant

Stormwater drainage should be constructed as mentioned in Section 5.4.1.1. Stormwater drains should not discharge water to Swamp 1, as this could exacerbate mosquito breeding in this already productive mosquito breeding site. Water from bunded areas, bunded drains and washdown areas should not be allowed to pool for more than five days. This may require water to be directed from the bunded areas and drains and washdown area to the processed water treatment plant on a weekly basis during the wet season, and whenever necessary to prevent mosquito breeding during the dry season. Bunded areas, bunded drains and wahsdown areas should be formalised to prevent vegetation growth and mosquito breeding.

Settling ponds should be constructed as mentioned in Section 5.4.1.3.

5.4.2.3 Access roads

Culverts should be fitted to access roads where necessary to prevent the upstream ponding of water for periods that will enable mosquito breeding.

5.4.3 Major mosquito breeding site control

5.4.3.1 Swamp 1

General comments

Generally a swamp of this size and potential as a mosquito breeding site close to residential areas would warrant either an engineering solution or periodic insecticide control to reduce mosquito numbers.

An engineering solution to reduce mosquito breeding would require several large drainage systems through the lowest areas of the various reed habitats, mudflats, as well as the paperbark swamp, to drain water to the tidal creek and into the sea. A central channel would need to be excavated in the upper reaches of the tidal creek to help the free flow of water into the regularly flushed tidal area of the creek. Yearly maintenance would be required to maintain the effectiveness of the drains. Even with a drainage system, insecticide control would still be required, but on a smaller scale than if there was no drainage construction. In light of the time limited construction period, and the small continuing operational staff, this engineering solution is not an appropriate control measure.

Control of mosquito breeding in the swamp by an aerial application of the biological larvicide *Bacillus thuringiensis* var. *israelensis* (B.t.i.) would be required within two to three days after significant rainfall or monthly high tides in September to January to temporarily (B.t.i. would only be effective for 1-2 days after being applied) control *Oc. vigilax* breeding. Alternatively methoprene 30 day residual pellets can be applied prior to tidal or rain flooding to provide longer lasting control of mosquito larvae, with pellets lasting for 30 days under water inundation before reapplication is required. The advantage for methoprene pellets is that they can be applied when breeding sites are dry, and hence timing of application is not as critical as with B.t.i. applications. It is likely that two or three methoprene 30 day residual pellet treatments will last the peak *Oc. vigilax* season months of October, November, December and early January. Methoprene 30 day residual pellets would need to be initially applied before the monthly high tide in October.

Further aerial insecticide control would be required in the post wet season months of April to June to control *Culex*, *Anopheles* and *Coquillettidia* breeding. Methoprene 30 day residual pellets can be applied at the start of April and reapplied every 30 days until the swamp sufficiently dries, which could be late May or late June, depending on the size of the wet season. The swamp is very large and can only be controlled successfully through the aerial application of a mosquito larvicide. Due to Swamp 1 being a large and productive mosquito breeding site, mosquito control is recommended for at least the construction phase, to minimise the risk of the transmission of potentially debilitating mosquito borne diseases when the workforce is large and more exposed.

Specific comments

Due to the distance of the swamp from the Blacktip Project site, and the limited operational staff required to run the onshore gas processing plant, it would be inappropriate to require the proponent to carry out expensive engineering solutions. There would also be issues with environmental issues and cultural sensitivity at Swamp 1.

It is however recommended that mosquito breeding at Swamp 1 be controlled during the construction phase to protect the public health of the larger workforce. Swamp 1 is very large and not all potential breeding areas have been delineated. All potential breeding areas in this swamp will be delineated in September 2004 and details provided to the proponent. Due to the size of the swamp insecticide

control would be expensive, and the proponent may only wish to carry out limited control. If limited control is to be conducted, the *Eleocharis* and *Shoenoplectus* reed areas of Swamp 1 are the areas of the swamp that should be targeted.

A simple and cheaper way to help reduce mosquito breeding in this swamp in the late dry and early to mid wet season would be to conduct annual burning of the reed swamp. This will remove dead reeds and would result in less prolific *Oc. vigilax* breeding. It may also reduce mid wet season numbers of *Culex* and *Anopheles* species, due to the absence of dead reeds providing high organic content in the water, allowing ease of predator access to mosquito larvae when the swamp is flooded, and enabling disruptive wave action to prevent larval development. Annual burning of the swamp however will not prevent all mosquito pest problems from this and other sources.

5.4.3.2 Swamp 2

General comments

The mosquito breeding areas can be treated with methoprene 30 day residual pellets. Aerial application of insecticides will significantly reduce the time involved in controlling mosquitoes at Swamp 2.

The best measure to reduce *Oc. vigilax* breeding at Swamp 2 would be to locate depressions in the upper tidal area after it has been burnt, and judiciously treat the depressions with methoprene 30 day residual pellets. Methoprene 30 day residual pellets should also be used to treat the large shallow depression in the mudflat. Methoprene 30 day residual pellets would need to be applied before the monthly high tide in late dry season month of October, with a further treatment required after the pellets have been inundated with water for 30 days or more. It is likely that two or three treatments will be sufficient to last the peak *Oc. vigilax* season of October, November, December and early January.

Specific comments

Due to the considerable distance of this tidal area from the Blacktip Project development area, it is not necessary to consider an engineering solution for mosquito breeding. However it is recommended that limited mosquito control or management be conducted in this area. The mosquito breeding potential of this tidal area is considerably smaller than Swamp 1, as there are no reed areas or extensive poorly draining areas. Most mosquito breeding likely to occur in shallow depressions in the grassy upper tidal area, and in the large depression in the mudflat.

Annual burning of the upper tidal grass areas is likely to result in less prolific *Oc. vigilax* breeding, and is recommended. Mosquito control does not appear to be warranted, due to the distance of this site from the development area and lower productivity of this area compared to Swamp 1.

5.4.3.3 Southern coastal vine thicket

General comments

Rectification of the poorly draining interdune areas adjacent to the Coastal Vine Thicket can be achieved by grading the flowlines from the interdune areas through the main beach dune, to allow water to drain from the poorly draining interdune areas. This will however allow tide entry into the interdune areas, resulting in the potential die back of vegetation. This engineering solution does not appear to be environmentally acceptable.

Alternatively aerial application of methoprene 30 day residual pellets before the start of monsoon rainfall could provide seasonal control of *Oc. vigilax* in the Coastal Vine Thicket. Further investigations of the interdune area adjacent to the southern Coastal Vine Thicket are required to locate all potential areas of flooding. *Ochlerotatus vigilax* breeding in the forest is likely to be a once or twice off event every year, so only one application of methoprene 30 day residual pellets per annum would be required.

Specific comments

The Coastal Vine Thickets and adjacent interdune areas have not been fully surveyed for potential mosquito breeding sites. Further surveys will be conducted in September 2004. Even if the breeding areas are delineated on ground, location of the breeding sites through the forest canopy may be difficult therefore it appears not to be suitable to require the proponent to conduct aerial control operations in the interdunal areas. Significant breeding will only occur in January or February, therefore avoidance of this area in January and February would be the most practical solution to reducing mosquito problems.

5.5 Personal protection measures

Personal protection measures will be required to reduce the mosquito pest problem. The major pest mosquito problem will be from *Oc. vigilax* during the late dry season and early wet season, as this species will bite during the day and will reach potentially severe numbers. Pest problems will also be encountered from other mosquito species during the mid wet season and post wet season, although the pest problems from other species will be mainly encountered after sundown.

All workers should be notified of the potential pest and disease problem associated with mosquitoes, and be made aware of periods of expected high numbers. All prospective workers should be provided with personal protection guidelines, which are provided in Appendix 5.

There may be periods or areas where workers notice pest mosquito problems. Workers should be advised to report any mosquito problems to the Environmental Officer, so that the Environmental Officer can provide warnings to other workers (such as in-coming workers) who are unaware of the mosquito problem or problem areas.

During the construction phase the Environmental Officer for the Blacktip Project should issue warnings to the workforce when mosquito numbers are expected to be high. Warnings will be required for the post wet season months of April to June, when mosquito numbers are expected to be continually high. Pest problems are likely to be high and continual in the mid wet season months of January and February, with minor to low pest problems in March. Pest mosquito problems in these months will occur mainly after sundown. The Blacktip Project Environmental Officer should advise workers of these problem periods and the need to avoid being exposed after sundown and the need for personal protection measures.

The greatest pest mosquito problems will occur approximately 9 days after the monthly high tide or flooding rainfall in the months of September to January. This problem will arise from the salt marsh mosquito, with very high pest problems likely to occur for at least 10 days in these months. The salt marsh mosquito bites readily during the daytime, therefore is likely to impact on the workforce and lead to complaints. The Blacktip Project Environmental Officer should advise workers of the potential day and night biting mosquito problem during these months and the need for personal protection or avoidance. Workers should be advised that large mosquito breeding sources exist at Swamps 1 & 2, and the interdune areas associated with the southern Coastal Vine Thicket.

5.6 Mosquito control

During the construction phase, temporary wet season mosquito breeding sites may be created in the Blacktip Project area and considerable breeding will occur in Swamps 1 & 2 and the interdune depressions adjacent to the southern coastal vine thicket. Very high numbers of the salt marsh mosquito may disrupt the workforce from the months of September to January, with most pest problems arising from Swamp 1.

Mosquito larval control should be conducted by the proponent and under the duties of the Blacktip Project Environmental Officer to control salt marsh mosquitoes during the construction phase, as this

mosquito species bites during the daytime and would therefore be harder to avoid. Aerial salt marsh mosquito control should be conducted in Swamp 1, with at least the highly productive reed areas controlled with methoprene 30 day pellets in the months of October to January. The MEB will delineate the reed areas of the swamp in September 2004 and provide the details to the proponent. Aerial larval control could then be carried out in the reed areas by the proponent before the monthly high tide in October, and after every 30 days of pellet inundation with water until the end of January.

Mosquito larval control does not appear to be warranted for the upper tidal areas of Swamp 2 and the interdunal areas associated with the southern Coastal Vine Thicket. Swamp 2 is located at least 3km away from the development area, and does not contain extensive mosquito breeding sites as Swamp 1 does. Pest numbers of the salt marsh mosquito will disperse to the development area from Swamp 2, but will only be a minor source compared to Swamp 1. Salt marsh mosquito breeding in the interdunal areas will only occur as a once or twice off event in January and/or February. Construction activities near the Coastal Vine Thickets should therefore be limited or avoided in January or February to avoid mosquito problems from the interdune areas.

Mosquito larval control of Swamp 1 does not appear to be warranted during the late wet season and post wet season months of April to June. Problem mosquito species in these months generally only bite after sundown, hence mosquito problems in these months can be avoided by preventing being exposed after sundown.

Adult mosquito control measures may be required in the development area if mosquito numbers reach extreme levels, or if there is a case of mosquito borne disease and subsequent entomological investigations indicate a further disease transmission risk. However adult mosquito control is inefficient because of the dependence on wind and the provision of satisfactory access to ensure the adequate dispersal of the insecticide. Adult mosquito control by ground operations would only be successful if the mosquitoes were breeding or harbouring in accessible areas relatively close to where they were causing the problem.

The use of bifenthrin barrier control for adult mosquito pest reduction has proven successful in Hervey Bay QLD (Standfast et. al. 2003), but this product has not been successfully trialled under local conditions. It will however provide adult mosquito control to some extent, and will be suitable to use in the development area in conjunction with appropriate landscaping in a similar methodology as recommended for biting midges (see Section 5.1.7.6.).

5.7 Mosquito monitoring and reporting

The Blacktip Project Environmental Officer should check Swamps 1 & 2 in late June or July during the construction phase to see if the swamps are dry enough to burn. If the swamps are dry enough to burn, then burning of the reed and grass areas of the swamps should be arranged and approved by the appropriate people from the Northern Land Council.

During the construction phase the Blacktip Project Environmental Officer should conduct initial inspections of incoming artificial receptacles such as machinery, used tyres or other receptacles capable of holding small amounts of water from overseas, North Queensland or Tennant Creek for mosquito breeding. Mosquito larvae should be sampled using a ladle or pipette, whichever is most suitable. Any mosquito breeding or likely water holding receptacles should be treated as per DHCS guidelines. Monthly periodic inspections of artificial receptacles should be also conducted to locate mosquito breeding, with appropriate treatment taken as necessary. A final inspection of artificial receptacles should be conducted upon the completion of the construction phase. Any mosquito larvae should be kept in a sample container with 70% alcohol and sent to the MEB laboratory in Darwin for analysis, with appropriate remedial action advised or coordinated by MEB.

Monthly inspections of the development area should be conducted by the Blacktip Project Environmental Officer in the wet season of the construction phase to locate any new mosquito breeding sites created by machinery disturbance. The processed water settling ponds and any bunded area or drain should be also checked monthly for mosquito breeding during the construction phase. Mosquito larval sampling can be conducted using a standard ladle painted white, to allow for the easier location of larvae in the ladle. Mosquito larval samples should be sent to the MEB laboratory in Darwin for analysis, with MEB to provide advice and control recommendations.

After construction of the Blacktip Project is finished, the MEB should be engaged to conduct a post construction inspection of the development area, to locate any potential or actual mosquito breeding sites created by the development. Appropriate mitigation measures would be provided for any actual or potential mosquito problem created by the development.

5.8 Limitations

The Blacktip Project trapping in June 2004 provided only very limited information on mosquitoes and biting midges in the Blacktip Project area vicinity. Trapping for mosquito species diversity and abundance at any new development should ideally be carried out for at least 12 months on a monthly basis. Trapping in November and December approximately 10 – 12 days after the monthly high tide or significant rainfall would provide an indication of peak numbers of *Oc. vigilax*. Trapping on a monthly basis will provide a better indication of the relative abundance of most other species.

The entire mosquito breeding potential of Swamp 1 was not determined, due to access difficulties and time constraints. Only a small section of the southern end of the swamp was surveyed, and it is likely that more extensive mosquito breeding sites exist in the northern area of the swamp that will contribute to greater pest numbers of mosquitoes.

Only the northern tidal area of the Yelcher Beach tidal area was surveyed. It is possible extensive mosquito breeding sites exist further south and may contribute some mosquito numbers to the development site.

6. Conclusions

The major findings from the June 2004 survey and assessment were:

6.1 Biting midges

a) Species

- *Culicoides ornatus* was the principal species of biting midge collected, representing 87.4% of all biting midges recovered

b) Source

- The largest biting midge breeding sites likely to affect the Blacktip Project area are the upper tidal creek mangrove areas associated with Swamp 2, which is located approximately 3km south-west of the onshore gas processing plant. Minor breeding sites may be the *Sonneratia* mangrove foreshores adjacent to the onshore pipeline crossing. Minor breeding sites may also be located in the small mangrove tidal creek area associated with Swamp 1, approximately 2km north of the onshore gas processing plant.

c) Pest problem

- *Culicoides ornatus* will be the principal biting midge pest species in the Blacktip Project development area.
- *Culicoides ornatus* may cause minor pest problems in the Blacktip Project development area in the months of August to November. It is unlikely that pest numbers of this species will affect the development area during other periods of the year.
- Highest numbers will be present in those areas of the development nearest to Swamp 2.
- Pest problems, when they occur, will be greatest for three or four days around the full moon and new moon periods in the months of August to November, with numbers being greater during full moon periods. Pest problems are likely to be greatest one hour either side of sunset, and one hour either side of sunrise.
- Adult biting midge trapping in September 2004 around the time of the full moon will be conducted to indicate actual peak season numbers of *C. ornatus* affecting the Blacktip Project area.

d) Mitigation measures

- The development will not reduce or affect the *C. ornatus* breeding sites likely to affect the Blacktip Project area.
- High use personnel areas such as accommodation, mess and recreation areas should be screened and landscaped to allow effective insecticide barrier control of midges. Yellow or red lights should be used in outdoor personnel areas, as well as light proof curtains for personnel buildings, to prevent attracting biting midges.
- The use of white or UV lights in non-personnel areas can be used to divert biting midges away from personnel areas.
- It is unlikely that *C. ornatus* will reach numbers sufficient to warrant fogging with insecticides in the development area, due to the considerable buffer distance of the development area from Swamp 2.

- The elimination of biting midge breeding sites is not feasible. It would require the filling of a considerable portion of the upper tidal creek mangrove areas in Swamp 1 and 2, and the filling of the entire *Sonneratia* mangrove foreshores adjacent to the onshore pipeline crossing.
- The workforce and visitors should be notified of a potential minor biting midge pest problem in the months of August to November, and they need to take appropriate personal protection precautions.
- The NT Government will not be responsible for any biting midge monitoring or control operations at the development site and within the vicinity of the development.

6.2 Mosquitoes

a) Species

- The species occurring in highest numbers during June 2004 were, in decreasing order of prevalence, *An. farauti* s.l. (the Australian malaria mosquito), *Cx. annulirostris* (the common banded mosquito), *Cq. xanthogaster* (the golden mosquito), *Cx. sitiens* (the salt water *Culex* mosquito) and *Oc. vigilax* (the salt marsh mosquito).
- *Anopheles farauti* s.l., *Cx. annulirostris* and *Oc. vigilax* will be the most important mosquito species affecting the Blacktip Project development area.

b) Source

- By far the major source of mosquitoes to the Blacktip Project area will be Swamp 1, a tidal and rainwater influenced swamp located approximately 1.5km north of the onshore gas processing plant. This swamp will be a breeding ground for extreme numbers of *Oc. vigilax*, very high numbers of *An. farauti* s.l. and high to very high numbers of *Cx. annulirostris*. This swamp will also be a breeding ground for non-disease transmitting pest mosquito species such as *Cq. xanthogaster*, *An. bancroftii* and *Ma. uniformis*.
- Swamp 2, a tidal and rainwater influenced swamp located approximately 3km south-west of the onshore gas processing plant, will also provide pest numbers of *Oc. vigilax* to the development sites. The interdunal areas adjacent to the coastal vine thicket to the south (referred to as 'Southern Coastal Vine Thicket') of the onshore gas pipeline crossing is also a likely significant *Oc. vigilax* breeding site.

c) Pest and potential disease problem

- *Ochlerotatus vigilax* will pose the greatest pest problem. Severe pest problems may occur for up to 10 days per month from September to January inclusive. Low to moderate pest problems may occur in February. Pest numbers will appear from 9 days after significant rainfall or monthly high tides in the months of September to February.
- *Ochlerotatus vigilax* will pose a high risk for Ross River Virus (RRV) and Barmah Forest Virus (BFV) transmission in the October to January period.
- *Culex annulirostris* were trapped in moderate pest numbers. A moderate pest problem from this species is likely to occur in the mid to late wet season months of January, February and March, with high to very high pest problems in the post wet season months of April, May and June. This species will pose a high risk for RRV and BFV transmission in January to March and a high risk for MVEV transmission from January to June.
- *Anopheles farauti* s.l. will pose a very high risk of local malaria transmission at the Blacktip Project development site, should a person with the infective stages of malaria be present in the

development area from April to June. High risk areas are located near Swamp 1 and the northern section of the onshore gas processing plant.

- Other mosquito species including *Cq. xanthogater* and *An. bancroftii* will cause pest problems only, mainly in the post wet season months of April, May and June.

d) Mitigation measures

- Advice should be given to all employees and visitors by the Blacktip Project Environmental Officer on the need for periodic personal protection measures against mosquitoes at the Blacktip Project area, to reduce pest problems and reduce exposure to mosquito borne diseases. Potential problem areas and problem periods should be pointed out to workers.
- Any mosquito complaint should be forwarded to the Blacktip Project Environmental Officer, who can then take remedial action by advising appropriate personal protection and advising other workers or visitors of problem periods or areas during the construction phase.
- Possible malaria cases should be reported as soon as possible to a doctor and health authorities, and mitigation measures put in place to ensure potential and actual cases are kept away from mosquitoes. This is to prevent the infection of local populations of *Anopheles* mosquitoes and subsequent local transmission. Employees recently arrived or returning from overseas should receive malaria awareness material.
- During the construction phase, any vessels and cargo capable of holding small amounts of water, such as machinery, used tyres etc from overseas or North Queensland should be inspected as per DHCS guidelines (Appendix 8) by the Blacktip Project Environmental Officer. This is to prevent the introduction of exotic dengue transmitting mosquitoes (*Ae. aegypti* and *Ae. albopictus*). Any road transport and cargo from North Queensland and Tennant Creek should also be inspected by the Blacktip Project Environmental Officer as per DHCS guidelines (Appendix 8), to prevent the introduction of *Ae. aegypti*. Any larvae found should be sent to the MEB laboratory in Darwin for analysis, with appropriate remedial action advised or coordinated by MEB.
- Artificial receptacles such as tyres, drums etc should be disposed of by landfill, holed or stored away from rainfall. If this is not possible, ongoing sanitation measures such as treatment with a chlorine solution or residual insecticide would be required to prevent mosquito breeding. Monthly inspections of artificial receptacles holding rainwater by the Blacktip Project Environmental Officer for mosquito breeding should be conducted during the construction phase, and a final inspection should be conducted upon the completion of construction, with appropriate treatment applied when necessary. Any larvae found should be sent to the MEB laboratory in Darwin for analysis, with appropriate remedial action advised by MEB.
- Swamps 1 & 2 should be burned annually as soon as possible after the swamps dry out each wet season. Burning reduces shelter for mosquito larvae, which allows predator access to larvae. The Blacktip Project Environmental officer should conduct inspections in late June or July to observe if the swamps are dry enough to burn.
- A mosquito larval control program for Swamp 1 should be established and conducted by the proponents and under the duties of the Blacktip Project Environmental Officer, to detect and control salt marsh mosquitoes during the construction phase. Helicopter larval control should be carried out at least in the productive reed areas of the swamp. The MEB will delineate the potentially most productive salt marsh mosquito breeding areas in September 2004 and provide this information to the proponents. The larvicide of choice would be a methoprene 30 day residual pellet formulation. The residual pellets should be applied at Swamp 1 before the October monthly high tide, and reapplied after every 30 days of water inundation in the breeding site until the end

of January. The Medical Entomology Branch should be consulted on any mosquito larval survey and control program.

- Stormwater drains throughout the development should have erosion control structures where appropriate. Drains with the likelihood of dry season low flows should be formalised with impervious linings and low flow facilities. All drains would need to be maintained annually to remove excess silt and vegetation. Drains should discharge to a suitable end point where water can not pool in downstream areas and cause mosquito breeding. Drains should not discharge water to Swamp 1, as this could exacerbate mosquito breeding in this swamp. Drains should be monitored monthly for mosquito breeding during the construction phase by the Blacktip Project Environmental Officer, with samples sent to the MEB laboratory in Darwin for analysis and advice on rectification measures.
- The processed water settling ponds should be deep and constructed with steep sides (1:2, 1:3 or 1:4 slope) to discourage marginal vegetation growth. A slightly sloping floor should be constructed so that during low water periods all of the water is contained in one area. Provisions should be allowed to ensure overflow water does not pool in any downstream areas, which could exacerbate mosquito breeding. The processed water ponds should be checked monthly for mosquito breeding by the Blacktip Project Environmental Officer during the construction phase, with any larvae found sent to the MEB laboratory in Darwin for analysis and control recommendations.
- The bunded drains, washdown area, condensate and fuel bunded areas, as well as any other bunded area should contain provisions that ensures that water does not pool for more than five days in these structures, to prevent mosquito breeding. It may be necessary to drain these areas into the processed water settling ponds on a weekly basis in the wet season, and whenever necessary to prevent mosquito breeding in the dry season. These areas should be formalised to prevent the establishment of vegetation and consequent mosquito breeding. These areas should be monitored monthly for mosquito breeding by the Blacktip Project Environmental Officer during the construction phase, with any larvae found sent to the MEB laboratory in Darwin for analysis advice.
- Construction activities should be monitored by the Blacktip Project Environmental Officer, to ensure activities such as machinery disturbance does not lead to the creation of new mosquito breeding sites. This would include monthly inspections for mosquito breeding during the wet season, with samples sent to the MEB laboratory in Darwin for analysis and advice.
- Sewage treatment facilities should dispose of effluent through sprinkler irrigation to designated areas or dispose of effluent to regularly flushed tidal areas. Disposal to regularly flushed tidal areas is the preferred option in regard to preventing mosquito breeding.
- Any high use personnel area for the onshore gas processing plant should be sited on the southern section of the onshore gas processing plant, as far away from Swamp 1 as possible. This is to create a greater buffer distance between personnel areas and the extensive mosquito breeding sources of Swamp 1.
- White or UV lights should be sited away from personnel areas, to divert mosquitoes to some extent away from personnel areas. Outdoor personnel areas should be fitted with yellow or red lights, and have light proof curtains fitted to prevent inside lights from attracting mosquitoes.
- The barrier spray bifenthrin should be utilised around personnel areas, to control adult mosquito numbers. The benefits of this product will be enhanced by planting shrub type vegetation or constructing a fence with dark shade matting around personnel areas, which can then be treated with the product. The shrub type vegetation or dark fencing will be attractive resting places for

mosquitoes (as well as biting midges), and they will receive a dose of the chemical when they rest on the treated surface. Bifenthrin can also be sprayed on insect screens and any other likely mosquito resting place.

- The laying of the underground pipeline must not result in the impediment of the natural flow of surface water. The finished surface must be level with the surrounding land. Any upstream embankment of water could lead to the creation of mosquito breeding sites. Any leftover spoil should not result in the embankment of water.
- Soil erosion, silt deposition and pooling of rain in excavations will need to be prevented to reduce the potential to create new mosquito breeding sites. Any disturbance caused by machinery should be rectified as soon as possible.
- Any sand or gravel pit in the Blacktip Project area and within 1.5km of the Blacktip Project area or Port Keats residential area should be filled or made free draining. No borrow pits should be constructed in an area with high wet season water tables to prevent new surface water features.
- Access roads should be fitted with culverts where necessary, to prevent the upstream ponding of water that can lead to mosquito breeding.

7.0 Recommendations

The major recommendations arising from the findings of the study are:

7.1 Biting midges

- The use of bifenthrin barrier treatments around personnel areas should be implemented to reduce adult biting midge numbers that could affect the workforce.
- The workforce and visitors should be notified of a potential minor biting midge pest problem in the development area in the months of August to November.

7.2 Mosquitoes

- There will be a requirement for periodic personal protection against mosquitoes at the Blacktip Project area to reduce pest problems and exposure to mosquito borne disease.
- Possible malaria cases should be reported as soon as possible to health authorities, and mitigation measures put in place to ensure potential and actual cases are kept away from mosquitoes.
- High use personnel areas should be sites as far away as possible from Swamp 1.
- Any vessels and cargo such as machinery or other receptacles capable of holding small amounts of water from overseas or Queensland, and road transport cargo from Queensland or Tennant Creek should be inspected as per DHCS guidelines to prevent the introduction of the dengue mosquito.
- Mosquito larval control with methoprene 30 day residual pellets is recommended for Swamp 1, to control salt marsh mosquitoes. This is recommended for the construction phase.
- Swamps 1 & 2 should be burned annually during the construction phase when the swamps dry after the wet season.
- Stormwater drains should be constructed in a manner that does not lead to the creation of new mosquito breeding sites.
- The processed water settling ponds should be constructed in a manner that does not lead to the creation of mosquito breeding sites. Hardy native fish species should be stocked in the settling ponds.
- Bunded areas should be managed to prevent mosquito breeding.
- Artificial receptacles should be managed to prevent mosquito breeding.
- Sewage treatment facilities should dispose of effluent through sprinkler irrigation or disposal to a regularly flushed tidal area. Disposal to a regularly flushed tidal area is the preferred option.
- Bifenthrin barrier treatment should be used around high use personnel areas, to reduce adult mosquito populations in these areas.
- The laying of the underground pipeline must not result in the ponding of water or impediment of the natural flow of surface water.

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- Construction activities should be monitored, to ensure activities such as machinery disturbance does not lead to the creation of new mosquito breeding sites.
- The construction of borrow pits must not lead to the creation of mosquito breeding sites, and should be avoided within 1.5km of personnel areas and 1.5km of Port Keats residential areas.
- Access roads should be fitted with culverts where necessary, to prevent the upstream ponding of water that can lead to mosquito breeding.

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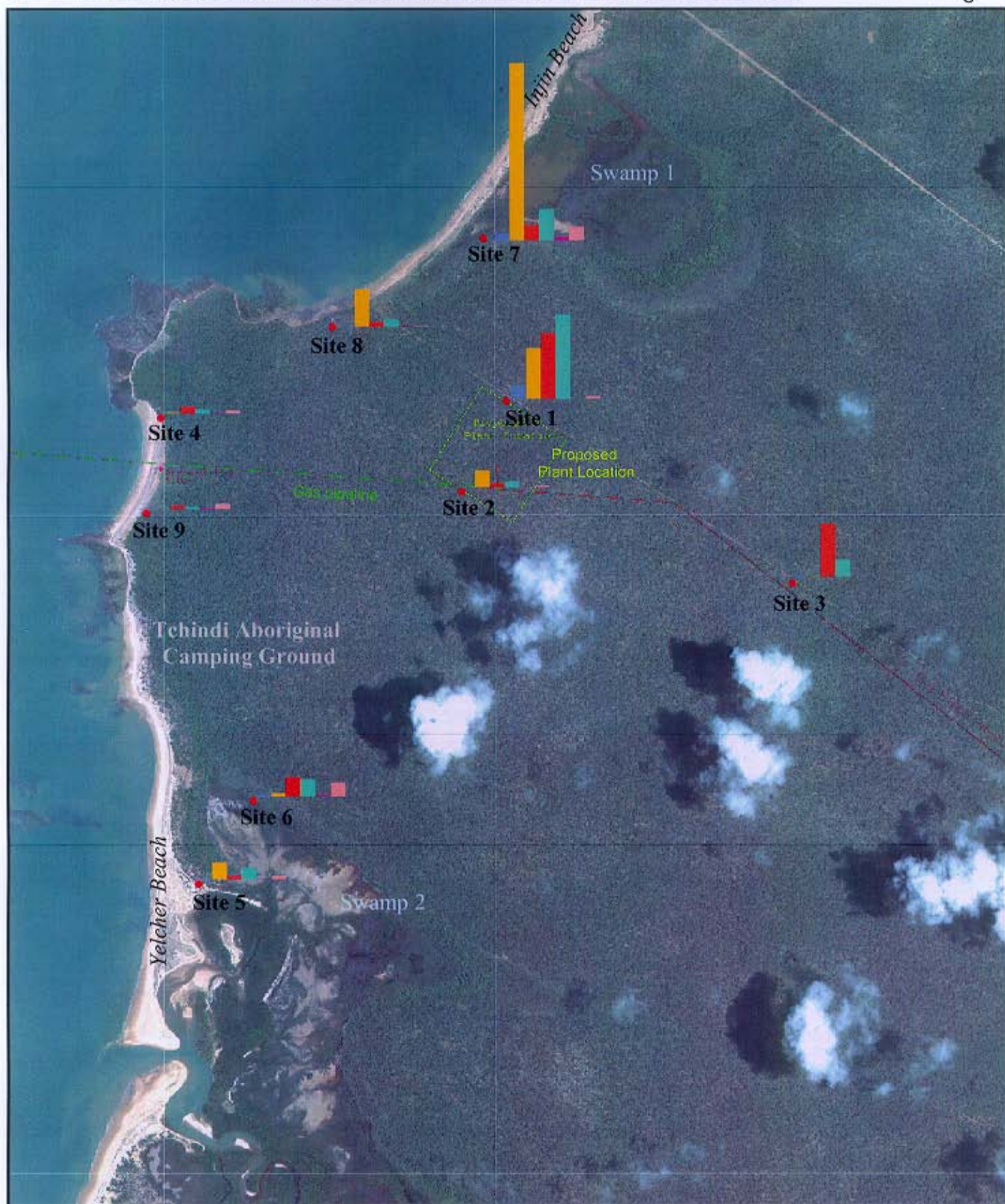
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Figures

Figure 2: Blacktip Project Biting Insect Survey, 2 - 3 June 2004
Spatial abundance of selected mosquito species collected in CO₂ baited EVS traps



Legend

640 bar length
 represents 640
 adult mosquitoes

- An. bancroftii*
- An. farauti s.l*
- Cq. xanthogaster*
- Cx. annulirostris*
- Ma. uniformis*
- Oc. vigilax*

• CO₂ EVS trap site

0 500 1,000 1,500
 Metres

Figure 3: Blacktip Project Biting Insect Survey, 2 - 3 June 2004
Spatial abundance of *Culicoides ornatus* collected in CO2 baited EVS traps

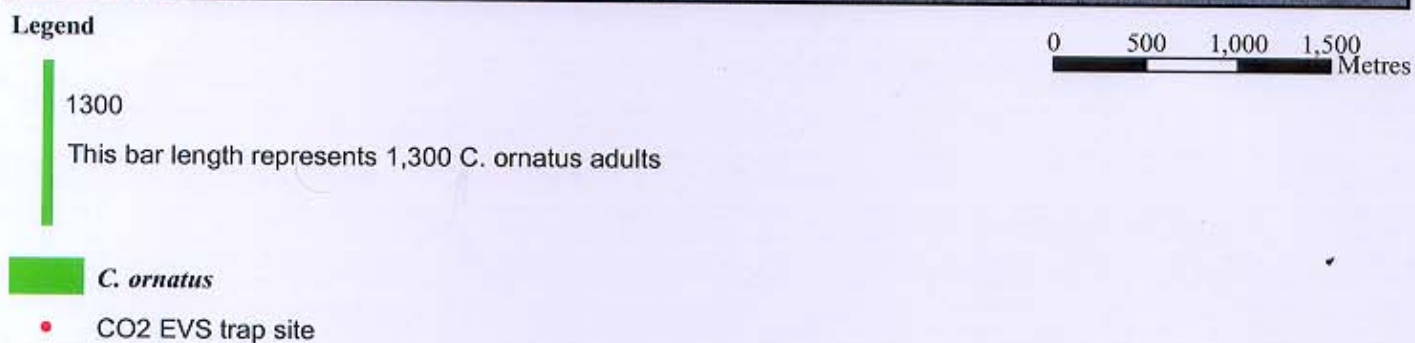
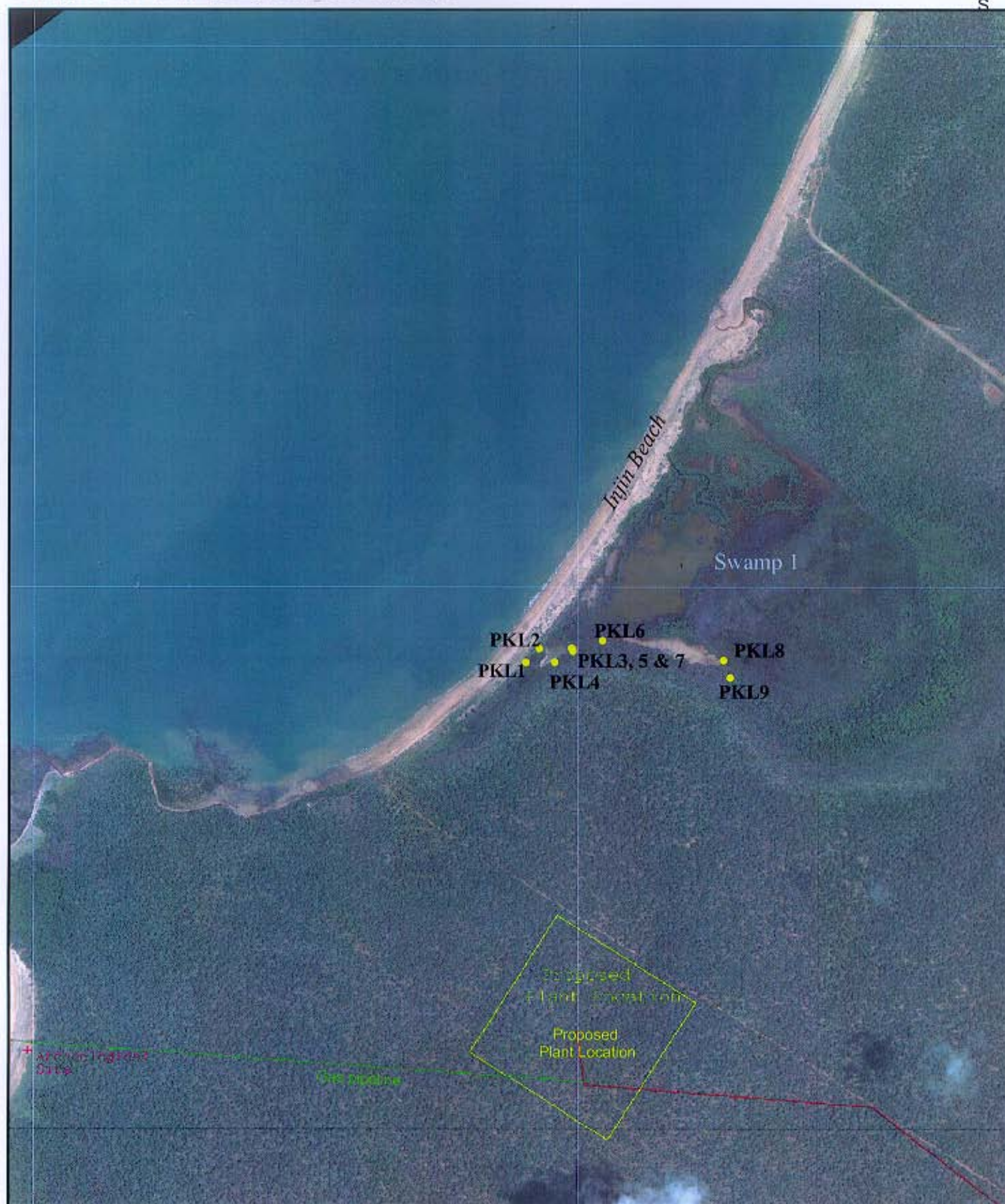


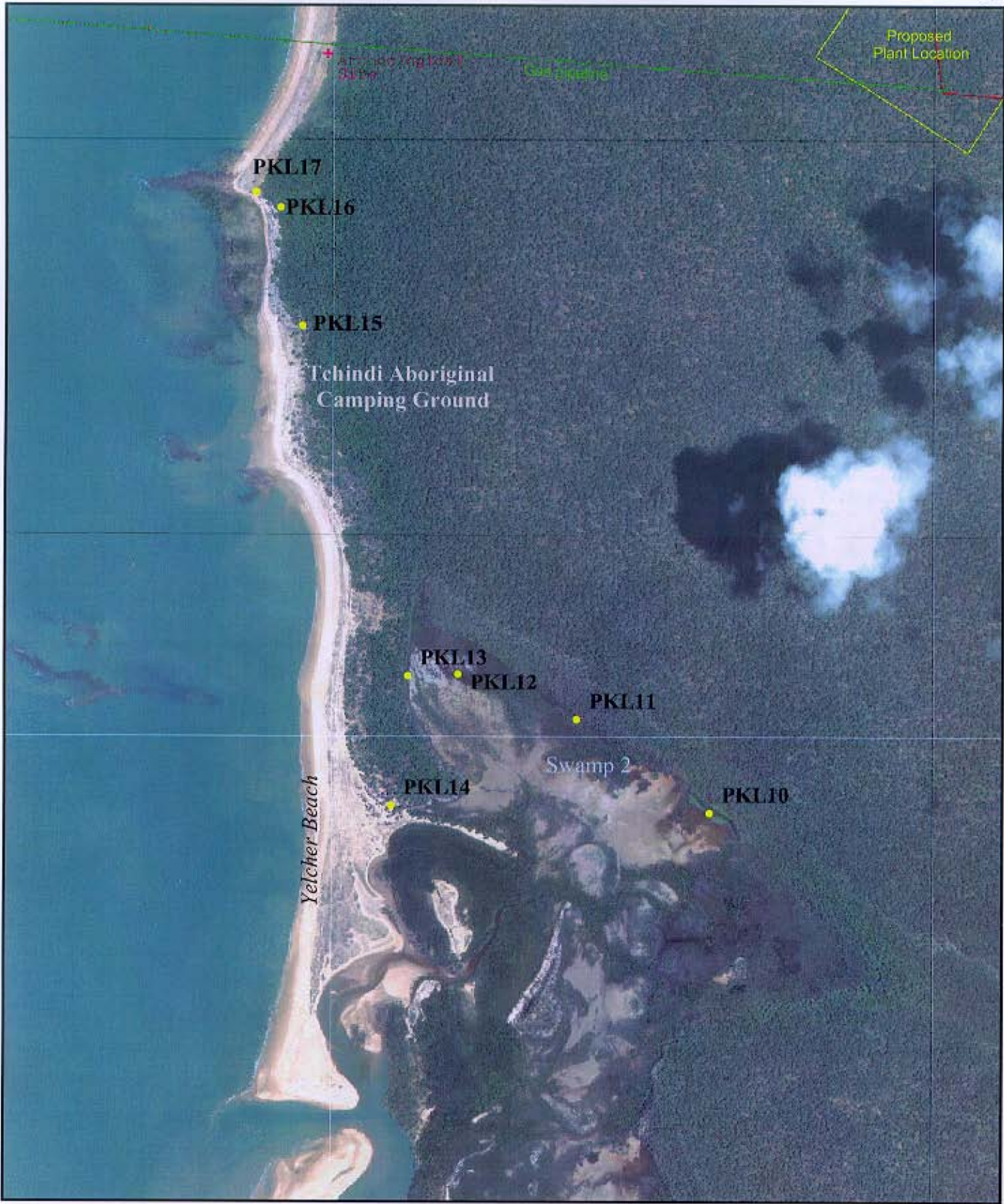
Figure 4a: Blacktip Project Biting Insect Survey, 3 June 2004
Mosquito larval sampling locations, Swamp 1



Legend

- Mosquito larval sampling locations

Figure 4b: Blacktip Project Biting Insect Survey, 3 June 2004
Mosquito larval sampling locations, Swamp 2 and southern coastal vine thicket

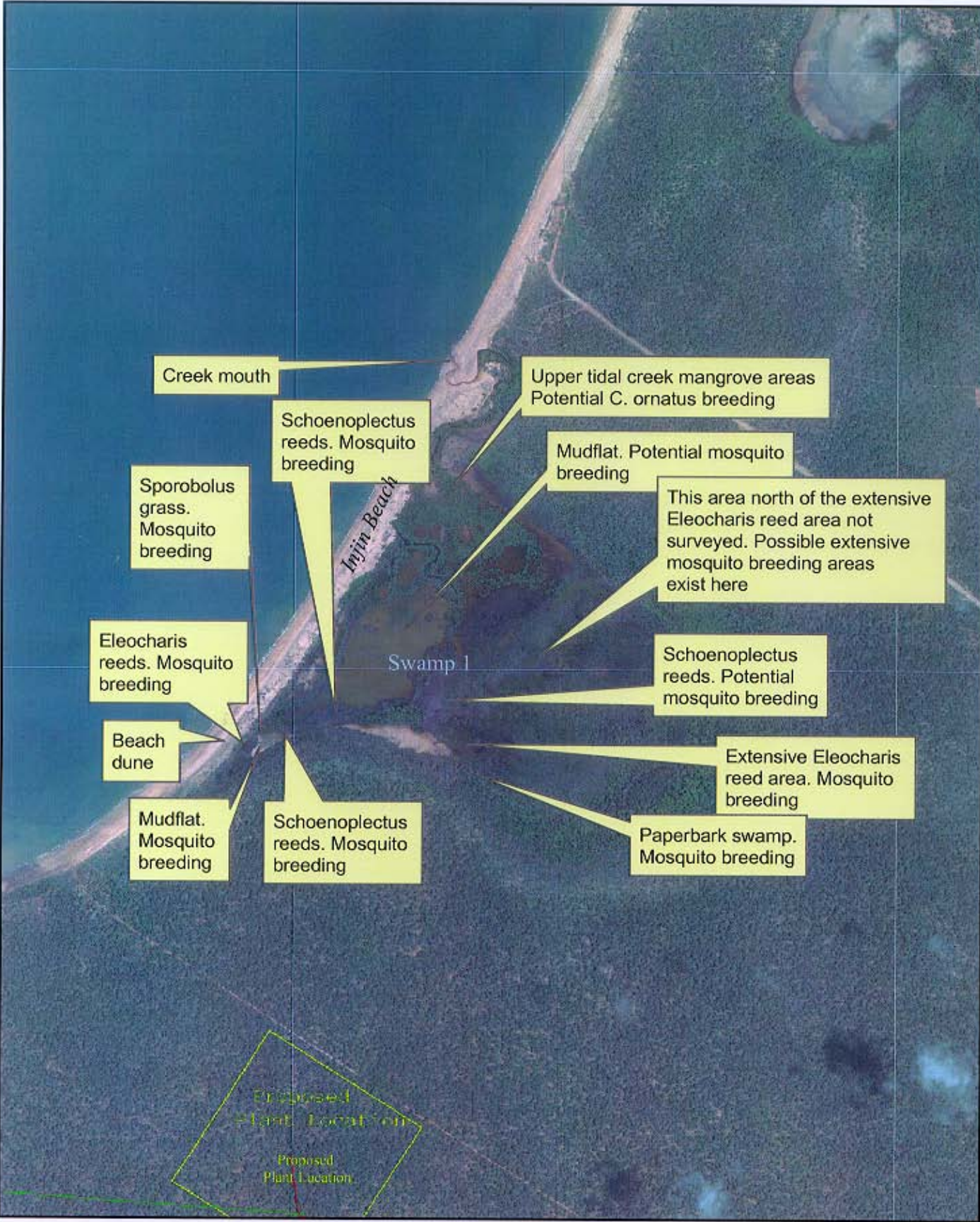


Legend

0 500 1,000 1,500 Metres

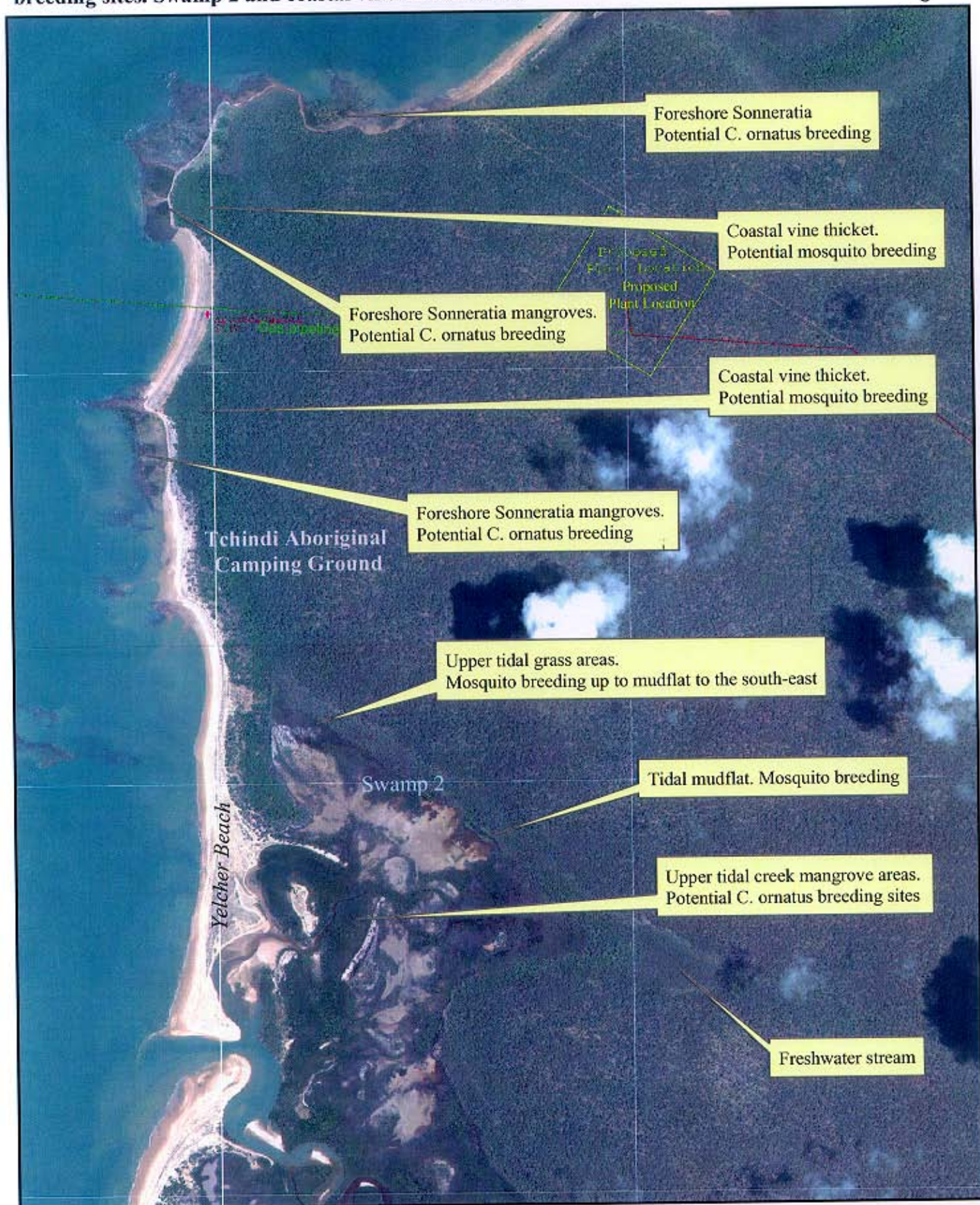
● Mosquito larval sampling locations

Figure 5a: Blacktip Project Biting Insect Survey, 2 - 3 June 2004
Actual and potential mosquito breeding sites, potential *C. ornatus* breeding sites, Swamp 1



0 500 1,000 1,500 Metres

Figure 5b: Blacktip Project Biting Insect Survey, 2 - 3 June 2004
Actual and potential mosquito breeding sites, potential *C. ornatus* breeding sites. Swamp 2 and coastal vine thicket areas



0 500 1,000 1,500 Metres

Figure 6 - Darwin weekly mosquito monitoring program - CO2 traps

HOLMES JUNGLE - 1996/02

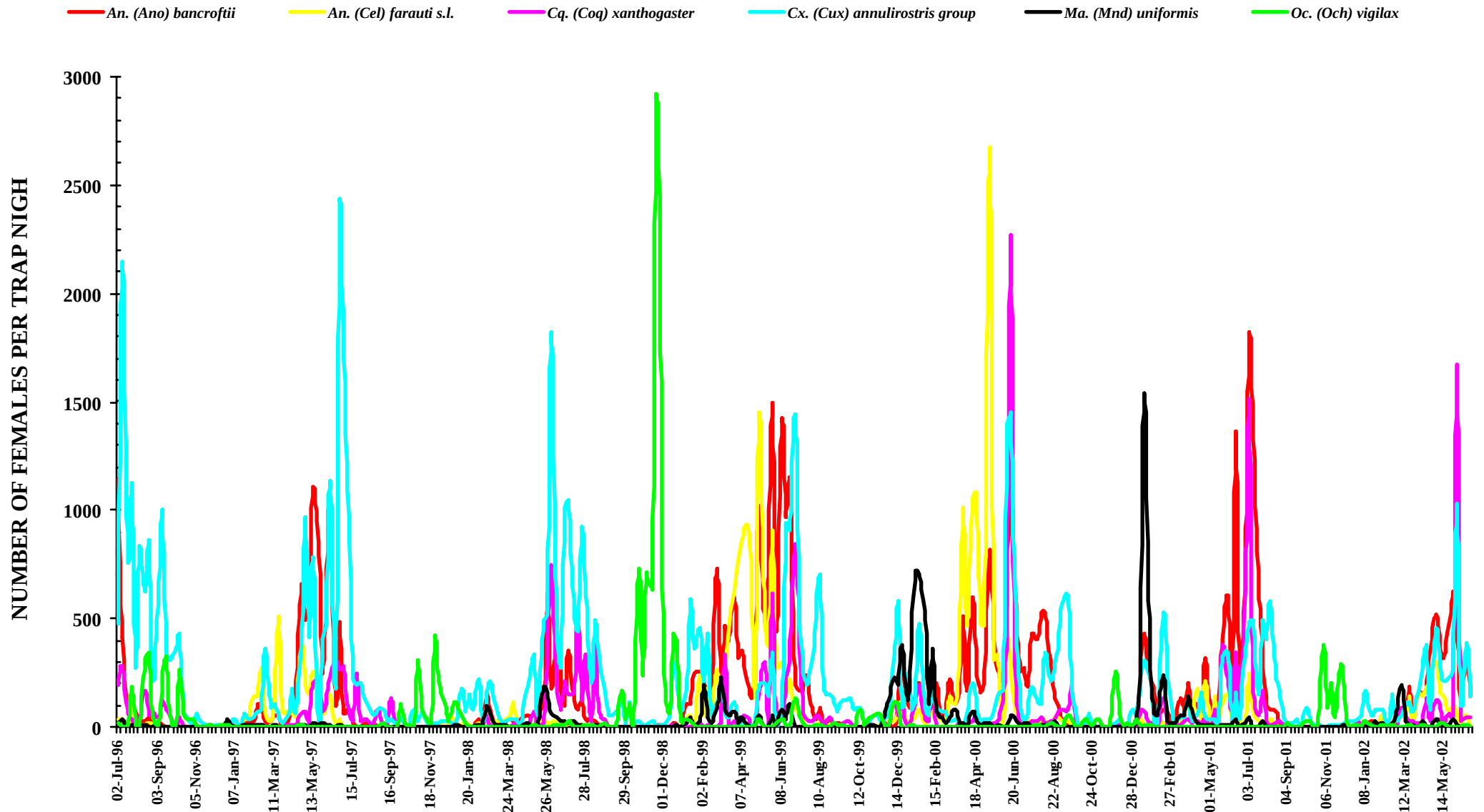
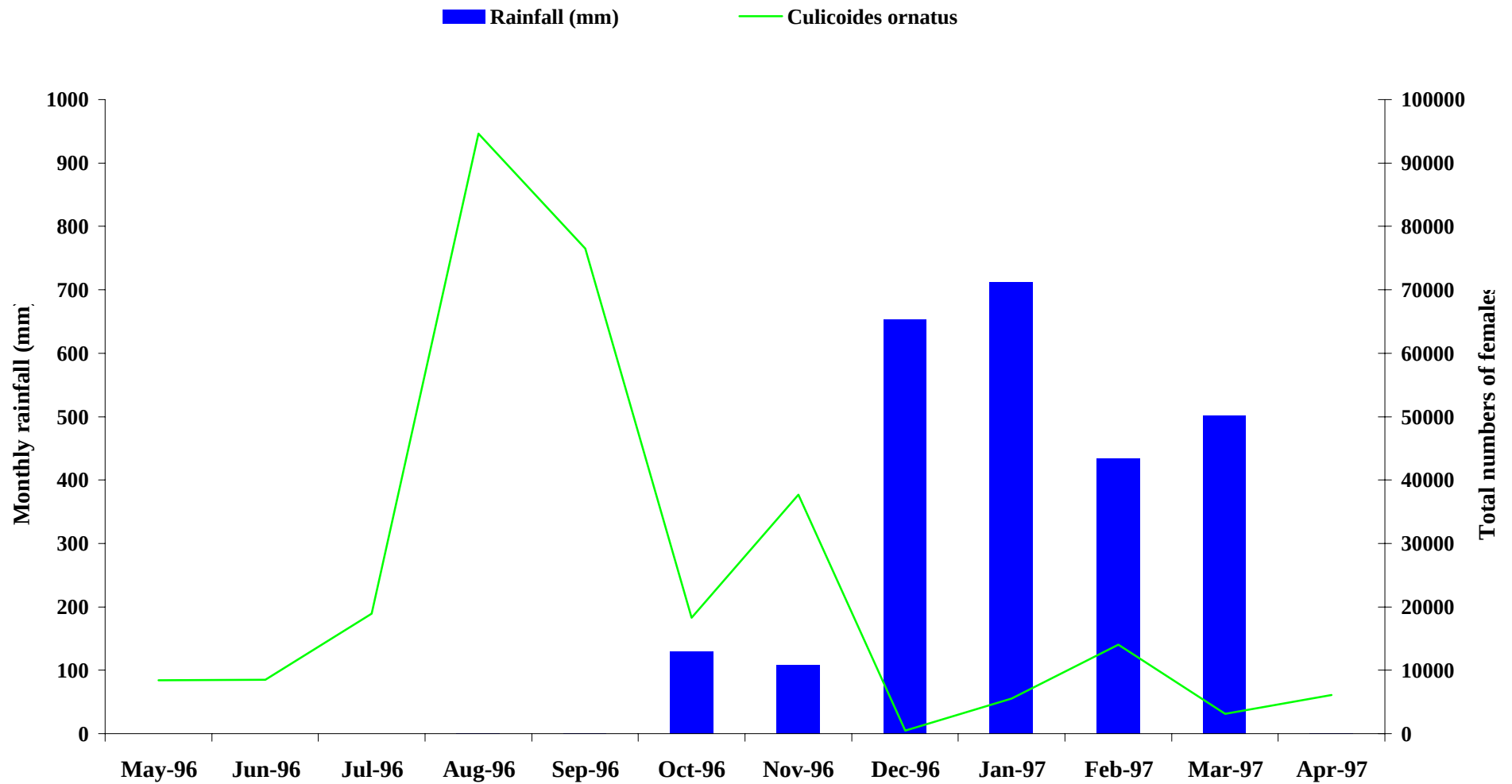


Figure 7 - Biting midge investigations "Fairway Waters" Palmerston May 1996 to April 1997
Seasonal trend of *C. ornatus* collected from all sites on all monthly trap nights,
and total monthly rainfall.



Tables

Table 1: BlacktipProject. Total number of female biting midges collected in CO2 baited EVS traps set on the afternoon of June 2, 2004 (one night before full moon). Refer to Figure 2 for trap locations

Trap location	Biting midge species									TOTAL	% OF TOTAL
	<i>C. (Ava) actoni</i>	<i>C. (Orm grp) ornatus</i>	<i>C. (Orm grp) papuensis</i>	<i>C. (Orm grp) undescribed sp No 6</i>	<i>C. (Vic grp) bundyensis</i>	<i>C. (Wil grp) austropalpalis</i>	<i>C. (Wil grp) narrabeenensis</i>	<i>C. (Wir) immaculatus</i>	<i>Culicoides unidentifiable</i>		
Site 1 - Port Keats Site 1, Centre of northern margin of proposed Gas plant	0	1	0	0	0	0	0	0	7	8	0.23
Site 2 - Port Keats Site 2, Centre of southern margin of proposed Gas Plant	2	52	0	0	44	0	0	2	0	100	2.83
Site 3 - Port Keats Site 3, 2 km from north east corner of proposed Gas Plant on access track	0	4	0	0	5	8	1	0	25	43	1.22
Site 4 - Port Keats Site 4, Vine thicket near sand dunes on western beachline	0	68	0	6	0	0	0	26	0	100	2.83
Site 5 - Port Keats Site 5, 100m north of northern mangrove margin of Tidal inlet south of Tchindi Aboriginal Camping Ground	0	380	10	0	0	100	10	0	0	500	14.16
Site 6 - Port Keats Site 6, Northern edge of paperbark/mangrove swamp	0	2530	1	55	0	0	0	55	0	2641	74.79
Site 7 - Port Keats Site 7, South west edge of Injin Beach Swamp, in paperbark margin	0	9	0	12	4	19	3	0	0	47	1.33
Site 8 - Port Keats Site 8, West end of Injin Beach, 100m back from cliff edge	0	8	0	0	0	0	0	15	0	23	0.65
Site 9 - Port Keats Site 9, Vine thicket near sand dunes on western beachline	0	34	0	1	0	0	0	20	14	69	1.95
TOTAL	2	3086	11	74	53	127	14	118	46	3531	100
% OF TOTAL	0.06	87.40	0.31	2.10	1.50	3.60	0.40	3.34	1.30	100	

**Table 2: BlacktipProject. Total number of female mosquitoes collected in CO2 baited EVS traps
set on the afternoon of June 2, 2004 (one night before the full moon). Refer to Figure 2 for trap locations**

	Mosquito species																				
Trap location	An. (Ano) bancroftii	An. (Ano) powelli	An. (Cel) farauti s.l.	An. (Cel) hilli	Cq. (Coq) xanthogaster	Cx. (Cui) pullus	Cx. (Cux) annulirostris	Cx. (Cux) palpalis	Cx. (Cux) sitiens	Cx. (Cux) squamosus	Cx. (Cux) Vishnui group	Cx. (Lop) species 167	Ho. () species 157	Ma. (Mnd) uniformis	Oc. (Cha) elchoensis	Oc. (Fin) notoscriptus	Oc. (Och) vigilax	Ur. (Ura) lateralis	Ve. (Ver) funerea	TOTAL	% OF TOTAL
Site 1 - Port Keats Site 1, Centre of northern margin of proposed Gas plant	96	0	364	10	470	0	604	0	0	0	0	0	10	0	1	0	19	0	0	1574	24.48
Site 2 - Port Keats Site 2, Centre of southern margin of proposed Gas Plant	4	1	121	0	27	0	40	9	1	0	0	0	0	0	2	0	13	0	0	218	3.39
Site 3 - Port Keats Site 3, 2 km from north east corner of proposed Gas Plant on access track	7	0	4	2	378	4	122	11	0	0	4	4	0	0	0	0	2	0	0	538	8.37
Site 4 - Port Keats Site 4, Vine thicket near sand dunes on western beachline	0	0	7	1	50	7	30	2	98	0	167	0	0	5	0	0	23	0	0	390	6.07
Site 5 - Port Keats Site 5, 100m north of northern mangrove margin of Tidal inlet south of Tchindi Aboriginal Camping	7	0	120	0	26	14	87	0	326	0	68	2	0	2	0	2	26	0	2	682	10.61
Site 6 - Port Keats Site 6, Northern edge of paperbark/mangrove swamp	15	0	25	33	141	12	124	0	77	0	0	0	2	10	0	0	102	2	0	543	8.45
Site 7 - Port Keats Site 7, South west edge of Injin Beach Swamp, in paperbark margin	50	0	1271	13	113	38	226	0	71	0	13	0	17	29	0	0	100	4	4	1949	30.32
Site 8 - Port Keats Site 8, West end of Injin Beach, 100m back from cliff edge	7	0	269	1	34	0	54	0	0	0	1	0	1	5	0	0	8	0	0	380	5.91
Site 9 - Port Keats Site 9, Vine thicket near sand dunes on western beachline	2	0	0	0	25	10	17	0	39	2	10	3	0	9	0	0	38	0	0	155	2.41
TOTAL	188	1	2181	60	1264	85	1304	22	612	2	263	9	30	60	3	2	331	6	6	6429	100
% OF TOTAL	2.92	0.02	33.92	0.93	19.66	1.32	20.28	0.34	9.52	0.03	4.09	0.14	0.47	0.93	0.05	0.03	5.15	0.09	0.09	100	

Table 3: Larval mosquito survey results. BlacktipProject Biting Insect Study June 2004. (Refer to Figure 4a & 4b for site locations)

Site number	Date	Site description	Water presence	Specific conductivity us/cm	Species	Comments
PKL1	03-Jun-04	Injin beach tidal/freshwater swamp. Grassy area near <i>Eleocharis</i> reeds, south-west edge of swamp, west of mudflat (Swamp 1)	Pooling	n/c	<i>Ve. funerea</i> 1 x 4th instar (5/dip)	Water pooling in grassy area near <i>Eleocharis</i> reeds. Recent rainfall, previous evening high tide added to flooding. Area flooded approximately 40m ² .
PKL2	03-Jun-04	Injin beach tidal/freshwater swamp. <i>Eleocharis</i> reed and <i>Sporobolus</i> grass area south-west edge of swamp, west of mudflat and south of mangroves (Swamp 1)	Flooded	n/c	<i>Oc. vigilax</i> 29 x 4th instar (22/dip) <i>Cx. sitiens</i> 4 x 2nd, 1 x 3rd, 4 x 4th instar (7/dip) <i>Culicine</i> pupae x 2 (1/dip)	Extent of flooding approximately 5000m ² . Breeding widespread throughout entire flooded area. Recent rainfall, previous evening high tide added to flooding
PKL3	03-Jun-04	Injin beach tidal/freshwater swamp. <i>Shoenopectus</i> / mangrove interface (Swamp 1)	Flooded	n/c	<i>Cx. sitiens</i> 1 x 2nd, 1 x pupae (5/dip)	Extent of flooding approximately 3500m ² . Breeding widespread throughout entire flooded area
PKL4	03-Jun-04	Injin beach tidal/freshwater swamp. Tidal mudflat, south-east end of swamp (Swamp 1)	Flooded	n/c	<i>Oc. vigilax</i> 4 x 4th, 1 x 3rd instar (1.7/dip) <i>Cx. sitiens</i> 1 x 4th instar (0.3/dip)	Larvae found amongst grassy edge, although were widespread throughout the mudflat. Area of water approximately 5000m ² .
PKL5	03-Jun-04	Injin beach tidal/freshwater swamp. <i>Shoenopectus</i> / mangrove interface, SE edge of reed area (Swamp 1)	Flooded	13,500	<i>An. farauti</i> 11 x 4th, 4 x 3rd instars (0.5/dip) <i>An. hilli</i> 2 x 4th instar (0.07/dip) <i>Cx. sitiens</i> 3 x 4th, 1 x 2nd instar (0.14/dip) <i>Oc. vigilax</i> 95 x 4th, 23 x 3rd, 2 x 2nd instars (4.2/dip) <i>Anopheline pupae</i> x 2 (0.07/dip)	Area flooded approximately 3500m ² . Larvae widespread
PKL6	03-Jun-04	Injin beach tidal/freshwater swamp. <i>Shoenopectus</i> reed area between two mangrove areas, south margin of swamp (Swamp 1)	Flooded	18,900	<i>Cx. sitiens</i> 5 x 4th, 3 x 3rd, 1 x 2nd, 2 x 1st instars (0.85/dip) <i>Oc. vigilax</i> 1 x 4th instar (0.077/dip) <i>An. farauti</i> 1 x 3rd instar (0.077/dip)	Area flooded approximately 17000 m ² . Larvae widespread

PKL7	03-Jun-04	Injin beach tidal/freshwater swamp. <i>Schoenoplectus</i> reed area, south-west margin of swamp (Swamp 1).	Flooded	n/c	<i>Oc. vigilax</i> 2 x 4th instars (0.9/dip) <i>Cx. sitiens</i> 1 x 4th, 6 x 3rd, 2 x 2nd instars (4.1/dip)	Area flooded approximately 3500m ² . Larvae widespread
PKL8	03-Jun-04	Injin beach tidal/freshwater swamp. Extensive <i>Eleocharis</i> reed area, south edge of swamp (Swamp 1)	Flooded	800	<i>An. bancroftii</i> 8 x 4th, 7 x 3rd instars (1.34/dip) <i>An. farauti</i> 2 x 3rd, 1 x 2nd instars (0.27/dip) <i>An. sp.</i> 3 x 2nd instars (0.27/dip) <i>Cx. annulirostris</i> 8 x 4th, 10 x 3rd, 4 x 2nd instars (2/dip) <i>Cx. sp. 32</i> 1 x 4th, 2 x 2nd instars (0.27/dip) <i>Mi. metallica</i> 1 x 3rd, 2 x 2nd instars (0.27/dip) <i>Mi. elegans</i> 1 x 3rd instar (0.09/dip) <i>Ur. nivipes</i> 1 x 4th instar (0.09/dip) <i>Cx. bitaeniorhynchus</i> 2 x 4th instar (0.18/dip) <i>Cx. (Lop) sp 155</i> 2 x 4th, 1 x 3rd instars (0.27/dip)	Area flooded approximately 23,000m ² . Larvae widespread
PKL9	03-Jun-04	Injin beach paperbark swamp. Pigrooted area south of <i>Eleocharis</i> reed area (Swamp 1).	Pooling	n/c	<i>Cx. halifaxii</i> 1 x 2nd instar (0.07/dip) <i>Cx. pullus</i> 5 x 4th, 7 x 3rd instars (0.83/dip) <i>Ve. funerea</i> 5 x 4th, 1 x 3rd, 2 x 2nd instars (0.48/dip) <i>Cx. (Lop) sp 155</i> 2 x 4th, 2 x 2nd instars (0.28/dip) <i>Culicine pupae</i> x 1 (0.07/dip) <i>Ur. tibialis</i> 1 x 2nd instar (0.07/dip) <i>An. farauti</i> 2 x 3rd instar, 1 x 2nd instar (0.21/dip)	Area pooling approximately 50m ² . Extensive flooding also noticed in the paperbark swamp to the east of this location.

PKL10	03-Jun-04	Large tidal mudflat north of freshwater creekline (Swamp 2)	Flooded	n/c	<i>Oc. vigilax</i> 4 x 4th, 1 x 2nd instar (0.83/dip) <i>An. farauti</i> 1 x 2nd instar (0.17/dip)	Area of flooding approximately 10,000m ² . Only eastern edge checked for mosquito breeding, larvae found along edge.
PKL11	03-Jun-04	Narrow tidal grass area between mangroves and paperbark fringe, including flowline from paperbarks to tidal area (Swamp 2)	Pooling	n/c	<i>Oc. vigilax</i> 4 x 4th, 2 x 3rd instars (3.75/dip) <i>Ve. funerea</i> 2 x 4th instar (1.12/dip)	Animal disturbed areas in paperbark forest and tidal grass area. Breeding found in tidal grass and paperbark fringe flowline. Area of water checked for breeding was approximately 40m ² , with the area breeding approximately 10m ² .
PKL12	03-Jun-04	Large tidal grass plain (Swamp 2)	Pooling	n/c	<i>Oc. vigilax</i> 6 x 3rd, 1 x 2nd instars (5/dip)	Area of water approximately 50m ² . Larvae found in 20m ² area of water. Considerable areas of this tidal grass area may pool water in the late dry and early wet season.
PKL13	03-Jun-04	Depressions in vehicle track along upper tidal margin of tidal grass swamp, and depressions in mudflat (Swamp 2)	Pooling	n/c	Nil mosquitoes	
PKL14	03-Jun-04	Depression in sand dune	Dry	n/a	Nil mosquitoes	Evidence of green grass indicates wet season pooling. Depression approximately 80m ² .
PKL15	03-Jun-04	Paperbark swamp behind beach dune, in-between coastal vine thicket	Dry	n/a	Nil mosquitoes	Water may pool for up to 500m ² during wet season
PKL 16	03-Jun-04	Coastal vine thicket. Restricted flowlines in vine forest	Dry	n/a	Nil mosquitoes	Could be large salt marsh mosquito breeding site
PKL17	03-Jun-04	Coastal vine thicket. Restricted flowlines in vine forest	Dry	n/a	Nil mosquitoes	Could be large salt marsh mosquito breeding site

Appendix 1



Trap site 1: Near centre of northern boundary of onshore gas processing plant, approximately 15 in from access road. People pictured are NLC helpers and Jane Carter of MEB.



Trap site 2: Centre of southern boundary of onshore gas processing plant site. Jane Carter in foreground, NLC workers in background.



Trap site 3: Approximately 2km south-east of onshore gas processing plant north-east boundary, 15m in from access track.



Trap site 4: South-west edge of northern coastal vine thicket. Approximately 5m in from beach dune



Trap site 5: In dunal area near mangroves of Swamp 1, south of southern coastal vine thicket and Tchindi Aboriginal Camping Ground



Trap site 6: Swamp 2. Paperbark/tidal grass fringe. Popeye Briston on right of picture with other NLC workers. Jane Carter holding trap.



Trap site 7: Swamp 1, south-west edge. Trap set in paperbark margin in centre of picture



Trap site 8: Approximately 50m east from shoreline cliff face, north-west of onshore gas processing plant site



Trap site 9: North-west edge of southern coastal vine thicket.

Appendix 2



Photo 1. Swamp 1, looking east from PKL1. *Sporobolus sp.* tidal grass area, corner of mudflat middle left hand side of picture.



Photo 2: Swamp 1. Looking NE from PKL1. Brown areas are *Eleocharis* reeds. Flooded mudflat located behind *Eleocharis* reeds.



Photo 3: Swamp 1. Dense flooded *Eleocharis* reed area just south of PKL2. Green area north of *Eleocharis* reeds, west of mudflat consists of *Sporobolus* sp. grass.



Photo 4: Swamp 1. Larval site PKL6, looking north. *Shoenoplectus* reeds associated with mangroves in centre of picture. Further extensive mudflat and *Shoenoplectus* area located behind this mangrove/*Shoenoplectus* area.



Photo 5: Swamp 1. Larval site PKL9. Pig rooted paperbark swamp, looking east. Similar areas like this extend for a considerable distance



Photo 6: Swamp 1, larval site PKL8. Extensive *Eleocharis* reed area, pig rooted area bottom right hand corner of picture. Photo taken looking east.



Photo 7: Swamp 1. Larval site PKL8. *Eleocharis* reed area looking north. *Shoenoplectus* reeds seen as dark brown band at northern limit of *Eleocharis* reeds.



Photo 8: Swamp 1. Larval site PKL8. Paperbark/*Eleocharis* fringe, looking east. Extensive feral pig damage.



Photo 9: Southern Coastal vine thicket interdune area. Larval site PKL17. Flowline from dune vegetation to frontal beach dune.



Photo 10: Southern Coastal vine thicket interdune area. Larval site PKL17. Flowline from forest to frontal beach dune.



Photo 11: Southern Coastal vine thicket interdune area. Larval site PKL16.
Beach Hibiscus at entrance to flowlines in forest



Photo 12: Interdune flowline adjacent to Southern Coastal vine thicket.
Larval site PKL 16. Inside forest from Photo 11.



Photo 13: Interdune flowline adjacent to Southern Coastal vine thicket. Larval site PKL16. Inside forest from Photo 11.



Photo 14: Interdune depression and flowline adjacent to Southern Coastal vine thicket. Larval site PKL 15. Low lying area looking north, frontal beach dune to the left of photo.



Photo 15: Interdune depression and flowline adjacent to Southern Coastal vine thicket. Larval site PKL15, Photo taken looking south



Photo 16: Interdune depression adjacent to Southern coastal vine thicket. Larval site PKL14. Low lying area, mangrove margin to the right, vine thicket to the left.



Photo 17: Swamp 2. Larval site PKL 13. Upper tidal limit, looking south-east.



Photo 18: Swamp 2. Larval site PKL13, upper tidal limit looking south..



Photo 19: Swamp 2. Large upper tidal grassy area slightly east of Larval site PKL13, looking south-east. Paperbark margin in background.



Photo 20: Swamp 2. Larval site PKL12. Upper tidal grassy area, looking south into mangrove margin



Photo 21: Swamp 2. Larval site PKL 11. Paperbark/upper tidal grass margin, looking east.



Photo 22: Swamp 2. Larval site PKL 10. Poorly draining mudflat area in upper high tide zone, bordering tidal grass area. Photo looking west.

Appendix 3

TABLE 1

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

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

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

TABLE 2

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

Peter Whelan

Medical Entomology Branch, Territory Health Services

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

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

Appendix 4



NORTHERN TERRITORY GOVERNMENT

DEPARTMENT
OF HEALTH
AND COMMUNITY
SERVICES

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

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Medical Entomology Branch
Department of Health and Community Services
1997

Updated January 2004

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

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

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

Flight range

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

Species identities

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

Pest levels

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

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

MAJOR PEST AND VECTOR MOSQUITO SPECIES IN THE TOP END OF THE NT* Peter Whelan, Medical Entomology Branch, Department of Health and Community Services 1997		
SPECIES	PEST STATUS ¹	VECTOR STATUS
<i>An. annulipes s.l.</i> ²	Widespread pest, bites at night and will enter houses.	Potential malaria vector.
<i>An. bancroftii</i>	Major pest, widespread, bites anytime near breeding site, nightly or shaded areas elsewhere.	Potential malaria vector.
<i>An. farauti s.l.</i> ²	Local pest, bites at night. Uncommon, except near mostly sub-coastal and extensive freshwater or brackish swamps.	Major potential vector of malaria.
<i>An. hilli</i>	Coastal pest, bites at night, enters houses. Common near brackish water swamps.	Potential malaria vector.
<i>An. meraukensis</i>	Local pest, bites after dark. Very common near extensive freshwater swamp.	Not potential malaria vector.
<i>Cx. annulirostris</i>	Major pest, very common and widespread in both urban and rural areas. Bites mainly in evening and at night.	Major arbovirus vector of Murray Valley encephalitis virus (MVEV), Kunjin virus, Ross River virus (RRV) and Barmah Forest virus (BFV) and dog heart worm. Vector of numerous other arboviruses.
<i>Cx. quinquefasciatus</i>	Major urban pest, bites at night, indoors, rests indoors, populations common with polluted water in dry season.	Potential arbovirus vector (MVEV). Vector of heartworm of dogs.
<i>Cx. sitiens</i>	Localized coastal pest, breeds in brackish or tidal waters, disperses widely, bites at night.	Probably no diseases. Possible RRV disease.
<i>Cq. xanthogaster</i>	Major localized pest near extensive reed swamps, disperses widely, bites at night, or in dense shade in day, attracted to lights.	No diseases. Filariasis in frill neck lizard
<i>Ma. uniformis</i>	Localized pest, bites at night near the breeding site, attracted to lights, does not disperse far from breeding sites.	No diseases.
<i>Oc. kochi</i>	Local pest at breeding site, does not disperse. Restricted to <i>Pandanus</i> thickets.	No diseases.
<i>Oc. normanensis</i>	Major pest, bites in evening and night within 3 km of breeding sites. Plagues in inland areas a week after widespread flooding rains in wet season.	Major vector of Ross River and Barmah Forest viruses. Potential vector of MVEV. Potential vector of many other arboviruses.
<i>Oc. notoscriptus</i>	Local urban pest, container or tree hole breeder, bites persistently, anytime in cool shade. Found naturally in forest areas.	Potential Ross River virus vector. Major vector of heartworm of dogs.
<i>Oc. tremulus</i>	Local urban pest, container or tree hole breeder, bites at sundown and dawn. Often caught in forest areas.	No diseases.
<i>Oc. vigilax</i>	Major pest, bites day or night within 5 km of breeding sites. Plagues associated with high tides in late dry season, early wet season. Fly up to 60 km in pest numbers.	Major vector of Ross River and Barmah Forest virus diseases and dog heartworm. Potential vector of many other arboviruses.
<i>Ve. funerea</i>	Local pest near breeding grounds, does not disperse. Common by day only locally inclosed forrest near tidal brackish swamps & Creeks.	Potential RRV and BFV arbovirus vector.
* Adapted and revised from P. Liehne et al. "Mosquitoes and biting midge investigation, Palmerston 1982 -85".		

**BIOLOGICAL ATTRIBUTES OF THE MAJOR PEST AND VECTOR MOSQUITO SPECIES
IN THE TOP END^ OF THE NT***

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

SPECIES	IMMATURE STAGES	ADULT STAGES
<i>An. annulipes s.l.</i>	Eggs laid singly on water surface; any freshwater body but numerous near <i>Eleocharis</i> reed swamps; temporary or permanent; some containers; larvae float on water surface and feed on particles on top of water.	Feeds on a variety of mammals include cattle and humans. Bites at night, especially dawn and dusk. Flies up to 2 km from breeding site; rests in cool shady locations such as stream margins, drains etc.
<i>An. bancroftii</i>	Eggs laid singly. Dark larvae, feeds at water surface; found in heavily shaded fresh to slightly brackish ground pools or swamps, especially in paperbark or <i>Eleocharis</i> reed swamps.	Feeds on all mammals readily; will fly up to 4 km from breeding site; bites any time near breeding site, nightly or in shade elsewhere.
<i>An. farauti s.l.</i> (Includes <i>An. farauti</i> , <i>An. hinesorum</i> and <i>An. torresiensis</i>)	Eggs laid singly on surface; larvae feed on water surface. <i>An. farauti</i> breeds in brackish water; <i>An. hinesorum</i> and <i>An. torresiensis</i> breed in freshwater swamps and pools. Larval habitat often sunlit.	Bites readily at night; feeds on humans, other mammals and birds. Will fly approximately 2 km from the breeding site.
<i>An. hilli</i>	Eggs laid singly on surface; larvae feed at surface; sunlit or shaded brackish to saline ground pools or swamps. Numerous in <i>Schoenoplectus</i> reed swamps near coast.	Bites humans, cattle and horses; mainly after sunset. Disperses up to 4 km from breeding site.
<i>An. meraukensis</i>	Eggs laid singly on surface of water; larvae feed at the surface; usually in freshwater <i>Eleocharis</i> reed swamps, sunlit or shaded.	Bites readily at dusk, feeds on humans and other mammals.
<i>Cx. annulirostris</i>	Eggs deposited as rafts of up to 200 on the water surface; larvae hang from surface and feed on suspended particles; breed in freshwater pools and swamps with emergent vegetation temporary or permanent; will colonize domestic containers and breed readily in semi polluted water in storm drains or sewage effluent with vegetation.	Adults are the most common species encountered in the NT and are present throughout the year; feed at night and will bite humans, other mammals and birds; will fly distances of up to 10 km from the breeding site, although common up to 4 km from breeding site.
<i>Cx. quinquefasciatus</i>	Eggs laid as rafts on the surface; breeding grounds are polluted to fresh domestic waters; major sources are septic tanks, leach drains, primary sewage ponds and other polluted ground waters.	Severe domestic pest of humans but will feed on poultry and dogs as well; will feed and rest indoors; bites at night; flies up to 1 km from breeding site.
<i>Cx. sitiens</i>	Eggs laid as rafts on surface; brackish coastal ground pools under tidal influence with or without vegetation; larvae hang from the surface and rest on bottom. Feed on suspended matter or on substrate.	Bites mammals and birds at night; pest near coast, will fly up to 5 km but common within 2 km of breeding site.
<i>Cq. xanthogaster</i>	Eggs laid as small raft on the surface; larvae attach themselves to the stems of aquatic plants by a modified siphon and obtain oxygen from the plants; breed in semi-permanent to permanent swamps with emergent vegetation; associated with <i>Eleocharis</i> and <i>Typha</i> reeds, water lilies and paperbark; larvae feed on suspended material in the water.	Adults are strong fliers and will disperse widely up to 3 - 5 km. Readily feed on birds and mammals including humans; rest in cool vegetation and bite mainly at dusk, also shade during day. Strongly attracted to light and easily disturbed.
<i>Ma. uniformis</i>	Eggs laid as small cluster attached to the under surface of floating leaves water lilies and plant stems; larval habitats and breeding area similar to <i>Cq. xanthogaster</i> .	Adults bite humans, other mammals and birds readily at night. Severe pest in cool shade near breeding site during the day and evening; generally does not fly more than 1 - 2 km from breeding sites; strongly attracted to light; adults rest in dense vegetation; pest in the wet season near breeding areas only.

SPECIES	IMMATURE STAGES	ADULT STAGES
<i>Oc. vigilax</i>	Eggs deposited singly in the mud or near plant stems in suitable habitats; breeds in tidal pools and marshes, usually those filled by tides in upper tidal zone associated with <i>Schoenoplectus littoralis</i> or landward ill draining mangrove areas; larvae browse on substrate.	Major and severe pest species; adults feed very readily on humans, other mammals and birds, day or night; will fly up to 60 km; shelter in thick vegetation.
<i>Oc. kochi</i>	Eggs laid singly on the axils of <i>Pandanus</i> leaves. Larvae feed on detritus and debris in the water collected in the axil space.	Severe pests near the breeding sites. Do not disperse far from the breeding habitat.
<i>Oc. normanensis</i>	Eggs deposited singly in drying mud substrate in poorly draining floodways. Pale larvae can be inconspicuous in colloidal clay suspension water. Tend to dive to bottom when disturbed. Feed by browsing on substrate. Mainly inland rural habitats.	Major pest species. Extreme numbers after flooding rains for 1- 2 weeks. Feeds readily on humans and other mammals, mainly in evening and night. Will fly 3 - 5 km in pest numbers.
<i>Oc. notoscriptus</i>	Eggs laid singly on the sides of tree holes. Dark larvae hang from the surface by siphon and feed by browsing on the substrate. Common in domestic container habitats.	Feeds on humans and all mammals; bites day or evening in the cool shade. Does not disperse widely.
<i>Ve. funerea</i>	Eggs laid singly on moist substrate at edge of breeding area, usually shaded with some salt influence. Dark larvae hang from water surface, generally feeding by browsing on the bottom of the water body.	Vicious biter in cool shaded vegetation near breeding site in day and in evening. Does not continue biting in sun. Do not disperse far from the breeding habitat.
* Adapted, revised and expanded from P. Liehne et al. "Mosquitoes and biting midge investigation, Palmerston 1982-85". ^ Applicable for general area of Top End north of and including Mataranka, Larrimah, from Victoria River to Roper River mouths.		

SEASONAL PREVALENCE OF THE MAJOR PEST AND VECTOR MOSQUITO SPECIES IN THE TOP END OF THE NT* Peter Whelan Medical Entomology Branch, Department of Health and Community Services 1997	
SPECIES	SUMMARY OF BIOLOGY & SEASONAL PREVALENCE
<i>An. annulipes s.l.</i>	Freshwater streams and vegetated swamps. Low to moderate numbers in the wet season, the persistence of populations after the wet season dependent on surface water.
<i>An. bancroftii</i>	Freshwater, paperbark and <i>Eleocharis</i> reed swamps and creeks. High to very high numbers at post wet and early dry season, when emergent vegetation at peak and standing water starting to recede.
<i>An. farauti s.l.</i>	Brackish and freshwater species, in vegetated swamps or creeks. Low to moderate numbers in late wet and early post wet season.
<i>An. hilli</i>	Brackish/saltwater breeder, often associated with <i>Schoenoplectus</i> reed swamps or creeks or remnant pools in landward mangroves. Low numbers except near extensive brackish water swamps in late wet and early dry season.
<i>An. meraukensis</i>	Open shallow freshwater <i>Eleocharis</i> reed swamps and creeks. Moderate to high numbers in the late and immediate post wet season,
<i>Ma. uniformis</i>	Same as <i>Cq. xanthogaster</i> but more associated with floating vegetation, (water lilies). Moderate to very high numbers near habitats in late wet, early dry season.
<i>Cx. annulirostris</i>	Breeds in the vegetated margins and pools in permanent and semi-permanent swamps, creeks and floodways. Exploits temporary vegetated ground pools in wet season. High numbers in polluted or wastewater with vegetation in dry season. High to very high numbers in the early to mid dry season.
<i>Cx. quinquefasciatus</i>	Domestic water sites, often with organic pollution. Moderate numbers in mid to late dry season, but can be present all year.
<i>Cx. sitiens</i>	Breeds in salt to brackish coastal pools or swamps. Low numbers except locally in tidal pools in upper tide zone in late dry, early wet season, and late wet season.
<i>Cq. xanthogaster</i>	Breeds in freshwater <i>Eleocharis</i> reed swamps and creeks. Very high numbers in mid to late dry season when maximum plant growth present in permanent and semi permanent swamps and creeks.
<i>Oc. kochi</i>	Breeds in <i>Pandanus</i> axils. Moderate numbers in wet season in <i>Pandanus</i> thickets.
<i>Oc. normanensis</i>	Floodwater, ground pool breeder in poorly draining floodways associated with creeks and rivers. Very high numbers during wet season, absent at other times.
<i>Oc. notoscriptus</i>	Tree hole or artificial container breeder. Low numbers in wet season but persists in dry season with artificial breeding sites.
<i>Oc. tremulus</i>	Tree hole or container breeder. Low numbers in wet season and early dry season.
<i>Oc. vigilax</i>	Breeds in tidal to brackish swamp or tidal pools in creeks. Extreme numbers in the very late dry and early wet season.
<i>Ve. funerea</i>	Brackish to tidal ground pools in tidal creeks and swamps, often in shade. Localised pest numbers in the pre wet and wet.
* Adapted, revised and expanded from P. Liehne et al. "Mosquitoes and biting midge investigation, Palmerston 1982-85".	

**PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT
PEST AND DISEASE VECTOR STATUS**

Peter Whelan 1997

Medical Entomology Branch, Department of Health and Community Services

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

PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT **INDICATIVE PEST LEVELS**

Peter Whelan 2002

Medical Entomology Branch, Department of Health and Community Services

Species	Main distribution	Peak Period	CO ₂ Trap at Residence *	CO ₂ Trap at Monitoring Site #
<i>Ochlerotatus vigilax</i>	Top End, north of Wave Hill, Larrimah and Borroloola	September - January	20	50
<i>Ochlerotatus normanensis</i>	Subcoastal Top End south to Ti Tree	January - April	30	50
<i>Culex annulirostris</i>	NT wide	January to August	50	100
<i>Anopheles bancroftii</i>	Top End north of Victoria and Roper River, south to Larrimah	February - July	30	60
<i>Coquillettidia xanthogaster</i>	Top End north of Victoria and Roper River, south to Larrimah	March - August	30	60
<i>Mansonia uniformis</i>	Top End south to Larrimah	March - June	30	60
<i>Anopheles farauti s.l.</i>	Top End north of Port Keats, Pine Creek, and Numbulwar	March - June	30	50
<i>Culex quinquefasciatus</i>	NT wide, primarily near residential areas	January - June	20	30
<i>Ochlerotatus notoscriptus</i>	NT wide, generally near residential areas	January - June	30	30
<i>Verrallina funerea</i>	Top End primarily coastal and sub-coastal but occasionally south to Larrimah	Nov - March	20	100
Pest Levels				
* Indicative significant pest threshold levels (mosquitoes per CO ₂ trap per night) at residence for relatively unprotected people at peak biting times.				
# Indicative significant pest threshold levels (mosquitoes per CO ₂ trap per night) in residential areas from monitoring sites close to but outside of residential areas, and for monitoring sites between the residential areas and major mosquito breeding areas that are within 2km of residential areas.				

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

Appendix 5



**Northern
Territory
Government**

Department of Health
and Community Services

PERSONAL PROTECTION FROM MOSQUITOES & BITING MIDGES IN THE NT

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April 2004*

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* Minor revisions 2004

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PERSONAL PROTECTION FROM MOSQUITOES & BITING MIDGES

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April 2004**

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

1.0 MOSQUITO & BITING MIDGE BITES

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

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

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

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

The place of feeding by mosquitoes or biting midges is varied. Some species, such as the brown house mosquito, readily 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 the skin. Blood is sucked up through one of the channels in the stylets, while saliva is injected down an adjacent channel. This saliva contains substances that the human body recognises as foreign and often stimulates a bite reaction. Sometimes the saliva can contain viruses or other pathogens that can cause disease.

Some people can become very sensitive after being bitten and suffer a general reaction from further bites. The bites may itch for days, producing restlessness, loss of sleep and nervous irritation. Scratched bites can lead to secondary infections and result in ugly scars. On the other hand, some people become tolerant to particular species and suffer little after-effects from repeated bites.

Biting insects create problems in the enjoyment of outdoor activities, causing a reluctance to enter certain areas after sundown or forcing people to be confined to insect-proof areas at certain times of the year. Personal protection and avoidance measures can offer considerable protection from bites, as well as offering protection against mosquito-borne disease.

2.0 MOSQUITO & BITING MIDGE AVOIDANCE

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

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

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

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

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

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

3.0 SCREENING

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

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

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

4.0 MOSQUITO NETS

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

5.0 INSECT PROOF CLOTHING

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

6.0 REPELLENTS

Relief from biting insect attack may be obtained by applying repellents to the skin and clothing (Schreck et al. 1984). Many repellents affect plastics and care is needed when applying them near mucous membranes such as the eyes and lips.

Repellents with the chemical diethyl toluamide (DEET) or picaridin give the best protection. Some specific repellent products, such as Aerogard, which are formulated to repel flies, are generally not efficient against mosquitoes or biting midges. Brands such as Rid, Tropical Strength Aerogard, Bushman's, Muskol, or Repel include specific products that are effective. Those products with higher amounts of DEET or picaridin are usually the most efficient.

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

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

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

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

7.0 ANIMAL DIVERSION

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

8.0 LIGHTING DIVERSION

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

curtains or similar screening can be very effective in reducing the attraction of biting insects to areas that are illuminated at night.

9.0 ADULT INSECT CONTROL

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

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

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

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

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

10.0 INSECTOCUTORS AND INSECT TRAPS

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

vicinity of people. Attractive odours and carbon dioxide emitted by humans then divert the insects from the trap device to the people.

11.0 TREATMENT OF BITES

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

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

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

12.0 EMERGENCY BITING INSECT PROTECTION

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

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

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Appendix 6



**Northern
Territory
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Department of Health
and Community Services

BITING MIDGES OR “SANDBLIES” IN THE NT

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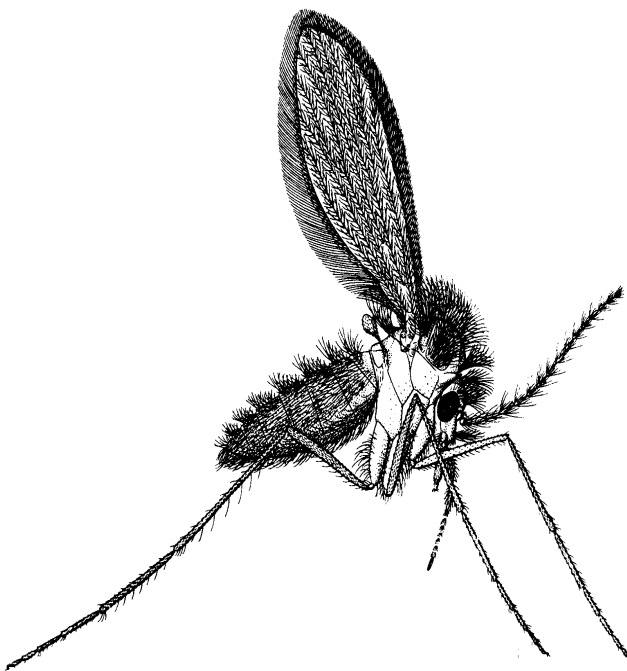
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Biting Midges or 'Sandflies' in the Northern Territory

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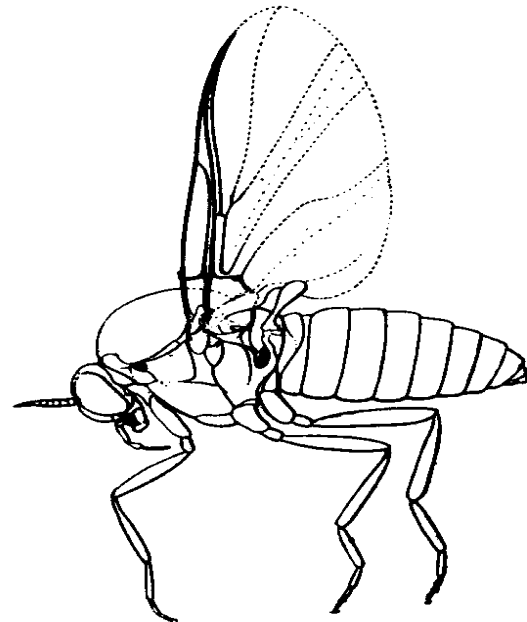
1.0 Introduction

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



Phlebotomus – a female "Sand Fly"

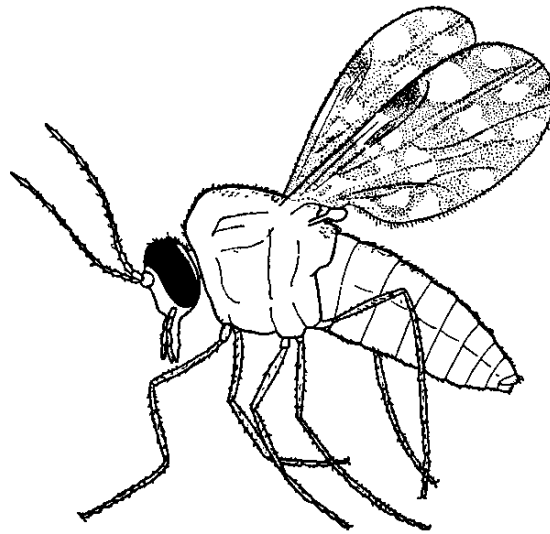
Insects of Medical Importance
British Museum 1956



Simulium – a female "Black Fly"

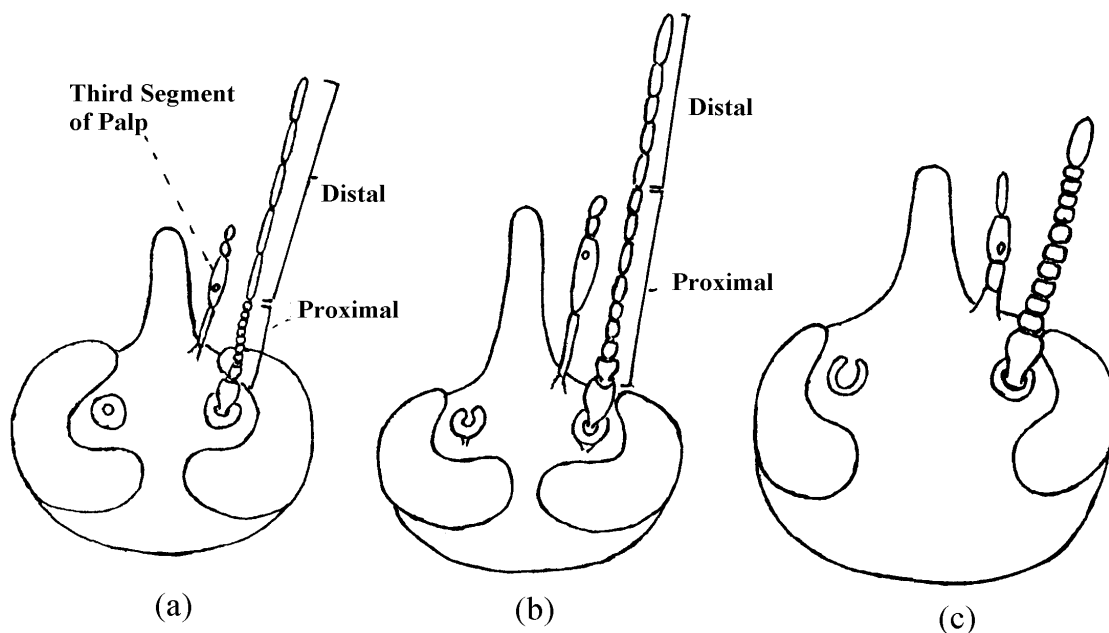
Insects of Medical Importance.
British Museum 1956

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



Culicoides – a female “Biting Midge”

Entomology for Students of Medicine. Blackwell Scientific Ltd. 1962



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

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

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

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

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

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

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

2.0 Bites of Biting Midges

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

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

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

3.0 Treatment of Bites

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

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

4.0 Breeding Sites of *Culicoides ornatus*

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

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

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

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

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

5.0 The Flight Activity of *Culicoides ornatus*

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

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

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

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

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

6.0 Seasonal Abundance of *Culicoides ornatus*

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

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

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

7.0 Protection from Bites of *Culicoides ornatus*

7.1 Avoidance

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

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

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

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

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

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

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

7.2 Clothing and Netting

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

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

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

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

7.3 Repellents

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

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

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

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

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

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

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

7.4 *Use of Lights*

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

7.5 *The reduction of vegetation*

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

7.6 *The use of attractant traps*

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

8.0 *Evaluation of Biting Midge Problems*

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

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

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

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

9.0 Control of *Culicoides ornatus*

9.1 Insecticide fogging for Adult Midges

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

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

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

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

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

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

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

9.2 *Barrier spraying*

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

9.3 *Insecticide Control of Larval Habitats*

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

9.4 *Elimination of Breeding Habitats*

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

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

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

9.5 *Buffer zones*

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

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

10.0 Planning Guidelines To Prevent Biting Insect Problems

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

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

Good urban planning is required to;

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

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

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Appendix 7

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

By

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Abstract

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

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

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

Introduction

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

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

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

- 1) low irritancy to mosquitoes, and thus increases mosquito-bifenthrin contact time (WHO 2002);
- 2) very low vapor pressure (1.81×10^{-7} mmHg);
- 3) low water solubility ($<1 \mu\text{g/litre}$) and good stability to hydrolysis and photolysis (2 years at 50°C. under natural daylight); and
- 4) long residual efficacy against target insects (WHO 1998, 2002; Hougard et al. 2002; Yadav et al. 2003).
- 5) safety to humans: "Noting its safety and efficacy, Bifenthrin 10WP is recommended for indoor residual spraying" (WHO/CDS/WHOPES/2001.4).

In house-scale trials in India, Bifenthrin (10% wettable powder) applied at a rate of 25 mg/m^2 provided persistent ($>80\%$ mortality for 24 weeks) insecticidal activity against *Anopheles culicifacies* on mud and brick surfaces (Yadav 2003).

It was these characteristics that led to selection of an 8% water-based, no-odor, non-irritant, suspension concentrate (SC) formulation for evaluation in Queensland against biting midges. Although this FMC Chemicals formulation is registered in Australia as a surface treatment for mosquitoes, it has not been evaluated for efficacy against biting midges infesting domestic situations. Therefore, this study was undertaken to produce efficacy data for biting midges, and in doing so provide a tool for control of these insects of public health and economic importance. Additional efficacy data was also collected for mosquitoes.

Materials and Methods

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



Plate 1. River Heads, Hervey Bay, Queensland. Clean estuarine sand and muddy sand surrounding River Heads provides larval habitat for *Culicoides subimmaculatus* Lee & Reye, while estuarine mud produces *Culicoides ornatus* Taylor. Saltmarsh and mangrove habitats produce the mosquito arbovirus vector, *Ochlerotatus vigilax* (Skuse).

Once the above detailed approval had been obtained, eight houses comprised of four randomized pairs (1 treatment + 1 untreated control) were selected, and the householders consent obtained ca. 2 weeks prior to the treatment date (29th October, 2002).



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

Application of Bistar 80 SC (Active Ingredient: 8% bifenthrin). In order to obtain the required efficacy data for biting midges, the 8% SC formulation was applied as per the label directions for applications against mosquitoes under conditions of high pest pressure, and when maximum residual protection is desired. The label directions state that at a recommended rate of 125 mL/10L: *“on non-porous surfaces apply as a coarse spray at the rate of 1 litre of emulsion per 20 m². When treating non-porous surfaces do not exceed the point of run-off. On porous surfaces or use through power equipment, spray at the rate of 1 litre of emulsion per 10 m². When treating porous surfaces do not exceed the point of run-off. To control mosquitoes apply prepared emulsion to surfaces where insects rest or harbour. Reapply as necessary.”*

Accordingly, a 0.1% mix (125 mL/10L water) was applied as per the label instructions described above, to external building and ornamental plant surfaces (Plate 2). To do this a Solo Back Pack Sprayer (Solo, Germany) was calibrated by the Centre for Pesticide Application and Safety (University of Queensland, Gatton Campus) to deliver a dilute spray comprised of large (150-200 micron) droplets.

Table 1. Property treatment rates.

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

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

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



Plate 3. Median midge and mosquito numbers caught overnight in unbaited vs baited light traps.

treatment and control properties. Light trap collections were made on the evening prior to treatment, and then each night for 9 nights post-treatment. Sampling frequency was then reduced to weekly collections for six weeks post-treatment.

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

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

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

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

Where: T_a = population in treatment post-treatment
T_b = population in treatment pre-treatment
C_a = population in control post-treatment
C_b = population in control pre-treatment

Results

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

Table 2. Mean $\pm$ SD 24 hour environmental conditions during field evaluation.

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

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

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

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

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

Table 4. Mann-Whitney Rank Sum analysis for six weeks biting midge and mosquito field data.

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

Table 5. Descriptive Statistics for 6 weeks field Data.

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

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

Efficacy of Bistar 80SC Insecticide Barriers

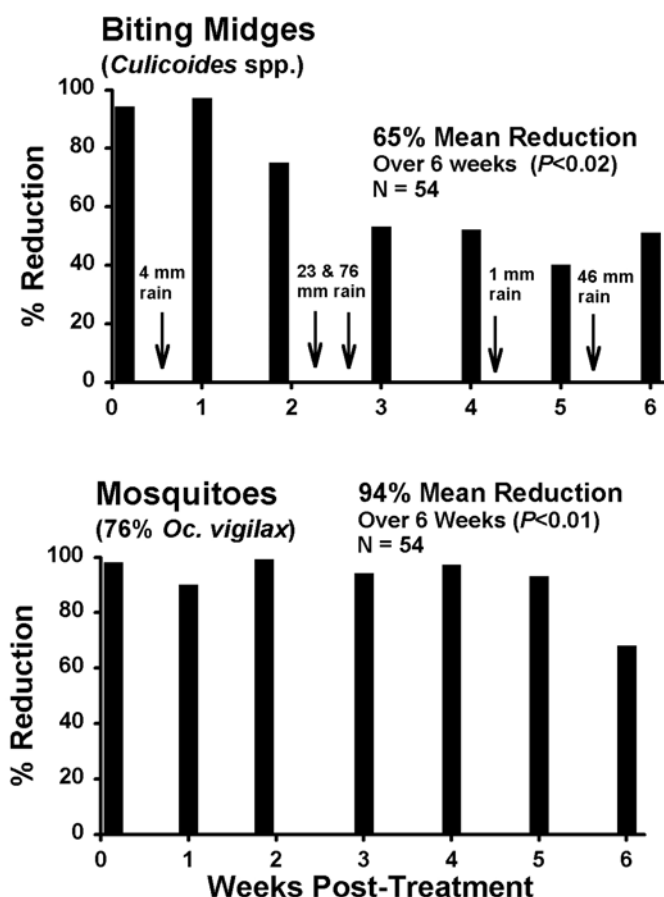


Fig. 1. % Reduction of peri-domestic biting midge and mosquito numbers over a six week study period. Rainfall events are also recorded.

Discussion

The authors are unaware of any other study which details effective, sustained reduction in adult biting midge numbers. The successful Bistar 80SC application was achieved during periods of peak biting midge and saltmarsh mosquito emergence, and despite rainfall events on six occasions. In doing so, the method meets Shivas (2001) recommendation for biting midge control, in that a sustained, effective method is required, and one that provides household protection is a priority. The peri-domestic applications also satisfied the EPA and Fisheries concerns, as they provide a safe alternative to broadscale application of organophosphates to sensitive estuarine habitats, at rates that would be ecologically disastrous. Also, in terms of comfort to the Local Government personnel

applying the product, and the residents of treated properties, the bifenthrin molecules non-alpha-cyano characteristics were appreciated. No skin or eye irritation characteristics occurred, and as expected with a bifenthrin SC formulation, no staining of peoples properties or phyto-toxic effects were recorded.

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

In refining this method, accurate laboratory determination of the Bistar 80SC concentration-mortality relationship for major biting midge and mosquito species of public health importance is essential. The incorporation of a discriminating dose test (2x LC₉₅) in routine monitoring programs will aid early detection of developing bifenthrin tolerance if it occurs. Future research efforts should also be dedicated towards determination of the longevity of control effected by Bistar 80SC applications on various resting surfaces. Surfaces such as treated and untreated wood, bricks, and waxy leaf surfaces would all retain bifenthrin at differing concentrations over time. Re-treatment strategies could vary depending on the predominant harborage or resting surface present in a given domestic situation. Accordingly, the authors recommend that a resistance management strategy be developed to safeguard the longevity of this valuable formulation. Bistar 80SC is one of the few effective options we have available for control of these adult insects of major public health significance.

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Appendix 8



NORTHERN TERRITORY GOVERNMENT

DEPARTMENT
OF HEALTH
AND COMMUNITY
SERVICES

EXOTIC MOSQUITOES ARRIVING ON SEAGOING VESSELS RECOMMENDED INSPECTION & ERADICATION PROCEDURES

Published in (1998) '*Bulletin of the Mosquito Control Association of Australia*', Vol 10, (2)
Amended July 2002

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1.0 INTRODUCTION

Various States in Australia are concerned about the possible importation and subsequent introduction of *Aedes aegypti* (the dengue fever mosquito), *Aedes albopictus* (The Asian tiger mosquito) and other exotic *Aedes* mosquitoes (such as the *Ae. scutellaris* group which occur in South East Asia, New Guinea and the Pacific) from interstate or overseas. *Aedes aegypti* is only established in northern Queensland (Sinclair 1992) but importation of this species from overseas to areas where it is already established could introduce new strains of the species or exotic viruses. Any measures to prevent the importation of *Ae. albopictus* into Queensland should also intercept *Ae. aegypti*, as Queensland (and the rest of Australia) is free of *Ae. albopictus* (Kay et al. 1990). One of the demonstrated methods of importation of these mosquitoes is via seagoing vessels, including commercial vessels, refugee vessels, fishing vessels and seagoing yachts (Whelan 1981, Kay et al. 1990).

In northern Australia the greatest potential risk arises by importing drought resistant eggs that have been deposited on the inside of drinking water storage containers. The containers likely to contain larvae or eggs are open jars or stoppered containers for transporting drinking water, such as drums or jerry cans, vehicle tyres used for packaging, spare tyres that are exposed to the rain, and deck stored machinery and equipment. The most frequent mode of importation has been on illegal fishing vessels intercepted in Australian waters. Vessels with refugees or illegal migrants, smaller trading vessels and barges, and private yachts, have also been sources of exotic mosquitoes (Whelan 1991).

An active inspection program of overseas vessels is currently being performed by Quarantine authorities in at least major ports. The intensity of inspection or the emphasis on detecting mosquitoes is probably variable between States. These, and additional inspections of other risk areas, are vital in excluding these vectors from Australia. The procedures outlined below are a guide to carrying out the inspection and eradication measures to ensure that Australia remains free of additional vectors or disease problems.

2.0 EQUIPMENT

The collecting equipment required includes a torch, a bulb pipette attached to a flexible clear hosing, white painted ladle, bucket, sample bottles, tissues, labels, pens, pipette, forceps, insect collection containers, aerosol knockdown insecticide spray, white sheets, and record forms. All this equipment should be readily available for each inspection. Control operations usually necessitate a return to a vessel for thorough treatment, and require cans of aerosol insecticide, a pressure sprayer with a residual pyrethroid insecticide and a 1 kg quantity of granular pool chlorine.

Onshore eradication procedures require a supply of granular pool chlorine, liquid insecticide application equipment, marker paint spray cans, recording equipment, and a mobile water supply (usually a trailer or truck mounted tank) of tap water.

3.0 VESSEL INSPECTION PROCEDURES

1. All vessels should be inspected for adult or larval mosquitoes. If possible all vessels should be inspected for adult mosquitoes before the vessels enter a harbour.
2. All inspections should be carried out in a specific quarantine area that should be at least 1 km from shore. If the vessel is brought direct to a landing, the inspection and control of adult mosquitoes should be carried out en route before any landing is made.
3. Any adult mosquitoes observed flying in any areas, such as holds or cabins, should be knocked down with aircraft disinsection spray. Attempts should be made to collect the knocked down mosquitoes by laying out white sheets in closed areas before spraying. Any insects collected from the sheets should be packaged in a secure container with a light packaging of tissue paper. The container should be labelled and forwarded as soon as possible to a specialist for identification.
4. The vessels containing live mosquitoes should be completely sprayed with aircraft disinsection sprays. Any intercepting vessel capable of offering mosquito harbourage that has been alongside a foreign vessel with adult mosquitoes should also be sprayed after leaving the intercepted vessel. Holds and other dark humid areas, including under beds and in cupboards, should be sprayed with aircraft disinsection spray. Any vessels with adult mosquitoes should be thoroughly searched to establish the source of the mosquitoes. Any vessel on which 4th instar larvae and pupae, or pupal skins are detected, should be sprayed on the presumption that live adult mosquitoes are present.
5. Any receptacles capable of holding or collecting water should be inspected for water and mosquito larvae. In most instances this will require the use of a torch and a white ladle. Receptacles needing examination will include bottles, cans, tyres, machinery parts, drums, and drinking water storages such as jars, jerry cans, and large water tanks. A large bulb pipette or siphon should be used for difficult to access receptacles or water tanks. Any receptacle used to carry water, irrespective of whether it is sealed, should be inspected for larvae. Water from water holding tanks should be sampled for mosquito larvae by net or by filling a bucket of water via a drain tap, or by using a large bulb pipette, or manual suction pump. Hygiene precautions should be taken when sampling drinking water to ensure water is not contaminated by the ladle or other sampling techniques.
6. All mosquito larvae or larval and pupal skins detected in any receptacles should be collected into labelled vials of 70 % alcohol and forwarded to a specialist for identification on the day of collection, together with collection details and a report form.
Where there are secure facilities, larvae and pupae in receptacles arriving from South East Asia, New Guinea and the Pacific should be collected live, placed in labeled secure containers with original water, and transported immediately to the State Health entomologist or entomology specialist, so that the larvae and pupae can be link reared to adults. This is to clarify the identity of possible unknown *Aedes* species entering Australia from the above areas. Secure facilities

and ready access to a mosquito specialist is required to prevent the escape of live exotic mosquitoes.

7. For larger vessels, built-in freshwater tanks should be inspected to ensure that all openings are sealed or mosquito proof. Any filling points should be made mosquito proof (at least temporarily) with the aid of materials such as insect netting, until examination and treatment are complete, or the vessel leaves port.

4.0 ERADICATION PROCEDURES ON VESSELS

1. Once examined for mosquito larvae, all water in any containers (except that in built-in water storages) should be emptied into the sea or the containers sealed until the vessel leaves port.
2. Any vessel on which adult mosquitoes, live larvae or pupae, or pupal skins are detected, should have all containers on board that are either holding water, or likely to have recently been mosquito breeding sites, treated with granular pool chlorine (100 g in 20 litres of water, approximately one full plastic 70 ml urine sample jar), or sprayed with deltamethrin, permethrin or lambdacyhalothrin to the point of run off.
4. Receptacles which held water or dry containers likely to have been a mosquito breeding site, should be stored under cover if the vessel is due to remain in port for more than one week.
5. No receptacle which held water or dry containers likely to have been a mosquito breeding site should be allowed off a vessel until it has been steam cleaned or super chlorinated or treated with a residual insecticide.
6. If the vessel is due to go to another Australian port and has receptacles which hold water, those containers should be steam cleaned, chlorinated, treated with residual insecticide, sealed or stored under cover. Authorities in the next port of call should be advised of potential risk problems.

5.0 ONSHORE ERADICATION MEASURES

1. Onshore inspection and eradication measures should be carried out within one day of detection of live exotic *Aedes* adults, or larvae in association with pupae in any receptacle on an overseas vessel that has docked at a port or landing facility. Onshore inspection and eradication should also be carried out immediately if any exotic mosquito larvae are detected in the onshore ovitraps.
2. All property owners and businesses in the immediate area of importation (generally 500 m is sufficient) should be briefed on the importation and the importance and details of the eradication measures. No potential receptacles, particularly tyres, should be allowed to be removed from the premises until treated.
3. Adult mosquito fogging operations should be carried out within 500 m of the importing vessel or ovitrap site, with particular attention to the interior of warehouses and sheltered areas, or areas that contain potential breeding and harbouring sites. The fogging should be done in the late evening when mosquitoes are likely to be most active.

4. A receptacle search should be done within 500 m of the landing site or ovitrap site. All containers with water should be located, with each container marked to indicate orientation. The number and location of each container, and the presence of water and larvae, should be documented.
5. All larvae in each receptacles should be collected and placed in individual labelled collection vials of 70 % alcohol. Pupae should be transferred live to secure vials with adequate breeding site water and hatched in a secure laboratory. All larvae and pupae should be identified on the day of collection to locate the highest risk containers.
6. All water holding receptacles should be filled completely with tap water and super chlorinated or treated with residual insecticide to the whole interior surface. Receptacles with exotic larvae should be highlighted to prevent movement and ensure additional scrutiny.
7. If time and resources allow, an evaluation of the presence of exotic eggs in any container could be made before super chlorination or insecticide treatment. For this procedure every receptacle with water should be completely emptied and dried. This is to ensure that no late instar larvae or pupae inadvertently missed can later develop to maturity and emerge. All previously wet receptacles or receptacles likely to have held water at the time of importation are then completely filled with tap water and left for 3 days before reinspecting for mosquito larvae. Each water filled receptacle should then be treated with a super chlorine solution or residual insecticide.
8. When using super chlorine the super chlorine solution should be left in place for 3 hours to kill any unhatched *Aedes* eggs.
9. The super chlorine solution should be completely emptied from all the containers within one day of treatment.
10. Additional ovitraps should be placed in the detection area and inspected weekly for two months and again after the start of the next rain season.
11. The public and local businesses should be informed of the results of the inspection and eradication measures.
12. The procedures and the results of the inspections should be completely documented, and the report should be forwarded to the relevant authorities.

6.0 CONCLUDING REMARKS

These inspection and eradication procedures should be supplemented by an *Aedes* ovitrap surveillance program at least around international port areas. The possibility of the introduction and establishment of *Ae. albopictus* and *Ae. aegypti* to various States in Australia is very real. There have been instances of the interception of these vectors in Darwin, Broome, Townsville, Cairns and Brisbane (Whelan 1991). If the vectors are introduced, particularly to the northern areas of Australia, there will be new pest mosquito problems and additional risks of dengue outbreaks and epidemics (Kay et al. 1984). Failure to detect an importation very early, and to react immediately

and thoroughly, could result in the establishment of these vectors, ongoing and expensive control operations, and increased mosquito borne disease.

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