Appendix 21

Biting insect survey of Blaydin Point, Darwin

Ichthys Gas Field Development Project: biting insect survey of Blaydin Point, Darwin

Report prepared by the Medical Entomology Section of the Centre for Disease Control, Department of Health and Families, Darwin, Northern Territory, for INPEX Browse, Ltd., Perth, Western Australia

September 2009

INPEX Document No. C036-AH-REP-0032

Ichthys Gas Field Development Project: biting insect survey of Blaydin Point, Darwin

Study undertaken on behalf of GHD Pty Ltd for INPEX Browse, Ltd., Perth, Western Australia

Allan Warchot
Medical Entomology Section
Centre for Disease Control
NT Department of Health and Families
August 2008
*Updated September 2009

For further information contact:

Medical Entomology Section
Centre for Disease Control
Department of Health and Families
PO Box 40596
Casuarina NT 0811

Phone: 08 8922 8901
Facsimile: 08 8922 8820
Email: medicalentomogyrdh@nt.gov.au

This report may be cited as follows:

Medical Entomology Section. 2009. *Ichthys Gas Field Development Project: biting insect survey of Blaydin Point, Darwin.* Report prepared by the Medical Entomology Section of the Centre for Disease Control, Department of Health and Families, Darwin, Northern Territory, for INPEX Browse, Ltd., Perth, Western Australia.

Table of Contents

List of Figures

List of Tables

List of Appendices

Executive summary

INPEX Browse, Ltd. (INPEX) proposes to develop the natural gas and associated condensate contained in the Ichthys Field situated about 220 km off Western Australia's Kimberley coast and about 820 km west-south-west of Darwin. The field encompasses an area of 800 km^2 in water depths ranging from 235 to 275 m.

The two reservoirs which make up the field are estimated to contain 12.8 tcf (trillion cubic feet) of sales gas and 527 MMbbl (million barrels) of condensate. INPEX proposes to process the reservoir fluids to produce liquefied natural gas (LNG), liquefied petroleum gases (LPGs) and condensate for export to overseas markets.

For the Ichthys Project, the company plans to install offshore extraction facilities at the field and a subsea gas pipeline from the field to onshore facilities at Blaydin Point in Darwin Harbour. A two-train LNG plant, an LPG fractionation plant, a condensate stabilisation plant and a product loading jetty will be constructed at a site on Blaydin Point. Around 85% of the condensate will be extracted and exported directly from the offshore facilities while the remaining 15% will be processed at and exported from Blaydin Point.

Blaydin Point is located on the Middle Arm Peninsula in Darwin Harbour (Figure 1). It is separated from the mainland by a narrow intertidal flat and it is bounded by Lightning Creek to the west, open sea to the north, and a relatively wide band of mangroves to the east. The mangrove areas surrounding Blaydin Point are expected to be significant sources of the mangrove biting midge *Culicoides ornatus.* This species is the most significant pest biting midge in the coastal areas of northern Australia, and the mangrove habitat surrounding Blaydin Point indicates the likelihood of very high seasonal numbers.

Mosquitoes are not expected to be a significant problem at Blaydin Point in comparison with other areas around Darwin because of the absence of extensive tracts of potential mosquito breeding habitat such as swamps, floodplains and rivers. However, because of the presence of tidal areas, it was expected that the northern salt marsh mosquito *Aedes vigilax* would be seasonally present in significant numbers. This species is a potential vector of Ross River virus and Barmah Forest virus.

As a result of the potentially significant biting-insect issues affecting Blaydin Point, the Medical Entomology Section of the Northern Territory's Department of Health and Community Services (DHCS) was commissioned by GHD Pty Ltd to conduct a biting-insect assessment of Blaydin Point for INPEX.

The responsibilities of the Medical Entomology Section were as follows:

- to carry out peak season trapping for biting midges at Blaydin Point
- to carry out peak season trapping for the northern salt marsh mosquito at Blaydin Point
- to examine aerial photography for potential biting midge and mosquito breeding sites
- to determine the likely seasonal abundance of pest biting midges and mosquitoes at Blaydin Point
- to examine INPEX's development plans to assess their potential to create new mosquito breeding sites, and to provide recommendations and management measures that would reduce any potential to create new mosquito breeding sites
- to discuss the likely health impacts of biting insects at Blaydin Point and the management measures that could be put in place to reduce the impact of biting insects.

The major findings of the Blaydin Point Biting Insect Assessment were as follows:

Biting midges

- The mangrove biting midge *C. ornatus* will be present in extremely high seasonal numbers during the late dry season (August to November). Very high numbers will be present during the early to mid dry season (April to July), while high numbers will be present during the wet season. It will be widespread throughout Blaydin Point and the mainland south of Blaydin Point.

- The pest problems caused by *C. ornatus* will be severe and unbearable for people without personal protection, for a period of 6 days around the full and new moons during the two hours around sunset and sunrise. Dry season pest problems will be significantly greater than wet season problems, especially during the late dry season.

- The pest problems caused by *C. ornatus* will disrupt the workforce, and can cause secondary effects such as intense itching, infection and scarring. Newcomers to the region will be particularly affected as they will lack immunity to biting midge bites.

- The mangrove biting midges *C.* sp. (an undescribed species near *C. immaculatus*) and *Culex flumineus* are likely to cause pest problems to workers inside mangrove areas.

- Biting midge pest problems could be reduced by the use of protective clothing and repellents. Barrier insecticides could also be used to lower adult biting midge numbers around personnel areas.

- Mangrove biting midge breeding sites cannot be controlled with insecticides. The only method of reducing biting midge breeding would be to remove their tidal mangrove breeding sites, which would be deemed environmentally unacceptable.

Mosquitoes

- Mosquito populations at Blaydin Point are not expected to be as high as other areas of Darwin, because of the lack of extensive breeding sites such as coastal plains, creeks and rivers. Localised mosquito populations will occur at Blaydin Point, and these would include pest and disease-carrying mosquito species. Twelve-month baseline trapping and wet season field surveys were not conducted at Blaydin Point; therefore mosquito populations affecting Blaydin Point were predicted based on limited trapping, a desktop examination of Blaydin Point and surrounding areas, and an examination of baseline data from Wickham Point.

- The northern salt marsh mosquito *Ae. vigilax* is will be present in low, and possibly moderate numbers, during the late dry and early wet season (September to January). This species will be sourced from poorly draining upper tidal areas surrounding Blaydin Point. Breeding sites appear to be localised and would mainly be associated with depressions in flowlines, areas of restricted tidal drainage, and vehicle-disturbed areas along the landward mangrove margin.

- Important mosquitoes such as *Culex annulirostris*, *Culex sitiens*, *Anopheles* species and *Coquillettidia xanthogaster* will be seasonally present at Blaydin Point in minor numbers during the wet season. Breeding sites at Blaydin Point would be localised ground pools with vegetation, these are likely to be located adjacent to the landward mangrove margin in seepage areas. The monsoon vine forest is likely to contain some areas of wet-season ponding and breeding sites for *Verrallina funerea,* and possibly *Ae. vigilax* if there are tide influenced depressions near the landward mangrove margin.

- The large borrow pit area to the south of Blaydin Point is a possible breeding site for *Cx. annulirostris, Anopheles* species and *Cq. xanthogaster*, if significant wet season ponding occurs there.

- Mosquito pest problems at Blaydin Point are expected to be minimal, with *Ae. vigilax* the only mosquito likely to be present in numbers high enough to cause a pest problem. *Aedes vigilax* is an aggressive biter, and will bite during the daytime in shaded areas, as well as at night, and will cause seasonally low and possibly moderate pest problems at Blaydin Point. Other mosquito species are not expected to be present in numbers high enough to cause appreciable pest problems.

- *Aedes vigilax* will pose a low and possibly moderate risk of Ross River virus (RRV) and Barmah Forest virus (BFV) transmission during the months of September to January, with December and January the highest risk months due to increased mosquito longevity. *Cx. annulirostris, Cx. sitiens* and *Verrallina funerea* will pose a minor risk of RRV transmission due to expected minor abundance, while *Cx. annulirostris* will also pose a minor risk of BFV, Murray Valley encephalitis virus (MVEV) and Kunjin virus (KUNV) transmission.

- The risk for potential malaria transmission at Blaydin Point is likely to be very low, due to the expected minor abundance of *Anopheles* species.

- The development has the potential to increase mosquito populations and subsequently increase the potential for mosquito borne disease transmission. Potential mosquito breeding sites could be created by the inappropriate storage and discharge of stormwater and wastewater, excavation activities, construction of roads and pipelines and disturbance to tidal areas.

- Artificial receptacles at the development site could become breeding sites for the endemic disease-carrying mosquito *Aedes notoscriptus,* and exotic dengue mosquitoes. Rubbish items washed on to the shoreline could also become breeding sites for endemic disease-carrying mosquitoes and exotic dengue mosquitoes.

- There would be no requirement for an insecticide mosquito control program if no new mosquito breeding sites are created by development, and potential breeding sites at Blaydin Point and on the mainland south of Blaydin Point are located and rectified.

The major recommendations arising from the Blaydin Point Biting Insect Assessment are as follows:

Biting midges

- All workers must be informed during the induction of the severe biting midge problems that will occur at Blaydin Point and the peninsula leading into Blaydin Point. Personal protection measures should be outlined to workers, and personal protective clothing and repellents should be made available, especially to early morning, late evening and night time workers.

- The Blaydin Point Health and Safety Officer or relevant officer should mark on a calendar all periods of the year that will experience biting midge pest problems, and alert workers of impending periods of pest biting midge problems.

- All offices, mess rooms, guard houses and other such office facilities should be fully sealed and air-conditioned to prevent the entry of biting midges.

- Outdoor recreation areas, work stations and the outside of personnel buildings should be treated with an appropriate residual barrier insecticide on an appropriate schedule, to reduce the number of biting midges in these areas. The effectiveness of barrier insecticide treatments could be enhanced by creating a shrub vegetation zone or fence (>3 m high with dark shadecloth or similar type structure) surrounding personnel areas, with the shrub or fence treated with a barrier insecticide on a suitable schedule.

- Insecticide larval control or the removal of biting midge breeding sites is not recommended due to the negative environmental impacts. Personal protection, avoidance of peak biting periods and the use of barrier insecticides are currently the best measures to prevent biting midges bites.

- There should be a biting insect management plan developed for the Blaydin Point LNG Facility, which outlines all measures that will be taken to minimise the impact of biting midges at Blaydin Point.

Mosquitoes

- Any depressions that pond tide or rainwater at Blaydin Point and the mainland south of Blaydin Point should be located and rectified, to reduce the number of mosquitoes affecting the Blaydin Point LNG plant.

- The existing borrow pits located south of Blaydin Point should be inspected in the wet season by the Blaydin Point Environmental Officer or relevant project officer for water ponding. Any areas of water ponding should be rectified by draining or filling, to remove potential mosquito breeding sites that could affect Blaydin Point.

- The access road should be fitted with culverts of appropriate dimensions, and culverts should be installed flush with the natural surface at all major and minor flowlines that the road embankment will cross. This is particularly important for tidal areas, where the embankment of even minor flowlines can lead to the creation of tide and rain ponding, and subsequent mosquito breeding.

- Any disturbance to tidal areas, such as machinery disturbance and mud waves, should be rectified to prevent tide and rain ponding, and subsequent mosquito breeding.

- Any new borrow pits created by development should be rendered free-draining once they are no longer required.

- The trench for the gas pipeline should be appropriately backfilled to match the existing surface level, to avoid the creation of areas that could pond water and breed mosquitoes.

Any machinery disturbed areas should also be rehabilitated to prevent water ponding. Regular wet season surveys should be conducted in at least the first year after construction, to ensure there is no subsidence in the backfilled trench that could lead to water ponding and mosquito breeding.

- Stormwater drains should be an appropriate standard to prevent mosquito breeding. Stormwater drains should discharge to a suitably designed sediment trap before discharging into tidal areas. Wet season discharge can be to the landward mangrove margin, while dry season discharge should be directed to a daily flushed tidal area.

- Sediment ponds should be designed to completely drain within 5 days, to prevent potential mosquito breeding. Sediment ponds are not recommended in tidal areas, due to the high potential for mosquito breeding. For those sediment ponds designed to retain water, they should be constructed with steep sides (1:2 slope or greater) and be relatively deep (>1m), and be stocked with hardy native fish from the Middle Arm area. Sediment traps receiving dry season flows should either have a deep permanent pool at the inlet site, or have a low flow provision to direct low flows to a daily flushed tidal area.

- Water storage ponds should be designed with steep sites (1:2 slope or greater) and be relatively deep (>1m), to minimise the potential for semi-aquatic vegetation growth and mosquito breeding. Alternatively water storage ponds can be lined to prevent semi-aquatic vegetation growth and mosquito breeding. If practical and if water quality permits, hardy native fish from the Middle Arm area should be stocked in water storage ponds.

- There should be regular wet season inspections of artificial receptacles at the development site. Any receptacle found ponding water should be disposed of, stored under cover, have drainage holes drilled or treated with an appropriate insecticide on an appropriate schedule. There should also be a regular clean up of rubbish items that float ashore at Blaydin Point.

- Any worker sourced or returning from an overseas country where malaria is endemic, whom experiences high fever should stay indoors away from mosquito bites until cleared of malaria or treated for malaria by a health professional.

- There should be an annual maintenance program established to desilt/clear vegetation from stormwater drains and sediment ponds, and repair any erosion in stormwater drains and at stormwater discharge sites.

- The development site should be graded to be free of depressions capable of ponding water for periods greater than 3 consecutive days in tidal areas, and 5 days in mainland areas, to prevent mosquito breeding. This includes areas underneath demountables and around buildings, which can accumulate water if levels are not suitable. Regular wet season surveys should be conducted to locate any ground depressions that require rectification.

- Effluent treatment facilities should be designed and operated in accordance to Department of Health and Community Services regulations. The best method of effluent discharge for Blaydin Point in regard to preventing mosquito breeding would be disposal to the sea.

- There should be a biting insect management plan developed for the Blaydin Point LNG Facility, which outlines all measures that will be taken to minimise the impact of mosquitoes at Blaydin Point.

1.0 Introduction

INPEX Browse, Ltd. (INPEX) proposes to develop the natural gas and associated condensate contained in the Ichthys Field situated about 220 km off Western Australia's Kimberley coast and about 820 km west-south-west of Darwin. The field encompasses an area of 800 km^2 in water depths ranging from 235 to 275 m.

The two reservoirs which make up the field are estimated to contain 12.8 tcf (trillion cubic feet) of sales gas and 527 MMbbl (million barrels) of condensate. INPEX proposes to process the reservoir fluids to produce liquefied natural gas (LNG), liquefied petroleum gases (LPGs) and condensate for export to overseas markets.

For the Ichthys Project, the company plans to install offshore extraction facilities at the field and a subsea gas pipeline from the field to onshore facilities at Blaydin Point in Darwin Harbour. A two-train LNG plant, an LPG fractionation plant, a condensate stabilisation plant and a product loading jetty will be constructed at a site on Blaydin Point. Around 85% of the condensate will be extracted and exported directly from the offshore facilities while the remaining 15% will be processed at and exported from Blaydin Point.

Blaydin Point is located on the Middle Arm Peninsula in Darwin Harbour (Figure 1). It is separated from the mainland by a narrow intertidal flat and it is bounded by Lightning Creek to the west, open sea to the north, and a relatively wide band of mangroves to the east. The mangrove areas surrounding Blaydin Point are expected to be significant sources of the mangrove biting midge *Culicoides ornatus.* This species is the most significant pest biting midge in the coastal areas of northern Australia, and the mangrove habitat surrounding Blaydin Point indicates the likelihood of very high seasonal numbers.

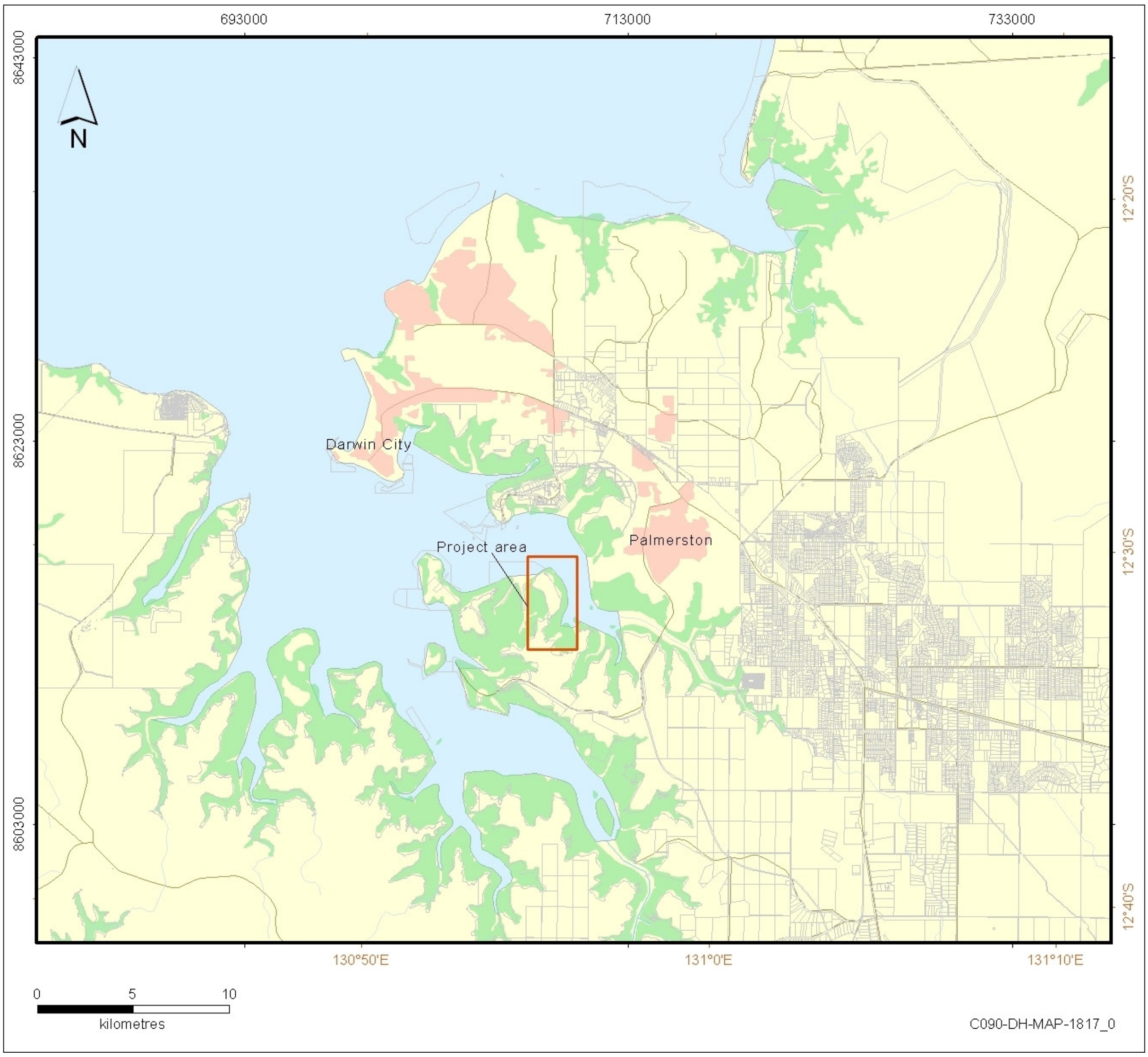
Mosquitoes are not expected to be a significant problem at Blaydin Point in comparison with other areas around Darwin because of the absence of extensive tracts of potential mosquito breeding habitat such as swamps, floodplains and rivers. However, because of the presence of tidal areas, it was expected that the northern salt marsh mosquito *Aedes vigilax* would be seasonally present in significant numbers. This species is a potential vector of Ross River virus and Barmah Forest virus.

As a result of the potentially significant biting-insect issues affecting Blaydin Point, the Medical Entomology Section of the Northern Territory's Department of Health and Community Services (DHCS) was commissioned by GHD Pty Ltd to conduct a biting-insect assessment of Blaydin Point for INPEX.

The responsibilities of the Medical Entomology Section were as follows:

- to carry out peak season trapping for biting midges at Blaydin Point
- to carry out peak season trapping for the northern salt marsh mosquito at Blaydin Point
- to examine aerial photography for potential biting midge and mosquito breeding sites
- to determine the likely seasonal abundance of pest biting midges and mosquitoes at Blaydin Point
- to examine INPEX's development plans to assess their potential to create new mosquito breeding sites, and to provide recommendations and management measures that would reduce any potential to create new mosquito breeding sites
- to discuss the likely health impacts of biting insects at Blaydin Point and the management measures that could be put in place to reduce the impact of biting insects.

Figure 1 – General location of Blaydin Point



2.0 Project aims

Biting midges can be considerable pests within a few kilometres of the coast in the NT (Whelan 1991a), with highest numbers occurring up to 1.5km from the mangrove margin (Shivas & Whelan 2001). These pests can disrupt workers due to the painful bites, while some people experience secondary effects such as intense itching, infection and scarring from scratching, with an accompanying loss of sense of well being. The mangrove biting midge *C. ornatus* is the most serious pest biting midge in coastal areas of the NT (Shivas & Whelan 2001). Peak seasonal numbers generally occur in the months of August to November, so trapping in October 2007 was designed to locate maximum numbers affecting Blaydin Point.

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). Although mosquito abundance at Blaydin Point is expected to be relatively low, there is the likelihood that the northern salt marsh mosquito would be seasonally present in significant numbers at Blaydin Point. Peak season northern salt marsh mosquito trapping in December 2007 was designed to locate maximum numbers after the November monthly high tide.

The results of the trapping program was to be evaluated to determine the potential for pest mosquito problems and the potential for mosquito borne disease transmission, and the potential for pest biting midge problems. Recommendations were to be provided to minimise as much as practical the potential biting insect problems that are likely to affect Blaydin Point. Baseline biting insect information from nearby Wickham Point was to be evaluated to determine the likely seasonal abundance of biting insects at Blaydin Point.

Development can also lead to the creation of new breeding sites for pest and disease-carrying mosquito species through the construction of road embankments across tidal areas, the construction of infrastructure in tidal areas, construction of stormwater drains and sediment basins and waste water storage and disposal. Artificial receptacles could also become breeding sites for certain mosquito species. A further aim of the biting insect assessment was to evaluate development plans for the potential to create new mosquito breeding sites, and provide design or management recommendations to prevent the creation of new mosquito breeding sites.

3.0 Methods

A total of 6 trap sites were selected for the Blaydin Point biting insect assessment. Five trap sites were on Blaydin Point, with one trap site on the mainland south of the Blaydin Point Island (Figure 2). The trap locations were recorded using a hand held GPS, and marked with flagging tape to aid in re-location of the sites. Traps were set in the afternoon one night before the full moon in October 2007 (25^{th}) and collected the following morning (26^{th}) after sunrise. Traps were also set 10 days after the November 2007 monthly high tide on the afternoon of the 6^{th} of December, and collected the following morning (7^{th}) after sunrise. The same 6 trap sites were used during the October 2007 and December 2007 trapping. Navigation was by 4WD vehicle to the southern edge of Blaydin Point, and then via 4WD quad bikes.

The traps used were carbon dioxide baited EVS traps (Rohe and Fall 1979). The traps consisted of an insulated bucket, a suction fan powered by two 'D' cell batteries, a 'grain of wheat' light, and a rigid collection container (4 litre, 220 mm in diameter) fitted with a muslin sleeve and very fine wire mesh vents. The traps were set around chest height and baited with approximately 1kg of dry ice.

Trapped mosquitoes were sorted and stored in a petri dish in a freezer (-10^0C). All adult mosquitoes were identified with the aid of light microscopes and various taxonomic keys (Lee et al 1944, 1982, 1984, 1987 & 1989, Marks & Reye 1982, Russell 1996). All species and totals for each individual collection were then entered into a database for evaluation.

The biting midges from each collection were randomly sub-sampled (50 individuals per sub-sample) when collections were over 50 individuals, and identified with the aid of light microscopes using taxonomic references and wing photos (Dyce and Wellings 1998, Wirth and Hubert 1989, & Dyce et al 2007). If the collection was less than around 1000 individuals, the remaining bulk was examined for any additional species not detected in the original sub-sample of 50. If the collection was more than around 1000 individuals, a separate sub-sample of approximately 600 individuals was examined for any additional species not detected in the original sub-sample of 50. Total numbers were estimated for each catch using a standard volume/number comparison method. All species and totals for each individual collection were then entered into a database for evaluation.

Potential *C. ornatus* breeding sites were deduced by examining aerial photography from Google Earth, using information on the breeding sites for this species (Shivas et al. 1997, Shivas et al. 1998, Shivas 1999, Whelan et al. 1997). Sites of interest were upper tidal mangrove tributaries associated with nearby creeks, as well as foreshore mangrove areas.

Potential mosquito breeding sites were also deduced by examining aerial photography from Google Earth. Sites of interest were upper tidal areas with potentially restricted drainage, seepage areas near the mangrove margin, disturbed upper tidal areas, and the monsoon vine forest and borrow pits.

4.0 Results

4.1 Biting midges

The results of the biting midge trapping at Blaydin Point are displayed in tables 1 and 2. Traps in October 2007 were set one night before the full moon on 25 October, and collected the morning of the full moon on 26 October (Table 1). Traps in December 2007 were set four days before the new moon on 6 December, and collected the following morning on the 7th of December (Table 2), which was also 10 days after the November monthly high tide. A total of 121 002 adult female biting midges were collected during trapping on the 25-26th October 2007 (Table 1), and a total 3,842 adult female biting midges were collected during trapping on the 6 and 7 December 2007 (Table 2).

<u>4.1.1 Species present</u>

The most common biting midge collected in October 2007 at Blaydin Point was *C. ornatus*, with a total of 118 500 collected in the 6 traps, accounting for 97.93% of all biting midges (Table 1). The most productive site was Trap Site 3, with 49 000 adult females collected, followed by Trap Site 6 (23,500), Trap Site 1 (18 000), Trap Sites 2 and 5 (10 000) and Trap Site 4 (8000).

Culicoides ornatus was also the most abundant biting midge species collected in December 2007, accounting for 88.08% of all biting midges (Table 2). The most productive site was Trap Site 3, with 2580 adult females, with other trap sites recording low numbers.

<u>4.1.2 Spatial abundance of *Culicoides ornatus*</u>

The most productive site was Trap Site 3, located adjacent to the upper reaches of small tidal mangrove tributaries associated with Lightning Creek. This site was more than twice as productive as any other site during trapping at Blaydin Point. The next most productive site during trapping at Blaydin Point was Trap Site 6, also located adjacent to the upper reaches of small tidal mangrove tributaries associated with Lightning Creek.

Very high numbers were also recorded at Trap Site 1, which was located on a narrow peninsula on the mainland south of the Blaydin Point Island (Table 1). This trap site was located nearby to the upper reaches of small tidal mangrove creeks and an extensive *Sonneratia* mangrove foreshore, and about 400 m from the landward mangrove margin of Lightning Creek. Trap Sites 2 and 5 recorded similar numbers of *C. ornatus* in October, both trap sites were on the east/south-east edge of Blaydin Point, facing an extensive *Sonneratia* mangrove foreshore, with Site 2 also close to small tidal mangrove creeks.

Trap Site 4 recorded the lowest numbers of *C. ornatus*, and was located facing the open ocean at the northern tip of Blaydin Point.

<u>4.1.3 Seasonal abundance of *Culicoides ornatus*</u>

The seasonal abundance of *C. ornatus* was not determined at Blaydin Point during trapping in October and December, as traps are required to be set monthly for 12 months to obtain seasonal biting midge information. However, 12 month baseline data from the nearby Wickham Point can be used to determine the seasonal abundance of *C. ornatus* at Blaydin Point, and has been attached as Table 3 and Figure 4.

Culicoides ornatus was most abundant in August at Wickham Point, followed by high abundance in October (two-thirds of the August numbers) and September (one-third of the August numbers). The months of June and July were the next most productive months, although numbers were around 7 times lower than August abundance. This was followed by November and April, which recorded numbers around 17 times lower than in August. The other months were the least productive months for *C. ornatus.* This pattern of seasonal abundance was similar to other areas of Darwin Harbour adjacent to tidal mangrove creeks, and will apply to Blaydin Point.

4.1.4 Potential *Culicoides ornatus* breeding sites

Confirmed breeding sites for *C. ornatus* adjacent to Blaydin Point were not determined during the biting insect investigation. However, actual breeding sites and their characteristics have been located during extensive surveying of tidal mangrove areas in other areas of Darwin (Shivas 1999). Three distinct breeding sites for *C. ornatus* were discovered by Shivas (1999); two were associated with the upper reaches of small mangrove tidal tributaries, while the third larval habitat was at the seaward mangrove foreshore (*Sonneratia* zone). These breeding site characteristics are applicable to other tidal mangrove areas in the Northern Territory, and other similar tidal mangrove areas in other parts of the Northern Australia.

Culicoides ornatus breeding sites adjacent to Blaydin Point are extensive, which explains the extremely high peak season October abundance. Blaydin Point, and the mainland south of Blaydin Point, is surrounded by tidal mangrove creeks and *Sonneratia* mangrove foreshores, all of which would contain significant breeding sites for *C. ornatus* (Figure 2). The most productive breeding sites will be the numerous upper tidal mangrove tributaries in Lightning Creek to the west of Blaydin Point, followed by the upper reaches of the small tidal mangrove creek at the south-east corner of Blaydin Point. The *Sonneratia* foreshore mangrove zones on the east side and north-west side of Blaydin Point will also be significant *C. ornatus* breeding sites.

4.2 Mosquitoes

The same traps used for biting midges were also used for mosquitoes at Blaydin Point. Results of the mosquito trapping are displayed in Tables 4 & 5.

4.2.1 Species present

There were minimal mosquitoes present during trapping in October, with only 12 mosquitoes collected in the six traps (Table 4). Mosquito abundance was higher in December, with a total of 304 mosquitoes collected in the six traps (Table 5).

The northern salt marsh mosquito *Ae. vigilax* was the most common mosquito collected in December, with a total of 236 adult females from the six trap sites, accounting for 77.73% of all mosquitoes from the December trapping. The common banded mosquito *Culex annulirostris* was the next most abundant mosquito in December, accounting for 16.12% of all mosquitoes, followed by the receptacle mosquito *Aedes notoscriptus* (2.63%).

4.2.2 Spatial abundance

When examining the December trap results, *Ae. vigilax* was most abundant at Trap Site 1 (Table 5), located on the narrow peninsula south of the Blaydin Point island. Trap Site 6 was the next most productive trap site for *Ae. vigilax,* and was located at the south-west edge of Blaydin Point. Trap Sites 3-5 recorded similar *Ae. vigilax* numbers, while the lowest *Ae. vigilax* numbers were recorded at Trap Site 2, at the south-east corner of Blaydin Point.

For the other mosquito species, *Cx. annulirostris* was relatively evenly distributed at all trap sites, while *Ae. notoscriptus* was most abundant at Trap Site 5, at the northern edge of the monsoon forest.

4.2.3 Seasonal abundance

The seasonal abundance of mosquitoes at Blaydin Point was not determined, but can be inferred from the 12 months trapping results at nearby Wickham Point, which has a similar environment. The 12 months mosquito trapping results from Wickham Point are displayed in Table 6.

Aedes vigilax was most abundant in December at Wickham Point, with high abundance in November, followed by moderate abundance in January and October. Abundance in other months was relatively low (Table 6).

Culex annulirostris was most abundant in February, with elevated abundance in January and April, and minimal abundance during other months. The golden mosquito *Coquillettidia xanthogaster* was most abundant in June, July and January, while *Ae. notoscriptus* was most abundant during the wet season months of November to March. The brackish water mosquito *Verrallina funerea* was most abundant during the mid wet season months of January and February.

4.2.4 Potential mosquito breeding sites

Potential mosquito breeding sites at Blaydin Point appear to be minimal, as there is an absence of salt marshes, brackish/freshwater swamps, rivers, creeks, floodplains and billabongs that generally typify areas of seasonally appreciable mosquito abundance. Mosquito breeding sites affecting Blaydin Point will be mainly isolated depressions in upper tidal areas and areas of restricted tidal drainage, primarily for *Ae. vigilax* and also for *Culex sitiens.* Depressions in tidal areas are likely to be associated with flow lines leading into the landward mangrove margin. There is possible some areas of restricted tidal drainage at the northern edge of Blaydin Point, due to the presence of old beach dunes in the upper tidal mangrove area (Figure 3).

There also appears to be vehicle disturbed areas along the west margin of Blaydin Point, and on the mudflat separating Blaydin Point from the mainland, these would also be potential *Ae. vigilax* and *Cx. sitiens* breeding sites. Productivity for both species in these isolated depressions is likely to be moderate to high. Potential areas of *Ae. vigilax* breeding are highlighted in Figure 3.

Further mosquito breeding sites that are likely to affect Blaydin Point would be seasonally flooded ground pools, for Blaydin Point these would generally be located in seepage areas adjacent to the landward mangrove margin. Vehicle disturbance along the west margin of Blaydin Point would have exacerbated water ponding in the seepage areas. *Culex annulirostris* is most likely to breed in ground pools that are vegetated with grass, while *Anopheles annulipes s.l.* and *Anopheles farauti s.l.* are also likely to breed in temporary flooded vegetated ground pools. Productivity of this type of habitat is likely to be low to moderate.

Depressions in the monsoon vine forest would be potential breeding sites for *Verrallina funerea,* and *Ae. vigilax* for salt-influenced depressions near the landward mangrove margin.

The productivity of *Ve. funerea* and *Ae. vigilax* in coastal monsoon vine forests in other parts of Darwin is usually moderate to high. The borrow pits near Wickham Point road, south of Blaydin Point, could be wet season and early dry season mosquito breeding sites for *Cx. annulirostris, Coquillettidia xanthogaster* and *Anopheles* species. The productivity of borrow pits would be dependent on the presence of extended wet season ponding and emergent vegetation such as grasses and semi-aquatic reeds.

5.0 Discussion

5.1 Biting midges

There is one species of biting midge that is likely to the cause of most pest problems at Blaydin Point, the mangrove biting midge *C. ornatus.* The other biting midge species that were recorded at Blaydin Point have not been implicated as significant pest species in the NT (Whelan 2004b). There are other species of biting midges that were not recorded during trapping which can be significant pests and are likely to be found at Blaydin Point, such as *C.* undescribed sp. (near *C. immaculatus*) and *C. flumineus.* These two species are only found inside mangrove areas and hence were not recorded during trapping. See Appendix 1 for further information on these species.

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

5.1.1 Potential Culicoides ornatus *breeding sites*

Potential *C. ornatus* breeding sites are highlighted in Figure 2. Actual breeding sites for *C. ornatus* at Blaydin Point were not determined by field investigations; however *C. ornatus* breeding sites have been located during detailed studies in other areas of Darwin Harbour, and the information from these studies can be used to determine likely breeding sites at Blaydin Point. The prime breeding sites for *C. ornatus* are upper tidal tributaries of mangrove creeks around the mean high water neap tide mark, associated with pneumatophores of the mangrove species *Avicennia marina* (Shivas 1999). The highest productivity of *C. ornatus* from upper tidal tributary breeding sites occurs during the mid to late dry season (Shivas 1999). Lightning Creek and the small creeks at the south-east edge of Blaydin Point contain significant upper tidal mangrove tributaries, which will be the most important breeding sites affecting Blaydin Point and the mainland south of Blaydin Point.

Other breeding sites of low to medium productivity occur at the front edge of the mangrove forest in the *Sonneratia* or woodland mangrove zone facing open water (Shivas 1999). These breeding sites are usually associated with mud substrates and not sandy substrates (Shivas 1999). There is an extensive *Sonneratia* mangrove foreshore zone on the east and south-east side of Blaydin Point, and also at the mouth of Lightning Creek at the north-west edge of Blaydin Point. These *Sonneratia* mangrove areas will be significant sources of *C. ornatus* to Blaydin Point and the mainland south of Blaydin Point.

Wet season breeding sites are found in the *Ceriops* zone at the back of the creek-bank forest, where moderate productivity occurs (Whelan 2003), and the *Rhizophora* zone upstream of *Sonneratia* foreshore mangrove areas (Shivas & Whelan 2001).

5.1.2 Spatial abundance

Culicoides ornatus actively disperses inland from their mangrove breeding sites (Shivas 1999, Shivas & Whelan 2001), which is a characteristic that makes this species a significant pest of humans. Mass movement of adults can occur to 0.5 to 1.5 km from the mangrove margin of their major breeding sites, with minor numbers up to 3km from the nearest mangrove margin (Whelan 2003). Greatest midge abundance is usually found at the top of the leading edge of escarpments within 1.5km of the mangrove margin (Shivas & Whelan 2001). Various studies have indicated the greatest *C. ornatus* numbers usually occur within 1km of the mangrove margin of their major breeding sites (Whelan et al 1988, Warchot & Whelan 2008a, Warchot & Whelan 2008b).

Wet season dispersal and mid dry season dispersal is lower than early and late dry season dispersal, with lower mid dry season dispersal associated with lower temperature, while the reasons for low inland dispersal in the wet season are unknown (Shivas & Whelan 2001), but may be associated with blood meal host availability, dense vegetation growth or rain and humidity effects. However, areas within about 500m of the mangrove margin of productive breeding areas can expect substantial levels of midges for most of the year (Shivas & Whelan 2001). Distance trapping by Shivas & Whelan (2001) indicated significant mid dry season dispersal does occur, at least 0.75km from the landward mangrove margin, but up to 1.2km from the landward mangrove margin.

All areas of Blaydin Point are located entirely within 300-400m of mangrove areas, indicating that *C. ornatus* will be present throughout all areas of the island. There was a marked peak in numbers on the western edge of Blaydin Point, due to the proximity of the upper tidal mangrove tributaries of Lightning Creek. However, due to the long dispersal range of *C. ornatus,* it can be expected that all areas of Blaydin Point will experience relatively similar numbers of *C. ornatus.* The entire mainland south of Blaydin Point will also be subject to widespread dispersal of *C. ornatus.*

5.1.3 Seasonal abundance

The annual peak in *C. ornatus* adult abundance in the Northern Territory is encountered in the August–November period in the late dry season, with lowest numbers in January and February (Whelan 2003). Populations start to build up from the end of the wet season to peak in the late dry season, with a slight decrease in the coldest months of June and July (Whelan 2003).

The seasonal trend in *C. ornatus* populations was not determined during trapping at Blaydin Point. However, the seasonal abundance of *C. ornatus* was determined at nearby Wickham Point and can be used to determine likely seasonal abundance at Blaydin Point. As discussed in Section 3.1.3, highest numbers at Wickham Point occurred from August to October, with increased numbers in June, July, November and April. December to March, and May recorded the fewest numbers. This seasonal trend followed the usual trend of highest *C. ornatus* numbers in the dry season and lowest numbers in the wet season. However the wet season numbers were still appreciable at Wickham Point, due to all areas of Wickham Point being located in close proximity to mangrove areas. Coastal areas further than 1km from the mangrove margin generally only experience appreciable *C. ornatus* levels in the dry season. Therefore due to the close proximity of mangrove areas at Blaydin Point, the seasonal trend in *C. ornatus* abundance at Blaydin Point will be same as Wickham Point.

Culicoides ornatus occurs in highest numbers over a four day period around the full moon, with a smaller peak, approximately half the size of full moon peaks, occurring over a four day period during new moons (Shivas & Whelan 2001). In areas affected by both *Sonneratia* foreshore and upper tidal tributary breeding sites, biting midge levels can be heightened for at least six days in each fortnight (which includes the four days of highest numbers), as biting midge dispersal from the foreshore mangrove areas occur approximately four days before the larger peak in dispersal from the upper tidal tributary breeding sites (Shivas & Whelan 2001). Due to the presence of both *Sonneratia* foreshore mangroves and upper tidal mangrove tributaries at Blaydin Point, peak biting midge numbers will occur over a 6 day period each fortnight around the full and new moons.

5.1.4 Pest problems and public health

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

The number of bites by *Culicoides* species that will constitute a pest problem will largely depend on the individual being bitten. It has been suggested that over 60 bites per hour for most experienced biting midge workers is 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. The number of bites in an hour on an exposed leg at the peak biting time around sunset is approximately a quarter of the number collected in a CO_2 trap over one night at the same position (Whelan et. al. 1997a). For example if there were 400 *C. ornatus* in a CO_2 trap this would equate to 100 bites per hour. Peak biting times for *C. ornatus* are in the two hours either side of sunset and sunrise (Whelan 2003). This species also bites in low levels throughout the night (Logan et al 1991).

The *C. ornatus* numbers recorded at Blaydin Point were extremely high. Trap Site 3 on October 2007 recorded 49 000 *C. ornatus* in a single night. When translating this to potential pest levels, it equates to over 10 000 bites per hour during the two hours around sunset and sunrise for an exposed person. This would be intolerable and would seriously disrupt the workforce. This pest level can be expected for all areas of Blaydin Point and the mainland south of Blaydin Point Island during August to November, for 6 days around the full and new moons. Even new moon problems, at around half the full moon problems, would equate to around 5000 bites per hour during August to November.

Pest problems around the full and new moon during the other dry season months of May to July will also be very high to extremely high. Moderate to high pest problems will be experienced during the wet season months around the full and new moon.

This type of pest problem will result in considerable complaints from workers, therefore there will need to be an induction program aimed at alerting workers of problem periods, and providing appropriate personal protection such as clothing and repellents. Newcomers to Northern Australia will be particularly affected by biting midge bites, as they will lack natural immunity to biting midge bites, therefore only a few bites may lead to associated health issues and lost productivity. Medical Entomology of the Department of Health and Community Services has created a *C. ornatus* pest calendar outlining potential problem periods in coastal areas of the Darwin Region for 2008 (Appendix 3). Information from this pest calendar should be used by the Blaydin Point Health and Safety Officer to create yearly pest calendars for Blaydin Point, to allow workers to be notified of impending problem periods.

Construction workers inside mangrove areas may also encounter significant pest problems from *C.* undescribed sp. (near *C. immaculatus*) and *C. flumineus.* These biting midges do not disperse outside of mangrove forests.

5.1.5 Biting midge control

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

The only way to effectively control *C. ornatus* breeding sites would be to permanently flood or fill their breeding sites, from the mean high water spring tide mark to below the level of occurrence of seaward mangrove (Shivas & Whelan 2001). For Blaydin Point, it would mean the removal of most of the mangroves within 1.5-2km of the development site, which would be environmentally unacceptable.

The barrier insecticide bifenthrin can be used to lower adult biting midge numbers affecting workers. Bifenthrin has been used to good effect during a trial in Hervey Bay, Queensland, with a 97-75% mean reduction in biting midge numbers in the first month of treatment, and a 65% mean reduction in biting midge numbers 6 weeks post treatment (Standfast et al 2003). Bifenthrin would be suitable to use around site offices, guard houses, and outdoor work and recreation areas, and should be applied by a licensed pest controller. The effectiveness of barrier insecticide treatments could be enhanced by creating a shrub vegetation zone or fence (>3m high with dark shadecloth or similar type structure) surrounding personnel areas, with the shrub or fence treated with a barrier insecticide on a suitable schedule.

However even with a 90% reduction in biting midge numbers, there will still be periods of significant pest problems in August to November, and personal protection will still be warranted.

5.1.6 Personal protection and avoidance

Avoiding exposure to biting midges during peak monthly abundance days around sunset and sunrise is the best form of personal protection, but this is unlikely to be practical at Blaydin Point. Other measures include the use of personal repellents and protective clothing such long trousers with socks and shoes, and long sleeve shirts. Further information on personal protection and avoidance can be found in Appendix 2 ‘Personal protection from mosquitoes and biting midges in the Northern Territory’.

Workers should be advised of impending periods of high biting midge abundance, so that they can take appropriate personal protection measures if they are likely to work during periods of high biting midge activity.

5.2 Mosquitoes

5.2.1 Species present

The important mosquitoes *Ae. vigilax, Culex annulirostris, Culex sitiens, Verrallina funerea, Aedes notoscriptus* and *Coquillettidia xanthogaster* were recorded at Blaydin Point during limited trapping. *Aedes vigilax* is an important mosquito due to its significant pest status and potential to transmit disease-causing arboviruses. *Culex annulirostris* can be a significant pest mosquito and can transmit a wide variety of disease-causing arboviruses. *Aedes notoscriptus, Culex sitiens* and *Ve. funerea* are also potential arbovirus vectors and pest mosquitoes. *Coquillettidia xanthogaster* can be a significant pest mosquito, but is not a vector of human disease in Australia.

Anopheles species mosquitoes were not recorded at Blaydin Point due to the timing of the trapping, which occurred in the late dry season and early wet season, when breeding sites were still likely to have been dry. *Anopheles* mosquitoes are potential vectors of malaria, and were recorded at nearby Wickham Point.

5.2.2 Potential breeding sites

Potential mosquito breeding sites were discussed in Section 3.2.4. Essentially Blaydin Point lacks extensive mosquito breeding sites. The most productive mosquito breeding sites at Blaydin Point will be localised depressions in upper tidal areas, depressions in seepage areas and in the monsoon forest near the landward mangrove margin. Outside of Blaydin Point, borrow pits and depressions in upper tidal areas could be potential sources of mosquitoes. Potential mosquito breeding sites are shown in Figure 3.

5.2.3 Spatial abundance

Aedes vigilax has a long flight range, up to 5km from productive breeding sites and up to 60km from extensive breeding sites (Whelan 1997a). *Aedes vigilax* is likely to be the most abundant mosquito species at Blaydin Point, and will be sourced from localised breeding sites in upper tidal areas. Due to the long flight range of this species, all areas of Blaydin Point will be affected by *Ae. vigilax*, although highest numbers can be expected adjacent to their tidal breeding sites.

Culex annulirostris can disperse up to 10km from extensive breeding sites, although are most common within 4km of breeding sites (Whelan 1997a), and there is usually a significant drop in *Cx. annulirostris* numbers up to 2km away from significant breeding sites (Whelan 2004a). *Culex annulirostris* is likely to be present throughout all areas of Blaydin Point, with highest abundance adjacent to seasonally flooded ground pools. Most other mosquito species are also likely to be present throughout all areas of Blaydin Point, with highest numbers adjacent to their seasonally flooded breeding sites. *Verrallina funerea* will only be found in shaded areas adjacent to their brackish water breeding sites.

5.2.4 Seasonal abundance

The seasonal abundance of most mosquito species is likely to be mainly low, unless new mosquito breeding sites are created. The only mosquito species likely to be present in significant numbers will be the northern salt marsh mosquito *Ae. vigilax,* with mainly low but potentially moderate numbers expected from September to January. Other mosquitoes at Blaydin Point are only expected to be present in seasonally minor numbers during the wet season and early dry season.

5.2.5 Pest problems and public health

Aedes vigilax is a potential vector of Ross River virus (RRV) and Barmah Forest virus (BFV), and can be a significant pest mosquito. This species is likely to cause a low to moderate RRV and BFV risk during the late dry season and early wet season (September to January), with the months of December and January being the highest risk months. December and January are hot and humid months, which increases the life span of mosquitoes and allows them more time to obtain an arbovirus from a vertebrate host. Low to moderate pest problems will begin 9 days after monthly high tides or significant rainfall from September to January, and last for around one week from September to November, and up to two weeks in December and January. *Aedes vigilax* is an aggressive biter, and will bite in shaded areas during the daytime as well as after sundown.

Culex annulirostris, Cx. sitiens, Ve. funerea and *Ae. notoscriptus* were other potential disease vector mosquitoes collected at Blaydin Point. *Culex annulirostris* is a potential vector of RRV, BFV, the potentially fatal Murray Valley encephalitis virus (MVEV), Kunjin virus (KUNV) and many other arboviruses. It is only expected to be present in minor numbers at Blaydin Point, so is unlikely to cause any significant pest and disease problems. *Aedes notoscriptus* and *Cx. sitiens* are potential vectors of RRV, while the former is also a potential BFV vector. Both species are only expected to be present in minor numbers, so should not pose any significant pest and disease problems. *Anopheles* species mosquitoes, which are potential vectors of malaria, are not expected to be present in significant numbers at Blaydin Point, so should pose a very minimal pest and potential malaria risk.

The potential for mosquito borne disease transmission and pest problems at Blaydin Point however will increase if new mosquito breeding sites are created by development.

Despite the probable minor *Anopheles* species numbers at Blaydin Point, any personnel that have returned from overseas malarious areas and experience a sudden onset of fever should be considered as possibly having malaria, and be advised to seek medical attention and avoid night time exposure to mosquitoes. Only people with malaria that are exposed after sundown would be at risk of spreading malaria, as *Anopheles* species bite only after dusk. People suspected of having malaria should not be rostered on for night shifts until appropriately treated or cleared of having malaria by a health professional.

5.2.6 Personal protection and avoidance

Personal protection measures for mosquitoes are essentially the same as for biting midges. The only mosquito likely to cause pest problems is *Ae. vigilax,* which is likely to require periodic personal protection in the months of September to January. Further information on personal protection can be found in Appendix 2.

5.2.7 Development aspects

5.2.7.1 Disturbance to tidal areas

Disturbance to tidal areas has the high potential to create new breeding sites for *Ae. vigilax*, *Cx. sitiens, An. farauti s.l.* and *Anopheles hilli.* This could be in the form of surface depressions caused by vehicle and machinery disturbance, impedance of tidal flows by roads and other embankments, erosion from stormwater flows, and the creation of mud waves by filling activities.

The construction of the jetty, drainage and effluent treatment area, material offloading facility and ground flares will result in some disturbance to tidal areas (Ichthys Gas Field Development Notice of Intent (NOI) 2008). The western and eastern boundary of the LNG site area skirts the upper tidal margin, therefore this may cause some disturbance to tidal areas. Any depressions created in tidal areas should be rectified upon completion of development, while the creation of areas of impeded drainage should be avoided, unless the areas of impeded drainage are filled and contoured or have appropriate culvert provisions.

5.2.7.2 Roads

The proposed road that crosses the tidal flat to the Blaydin Point island will require the careful provision of culverts, to ensure no impedance of tidal drainage occurs. Shallow ponding of even 20mm would be enough to create new mosquito breeding sites. Detailed engineering surveys should be conducted to determine all areas of the road embankment that will require both major and minor culverts. Culverts would need to be installed flush with the natural surface, to ensure no upstream ponding occurs.

5.2.7.3 Stormwater drains

Stormwater drains that discharge into tidal areas have the potential to act as mosquito breeding sites by allowing tide water and rainwater ponding, and can create mosquito breeding sites at the discharge point if the end point is not free-draining or if erosion and silt deposition occurs at the end point.

Stormwater drains that discharge wet season site runoff only should discharge water to the landward mangrove margin/4m AHD level. The invert of the stormwater drain should not be below the 4m AHD level, to prevent tide entry and possible ponding and mosquito breeding. Erosion prevention structures such as a reno mattress would be required at the drain end point.

Stormwater drains that will receive dry season flows would require concrete low flow inverts and should discharge water to a free-draining tidal area below the 4 m AHD level. All stormwater drains would be required to be placed on an annual maintenance program to remove silt and vegetation, and repair erosion.

Stormwater pits (road side entry pits, grate inlet pits) within the development site should be free-draining, to prevent ponding and mosquito breeding within the stormwater pits. Oily water separators and other similar structures should be designed to have the clean water section either mosquito-proof, or be routinely pumped out on a weekly basis during the wet season, and dry season if subject to dry season flows. Bunded areas should be drained/pumped dry on a weekly basis during the wet season, and dry season if subject to dry season flows.

5.2.7.4 Sedimentation ponds

Sedimentation ponds are likely to be required to capture silt runoff from the development site. If practical, sedimentation ponds should be avoided in tidal areas, to prevent the creation of breeding sites for *Ae. vigilax, Cx. sitiens, An. farauti s.l.* and *An. hilli.* These tidal to brackish water mosquito species, especially *Ae. vigilax* and *Cx. sitiens,* can breed in areas with no semi-aquatic vegetation, therefore management measures to prevent mosquito breeding in tidal sedimentation ponds would be greater than for freshwater sedimentation ponds. This would include regular inspections for mosquito larvae after high tides (due to seepage through the floor of the pond) and rainfall during the late dry and early wet season, regular inspections for mosquito larvae in the late wet-mid dry season, and annual removal of semi-aquatic vegetation.

The proposed drainage and effluent treatment area is in an upper tidal zone (NOI 2008), therefore any sedimentation ponds in this area would pose a potential mosquito breeding issue unless a comprehensive monitoring and maintenance program is established.

Mosquito breeding in sedimentation ponds in freshwater areas can be avoided by simple preventing the establishment of semi-aquatic vegetation, as semi-aquatic vegetation provides harbourage for mosquito larvae.

In general, sedimentation ponds should be completely free-draining within 5 days for freshwater areas. If sedimentation ponds are required to be constructed in tidal areas, then they should completely drain within 3 days. If extended water impoundment is required, then the pond should have steep internal sides (at least 1V:2H, vertical is optimal) and be relatively deep (>1m), and be stocked with predatory hardy native fish from the Middle Arm area. The discharge site should be the landward mangrove margin, with suitable erosion prevention structures constructed at the discharge site. The sedimentation ponds would require annual maintenance to remove silt and semi-aquatic vegetation.

If dry season low flows are to be directed into the sedimentation traps, then the low flows should be contained within a permanent pool (at least 0.5m deep) in the sedimentation trap. The permanent pool should be stocked with predatory hardy native fish from the Middle Arm area. Alternatively, dry season flows should be diverted to a daily flushed tidal area via a low flow pipe provision.

In general, hardy native fish appropriate for mosquito control would be various grunter species, gudgeons, rainbowfish, glass perchlets and blue eyes from the local waterways.

5.2.7.5 Water storage ponds

Any water storage pond should have steep internal sides (at least 1V:2H, vertical is optimal) and be relatively deep (1m wet season stabilised water level), or be lined with concrete or HDPE lining, to prevent semi-aquatic vegetation growth and mosquito breeding. If practical or if water quality permits, hardy native fish from the Middle Arm area should be stocked in water storage ponds.

5.2.7.6 Borrow pits

All borrow pits should be rendered free-draining once they are no longer required, to prevent the creation of potential mosquito breeding sites. The borrow pit area to the south of Blaydin Point should be examined in the wet season for areas of ponding, with those ponding areas earmarked for draining or filling.

5.2.7.7 Artificial receptacles

Artificial receptacles such as used tyres, drums, disused machinery and any rubbish items that can collect rainwater are potential mosquito breeding sites. Mosquito species that are commonly found breeding in artificial receptacles are *Aedes notoscriptus* and *Culex quinquefasciatus,* with the former a potential vector of RRV. Mosquito species that occasionally breed in artificial receptacles include the potential malaria vector *An. annulipes s.l.* and the major arbovirus vector *Cx. annulirostris.*

Any used tyres, water drums, rainwater tanks, machinery items that can pond water (ie backhoe buckets, excavator tracks), building material and equipment wrapped in plastic sheeting with the potential to hold water, and any other item capable of ponding even small amounts of water, which are sourced from overseas or North Queensland, has the potential to introduce the dengue mosquito *Aedes aegypti* as drought resistant eggs. Artificial receptacles that have previously held rainwater should be treated with a 10% chlorine solution or an appropriate residual insecticide (alpha-cypermethrin or lambda-cyhalothrin), to prevent the possible introduction of *Ae. aegypti* into Blaydin Point.

Periodic inspections of artificial receptacles should be conducted during the wet season at the Blaydin Point LNG Facility, with any receptacle found ponding water either disposed of, stored under cover, have drainage holes drilled or treated with an appropriate insecticide on an appropriate schedule. This would be required to prevent endemic mosquito breeding and minimise the potential for the re-introduction of the dengue mosquito *Ae. aegypti*. The beach line around Blaydin Point should also be periodically cleaned of rubbish items that float ashore, as these items could become breeding sites for endemic and exotic receptacle breeding mosquitoes.

5.2.7.8 Wastewater disposal

All wastewater should be treated and disposed of according to Department of Health and Community Services (DHCS) regulations. The inappropriate disposal of wastewater can lead to effluent ponding and high mosquito breeding, therefore it is important that a suitable method of wastewater disposal is chosen. Wastewater disposal for Blaydin Point could be achieved by infiltration (if soil conditions are favourable), sprinkler irrigation or disposal to the sea or a daily flushed tidal area. Discharge to the sea appears to be the simplest and would be the most preferred method of disposal from a mosquito prevention aspect. The inappropriate storage of wastewater could also lead to mosquito breeding, therefore all wastewater storage and treatment systems must be a suitable design approved by the Environmental Health Section of DHCS.

5.2.7.9 Site grading

The general site grading should be of a standard that avoids the creation of depressions that can pond water for periods greater than 3 days in tidal areas, and 5 days in other areas. This includes ensuring water can not pool underneath demountables or around buildings, from rainfall or airconditioning condensation. This would be required to prevent the creation of new mosquito breeding sites. The development site should be inspected after heavy rainfall each wet season for water holding depressions, with any water holding depression earmarked for rectification.

5.2.7.10 Gas pipeline installation

Potential mosquito breeding can arise if shallow depressions are created on the filled trench through subsidence or unsatisfactory filling and levelling, especially in sensitive tidal areas where depressions as shallow as 20mm could pond water for extended periods and breed mosquitoes. Through careful backfilling of the pipeline trench in tidal and mainland areas, and rehabilitation of any vehicle disturbed areas, the creation of mosquito breeding sites can be avoided.

Regular wet season surveys should be conducted in at least the first year after construction, to ensure there is no subsidence in the backfilled trench that could lead to water ponding and mosquito breeding.

5.2.8 Mosquito control

Mosquito control can be achieved by physical means or chemical means. The best way to control mosquito breeding is by eliminating potential breeding sites. For Blaydin Point, this would include rectifying existing vehicle disturbed areas adjacent to the landward mangrove margin, filling/draining depressions that seasonally pond tide or rain water, and ensuring the borrow pits south of Blaydin Point are free-draining or filled to prevent water ponding. To locate tide mosquito breeding sites, this would entail a late dry season/early wet season survey 2-3 days after the highest tide in October to December to locate actual or potential mosquito breeding depressions. Wet season mosquito breeding sites should be searched for one week after the first monsoon spell, which usually occurs during late December or January in the Top End of the NT. The development is likely to remove many existing seasonally flooded areas, while any remaining seasonally flooded areas on Blaydin Point and the mainland south of Blaydin Point should be identified and rectified.

Temporary mosquito control may be required during the construction phase, when machinery disturbed areas pond water during the wet season. Temporary mosquito control could be achieved by using the ecologically friendly insecticides *Bacillus thuringiensis* var. *israelensis* or methoprene, until the breeding sites have been rectified.

By preventing the creation of mosquito breeding sites, and conducting annual maintenance of stormwater drains, sedimentation traps and water storage features, as well as rectifying existing mosquito breeding sites, there should be no requirement for a routine larval mosquito control program at Blaydin Point during the operational phase.

The barrier insecticide ‘bifenthrin’ could be used to control adult mosquitoes if numbers reach appreciable levels, see Section 5.1.5 for information on bifenthrin. It is not envisaged that bifenthrin treatments would be required for mosquitoes at Blaydin Point.

5.2.9 Limitations

The mosquito information for Blaydin Point is limited. The discussion above reflects the authors predictions on mosquito abundance and diversity based on limited trapping, an examination of aerial photography and an examination of baseline mosquito data from nearby Wickham Point. There may be seasonally productive localised mosquito breeding sites at Blaydin Point that were not visible from aerial photography, which could give rise to seasonally significant populations of mosquitoes. The only method to accurately determine mosquito populations at Blaydin Point would have been to conduct monthly trapping for 12-months, conduct mid wet season and late wet/early dry season larval mosquito surveys, and conduct larval surveys after the monthly high tide in October or November.

6.0 Conclusions

6.1 Biting midges

- The mangrove biting midge *C. ornatus* will be present in extremely high seasonal numbers during the late dry season (August to November). Very high numbers will be present during the early to mid dry season (April to July), while high numbers will be present during the wet season. The species will be widespread throughout Blaydin Point and the mainland south of Blaydin Point.

- The pest problems caused by *C. ornatus* will be severe and unbearable for people without personal protection, for a period of 6 days around the full and new moons during the two hours around sunset and sunrise. Dry-season pest problems will be significantly greater than wet season problems, especially during the late dry season.

- Problems with *C. ornatus* will disrupt the workforce, and can cause secondary effects such as intense itching, infection and scarring. Newcomers to the region will be particularly affected, as they will lack immunity to biting midge bites.

- The mangrove biting midges *C.* undescribed sp. (near *C. immaculatus*) and *C. flumineus* are likely to cause pest problems to workers inside mangrove areas.

- Biting midge pest problems could be reduced by the use of protective clothing and repellents. Barrier insecticides could also be used to lower adult biting midge numbers around personnel areas.

- Mangrove biting midge breeding sites cannot be controlled with insecticides. The only method of reducing biting midge breeding would be to remove their tidal mangrove breeding sites, which would be deemed environmentally unacceptable.

6.2 Mosquitoes

- Mosquito populations at Blaydin Point are not expected to be as high as other areas of Darwin, due to the lack of extensive breeding sites such as coastal plains, creeks and rivers. Localised mosquito populations will occur at Blaydin Point, and these would include pest and disease-carrying mosquito species. Twelve-month baseline trapping and wet season field surveys were not conducted at Blaydin Point, therefore mosquito populations affecting Blaydin Point were predicted based on limited trapping, a desktop examination of Blaydin Point and surrounding areas, and an examination of baseline data from Wickham Point.

- The northern salt marsh mosquito *Ae. vigilax* is will be present in low, and possibly moderate numbers, during the late dry and early wet season (September to January). This species will be sourced from poorly draining upper tidal areas surrounding Blaydin Point. Breeding sites appear to be localised, and would mainly be associated with depressions in flowlines, areas of restricted tidal drainage, and vehicle disturbed areas along the landward mangrove margin.

- Important mosquito species such as *Culex annulirostris, Culex sitiens, Anopheles species* and *Coquillettidia xanthogaster* will be seasonally present at Blaydin Point in minor numbers during the wet season. Breeding sites at Blaydin Point would be localised ground pools with vegetation, these are likely to be located adjacent to the landward mangrove margin in seepage areas. The monsoon vine forest is likely to contain some areas of wet season ponding and breeding sites for *Verrallina funerea,* and possibly *Ae. vigilax* if there are tide influenced depressions near the landward mangrove margin.

- The large borrow pit area to the south of Blaydin Point is a possible breeding site for *Cx. annulirostris, Anopheles species* and *Cq. xanthogaster,* if significant wet season ponding occurs there.

- Mosquito pest problems at Blaydin Point are expected to be minimal, with *Ae. vigilax* the only mosquito likely to be present in numbers high enough to cause a pest problem. *Aedes vigilax* is an aggressive biter, and will bite during the daytime in shaded areas, as well as at night, and will cause seasonally low and possibly moderate pest problems at Blaydin Point. Other mosquito species are not expected to be present in numbers high enough to cause appreciable pest problems.

- *Aedes vigilax* will pose a low and possibly moderate risk of Ross River virus (RRV) and Barmah Forest virus (BFV) transmission during the months of September to January, with December and January the highest risk months due to increased mosquito longevity. *Culex annulirostris, Culex sitiens* and *Verrallina funerea* will pose a minor risk of RRV transmission due to expected minor abundance, while *Cx. annulirostris* will also pose a minor risk of BFV, Murray Valley encephalitis virus (MVEV) and Kunjin virus (KUNV) transmission.

- The risk for potential malaria transmission at Blaydin Point is likely to be very low, due to the expected minor abundance of *Anopheles* species.

- The development has the potential to increase mosquito populations and subsequently increase the potential for mosquito borne disease transmission. Potential mosquito breeding sites could be created by the inappropriate storage and discharge of stormwater and wastewater, excavation activities, construction of roads and pipelines and disturbance to tidal areas.

- Artificial receptacles at the development site could become breeding sites for the endemic disease-carrying mosquito *Aedes notoscriptus,* and exotic dengue mosquitoes. Rubbish items washed on to the shoreline could also become breeding sites for endemic disease-carrying mosquitoes and exotic dengue mosquitoes.

- There would be no requirement for an insecticide mosquito control program if no new mosquito breeding sites are created by development, and potential breeding sites at Blaydin Point and on the mainland south of Blaydin Point are located and rectified.

7.0 Recommendations

7.1 Biting midges

- All workers must be informed of the severe biting midge problems that will occur at Blaydin Point and the peninsula leading into Blaydin Point during the induction. Personal protection measures should be outlined to workers, and personal protective clothing and repellents should be made available, especially to early morning, late evening and night time workers.

- The Blaydin Point Health and Safety Officer or relevant officer should mark on a calendar all periods of the year that will experience biting midge pest problems, and alert workers of impending periods of pest biting midge problems (see Appendix 3).

- All offices, mess rooms, guard houses and other such office facilities should be fully sealed and air-conditioned to prevent the entry of biting midges.

- Outdoor recreation areas, work stations and the outside of personnel buildings should be treated with an appropriate residual barrier insecticide on an appropriate schedule, to reduce the number of biting midges in these areas. The effectiveness of barrier insecticide treatments could be enhanced by creating a shrub vegetation zone or fence (>3m high with dark shadecloth or similar type structure) surrounding personnel areas, with the shrub or fence treated with a barrier insecticide on a suitable schedule.

- Insecticide larval control or the removal of biting midge breeding sites is not recommended due to the negative environmental impacts. Personal protection, avoidance of peak biting periods and the use of barrier insecticides are currently the best measures to prevent biting midges bites.

- There should be a biting insect management plan developed for the Blaydin Point LNG Facility, which outlines all measures that will be taken to minimise the impact of biting midges at Blaydin Point.

7.2 Mosquitoes

- Any depressions that pond tide or rainwater at Blaydin Point and the mainland south of Blaydin Point should be located and rectified, to reduce the number of mosquitoes affecting the Blaydin Point LNG Facility.

- The existing borrow pits located south of Blaydin Point should be inspected in the wet season by the Blaydin Point Environmental Officer or relevant project officer for water ponding. Any areas of water ponding should be rectified by draining or filling, to remove potential mosquito breeding sites that could affect Blaydin Point.

- The access road should be fitted with culverts of appropriate dimensions, and culverts should be installed flush with the natural surface at all major and minor flowlines that the road embankment will cross. This is particularly important for tidal areas, where the embankment of even minor flowlines can lead to the creation of tide and rain ponding, and subsequent mosquito breeding.

- Any disturbance to tidal areas, such as machinery disturbance and mud waves, should be rectified to prevent tide and rain ponding, and subsequent mosquito breeding.

- Any new borrow pits created by development should be rendered free-draining once they are no longer required.

- The trench for the gas pipeline should be appropriately backfilled to match the existing surface level, to avoid the creation of areas that could pond water and breed mosquitoes. Any machinery disturbed areas should also be rehabilitated to prevent water ponding. Regular wet season surveys should be conducted in at least the first year after construction, to ensure there is no subsidence in the backfilled trench that could lead to water ponding and mosquito breeding.

- Stormwater drains should be an appropriate standard to prevent mosquito breeding. Stormwater drains should discharge to a suitably designed sediment trap before discharging into tidal areas. Wet season discharge can be to the landward mangrove margin, while dry season discharge should be directed to a daily flushed tidal area.

- Sediment ponds should be designed to completely drain within 5 days, to prevent potential mosquito breeding. Sediment ponds are not recommended in tidal areas, due to the high potential for mosquito breeding. For those sediment ponds designed to retain water, they should be constructed with steep sides (1:2 slope or greater) and be relatively deep (>1m), and be stocked with hardy native fish from the Middle Arm area. Sediment traps receiving dry season flows should either have a deep permanent pool at the inlet site, or have a low flow provision to direct low flows to a daily flushed tidal area.

- Water storage ponds should be designed with steep sites (1:2 slope or greater) and be relatively deep (>1m), to minimise the potential for semi-aquatic vegetation growth and mosquito breeding. Alternatively water storage ponds can be lined to prevent semi-aquatic vegetation growth and mosquito breeding. If practical and if water quality permits, hardy native fish from the Middle Arm area should be stocked in water storage ponds.

- There should be regular wet season inspections of artificial receptacles at the development site. Any receptacle found ponding water should be disposed of, stored under cover, have drainage holes drilled or treated with an appropriate insecticide on an appropriate schedule. There should also be a regular clean up of rubbish items that float ashore at Blaydin Point.

- Any worker sourced or returning from an overseas country where malaria is endemic, whom experiences high fever should stay indoors away from mosquito bites until cleared of malaria or treated for malaria by a health professional.

- There should be an annual maintenance program established to desilt/clear vegetation from stormwater drains and sediment ponds, and repair any erosion in stormwater drains and at stormwater discharge sites.

- The development site should be graded to be free of depressions capable of ponding water for periods greater than 3 consecutive days in tidal areas, and 5 days in mainland areas, to prevent mosquito breeding. This includes areas underneath demountables and around buildings, which can accumulate water if levels are not suitable. Regular wet season surveys should be conducted to locate any ground depressions that require rectification.

- Effluent treatment facilities should be designed and operated in accordance to Department of Health and Community Services regulations. The best method of effluent discharge for Blaydin Point in regards to preventing mosquito breeding would be disposal to the sea.

- There should be a biting insect management plan developed for the Blaydin Point LNG Facility, which outlines all measures that will be taken to minimise the impact of mosquitoes at Blaydin Point.

8.0 Acknowledgements

Biting insect trapping was conducted by Jane Carter, Alan Niscioli and Bruce Hitchins of Medical Entomology, Department of Health and Community Services. Mosquitoes were identified by Jane Carter and Alan Niscioli. Biting midges were identified by Nina Kurucz of Medical Entomology. Figures were prepared by Raelene Whitters of Medical Entomology.

Medical Entomology would also like to thank Bill Freeland from GHD Pty Ltd for commissioning the biting insect assessment.

9.0 References (cited and uncited)

Bishop, A. & Dyce, A. (1988), 'A manual of known larval habitats of Australian *Culicoides* spp.', National Arbovirus Monitoring program *Culicoides workshop 27-29 October 1998.*

Butterworth, V (2007), 'Creating ideal biting midge habitat, the Currimundi Lake experience', Published in Mosquito Bites in the Asia Pacific Region, Volume 2, Issue 2 December 2007.

Communicable Disease Centre (CDC), Department of Health and Community Services NT Factsheet (April 2003) 'Ross River virus'.

Communicable Disease Centre (CDC), Department of Health and Community Services NT Factsheet (April 2004) 'Murray Valley encephalitis virus'.

Communicable Disease Centre (CDC), Department of Health and Community Services NT Factsheet (May 2006) 'Mosquitoes'.

Dyce, A., & Wellings, G. (1998), '*Culicoides of Australasia* (Morphology-Taxonomy-Systematics-Biogeography & Techniques). A Manual in four parts I-IV.' National Arbovirus Monitoring Program, Gosford *Culicoides* Workshop 27-29 October 1998.

Dyce. A.L., Bellis, G.A. & Muller, M.J. (2007), 'Pictorial atlas of Australian *Culicoides* wings (Diptera:Ceratopogonidae)', Australian Government, Department of the Environment and Water Resources.

'Guidelines to minimise mosquito and biting midge problems in new development areas', Queensland Health 2002, Queensland Government.

Inpex Browse LTD Notice of Intent (2008)'Ichthys Gas Field Development Project Blaydin Point, Darwin'.

Lee, D. J. (1944), 'An Atlas of the Mosquito Larvae of the Australasian Region. Tribes-Megarhinini and Culicini.' Department of Zoology, University of Sydney.

Lee, D. J. & Woodhill, A. R. (1944), 'The Anopheline Mosquitoes of the Australasian Region.' Publications of the University of Sydney, Department of Zoology. Monograph No. 2.

Lee, D. J., Hicks, M. M., Griffiths, M., Russell, R. C., & Marks, E. N. (1982), 'The Culicidae of the Australasian Region Vol. 2', Commonwealth Department of Health & Commonwealth Institute of Health incorporating School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.

Lee, D. J., Hicks, M. M., Griffiths, M., Russell, R. C., & Marks, E. N. (1984), 'The Culicidae of the Australasian Region Vol. 3', Commonwealth Department of Health & Commonwealth Institute of Health incorporating School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.

Lee, D. J., Hicks, M. M., Griffiths, M., Debenham, M. L., Bryan, J. H., Russell, R. C., Geary, M., & Marks, E. N. (1987), 'The Culicidae of the Australasian Region Vol. 4', Commonwealth Department of Health & School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.

Lee, D. J., Hicks, M. M., Debenham, M. L., Griffiths, M., Marks, E. N. Bryan, J. H., & Russell, R. C., (1989), 'The Culicidae of the Australasian Region Vol. 7', University of Queensland and University of Sydney in collaboration with Commonwealth Department of Community Services and Health, Monograph Series, Entomology Monograph No. 2.

Lee, D. J., Hicks, M. M., Griffiths, M., Debenham, M. L., Bryan, J. H., Russell, R. C., Geary, M., & Marks, E. N. (1988), 'The Culicidae of the Australasian Region Vol. 8', Commonwealth Department of Health & School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.

Lee, D. J., Hicks, M. M., Griffiths, M., Debenham, M. L., Bryan, J. H. & Marks, E. N. (1988a), 'The Culicidae of the Australasian Region Vol. 9', Commonwealth Department of Health & School of Public Health and Tropical Medicine, Monograph Series, Entomology Monograph No. 2.

Liehne, P. F. in consultation with Medical Entomology Branch (1985), 'Mosquito and Biting Midge Investigations, Palmerston 1982-85', Palmerston Development Authority.

Logan, D., Kelton, W. & Whelan, P. (1991), 'Bayview Haven Canal Estate Biting Insect Investigation', Medical Entomology Branch, Department of Health and Community Services.

Marks, E.N. and Reye, E.J, (1982), 'An atlas of common Queensland mosquitoes with a guide to common Queensland biting midges', Queensland Institute of Medical Research.

Merianos, A., Farland, A. M., Patel, M., Currie, B., Whelan, P. I., Dentith, H. & Smith, D. (1992), 'A concurrent outbreak of Barmah Forest and Ross River virus disease in Nhulunbuy, Northern Territory', *Comm Dis Intel*, vol. 16, no. 6, pp. 110-111.

Rohe, D. L. & Fall, R. R. (1979), 'A miniature battery powered CO_2 baited light trap for mosquito borne encephalitis virus surveillance', *Bull Soc Vector Research,* 4, pp. 24-27.

Russell, R. C., (1986), 'Dispersal of the arbovirus vector *Culex annulirostris* Skuse (Diptera:Culicidae) in the Murray Valley of Australia', *Gen Appl Ent,* 18.

Russell, R. C., (1987), 'Seasonal abundance, longevity and population age composition of potential malaria vectors in northern and southern Australia.' Aust. J. Zool.35:289-306.

Russell, R. C. (1999), 'Constructed wetlands and mosquitoes: Health hazards and management options – An Australian perspective', *Ecological Engineering* 1**2** (1999) 107 – 124.

Russell, R. C. & Kay, B.H. (2004), 'Medical Entomology: changes in the spectrum of mosquito-borne disease in Australia and other vector threats and risks, 1972-2004', *Australian Journal of Entomology* (2004) 43**,** 271-282.

Russell, R. C., Currie, B.J., Lindsay, M.D.A., Mackenzie, J.S., Ritchie, S.A., Walker, J.C. and Whelan, P.I. (2007), 'Climate change and vector-borne disease in Australia: what are the real threats from malaria, dengue and endemic arboviruses', A discussion paper prepared for NAMAC.

Shivas, M., Whelan, P. I., & Webb, C. (1997), 'The characterization of emergence sites of the biting midge *Culicoides ornatus* (Diptera:Ceratopogonidae) in mangroves near Darwin, NT, Australia', in *Arbovirus Research in Australia,* vol. 7, *Proceedings of the Seventh Arbovirus Research in Australia Symposium, & Second Mosquito Control Association of Australia Conference*, *1996*, pp. 275-279.

Shivas, M. (1999), 'The larval biology of *Culicoides ornatus* Taylor in mangroves near Darwin, NT.' Faculty of Science, Northern Territory University Darwin. PHD Doctor of Philosophy.

Shivas, M., and Whelan, P. I. (2001), 'Biting midge research project' (Study undertaken on behalf of Department of Lands, Planning and Environment). Territory Health Services.

Standfast, H., Fanning, I., Maloney, L., Purdie, D., and Brown, M. (2003), 'Field evaluation of Bistar 80 S.C. as an effective insecticide harbourage treatment for biting midges and mosquitoes infesting peri-domestic situations in an urban environment'. *Bulletin MCAA* vol. 15; 2, pp 19-33.

Tai, K. S., Whelan, P. I., Patel, M. S. & Currie, B. (1993), 'An outbreak of epidemic polyarthritis (Ross River virus disease) in the Northern Territory during the 1990-1991 wet season. *Medical Journal of Australia,* vol. 158, pp. 522-525.

Warchot, A. & Whelan, P. (2004), 'Wickham Point Baseline Biting Insect Report', Medical Entomology Branch, Department of Health and Community Services.

Whelan, P. I. (1991), 'Biting midge investigations near Darwin and their implications for urban planning', in *Proc. Nat. Conf. on Biting Midges*, Surfers Paradise, Qld, 8-9 Feb, 1990, pp. 39-50.

Warchot, A. & Whelan, P. (2008a), 'Muirhead Biting Insect Assessment', Medical Entomology, Department of Health and Community Services.

Warchot, A. & Whelan, P. (2008b), 'Palmerston Eastern Suburbs Biting Insect Assessment', Medical Entomology, Department of Health and Community Services.

Whelan, P. I. (1994), 'Construction practice near tidal areas in the NT', *Bulletin of the Mosquito Control Association of Australia*, Vol. 6, No. 1, pp. 18-39.

Whelan, P. I. (1995), 'Malaria and the receptive area of the Northern Territory', Medical Entomology Branch, Department of Health and Community Services.

Whelan, P.I. (1997a), 'Problems mosquito species in the Top End of the NT – Pest and vector status, habitat and breeding sites', Medical Entomology Branch, Department of Health and Community Services.

Whelan, P.I. (1997b), 'Arbovirus disease risk periods in the Northern Territory', Medical Entomology Branch, Department of Health and Community Services.

Whelan, P. I. (2003), 'Biting midges or "sand flies" in the Northern Territory.' *Northern Territory Disease Control Bulletin* Vol. 10, No.3, pp. 1-9, September 2003.

Whelan, P.I. (2004a), 'Common mosquito species in the Top End of the NT – Their biology and disease significance', Medical Entomology Branch, Department of Health and Community Services.

Whelan, P.I. (2004b), 'Summary of the biology of selected *Culicoides* species in the Top End of the Northern Territory & Seasonal prevalence of selected *Culicoides* species in the Top End of the Northern Territory', Medical Entomology Branch, Department of Health and Community Services.

Whelan, P.I., Booth, D. and Kelton, W. (1988), 'Biting insects in the proposed Newtown (Weddell) development, Darwin', Medical Entomology Branch, Department of Health and Community Services.

Whelan, P. I. and Hayes, G.A. (1992). Arbovirus Outbreak Nhulunbuy NT 1992 - Medical Entomology Aspects. December to March 1992, Medical Entomology Branch, Department of Health and Community Services.

Whelan, P.I., & Hayes, G.A., (1993), 'Biting insect investigations Darwin South, Stage I' (Study undertaken on behalf of the Dept of Lands, Housing and Local Government), NT Dept of Health & Community Services.

Whelan, P. I., Merianos, A., Patel, M., Tai, K. S. & Currie, B. (1993), 'The epidemiology of arbovirus infection in the Northern Territory 1980-92', *Arbovirus Research in Australia,* vol. 6, *Proc. of the 6th Arbovirus Conference, 1993*.

Whelan, P. I. & Weir, R. P. (1993), 'The isolation of alpha and flavi viruses from mosquitoes in the Northern Territory 1982-1992', *Arbovirus Research in Australia*, vol. 6, *Proceedings of the 6th Arbovirus Conference, 1992*.

Whelan, P. I., Montgomery, B.L., Hayes, G.A., Nowland, R.A. & Love, B.L. (1994), 'Biting insect investigations Darwin South Stage II. Twelve month baseline study of species, abundance and distribution of biting insects in the Darwin South area', Medical Entomology Branch report.

Whelan, P. I., Hayes, G., Montgomery, B. L. (1997a), 'Biting midge surveillance in Darwin Harbour, *Culicoides ornatus* (Diptera:Ceratopogonidae) abundance and dispersal', in *Arbovirus Research in Australia,* vol. 7, *Proceedings of the Seventh Arbovirus Research in Australia, & Second Mosquito Control Association of Australia Conference*, *1996*, pp. 326-336.

Whelan, P. I., Merianos, A., Hayes, G., & Krause, V. (1997b), 'Ross River virus transmission in Darwin, Northern Territory, Australia', in *Arbovirus Research in Australia,* vol. 7, *Proceedings of the Seventh Arbovirus Research in Australia Symposium, & Second Mosquito Control Association of Australia Conference*, *1996*, pp. 337-345.

Whelan, P., Montgomery, B., Hayes, G., Nowland, R., Love, B. & Carter, J. (1997c), 'Biting insects of medical importance at Wickham Point Darwin Harbour', Medical Entomology Branch, Territory Health Services.

Whelan, P., Kurucz. K., Warchot, A., Carter, J., Pettit. W., Shortus. M., Nguyen. H., Anderson. S., Copley. N., Whitters. R. & Pearce. T. (November 2007), 'Medical Entomology Branch Annual Report 2006/07 (Draft)', Medical Entomology Branch, Department of Health and Community Services.

WHO. 2002. Report of the fifth WHOPES working group meeting: review of Olyset Net and Bifenthrin 10%WP. WHO/CDS/WHOPES/2001.4

Wirth, W., & Hubert, A. (1989), '*Culicoides* of South East Asia.' The American Entomological Institute, Florida U.S.A.

Figures

Figure 2 - Blaydin Point CO2 biting insect trap locations.
Potential culicoides ornatus breeding sites.

0 500 1,000 1,500 Meters Scale 1:24,000

Filename F:\ENTO\ento_files\gis\gis_data\Blaydin Point\Blaydin 2007 Fig 2.mxd

Legend
- Adult CO_2 trap sites
- Potential culicoides ornatus breeding sites

Figure 3 - Blaydin Point Biting Insect Assessment.
Potential mosquito breeding sites affecting Blaydin Point.

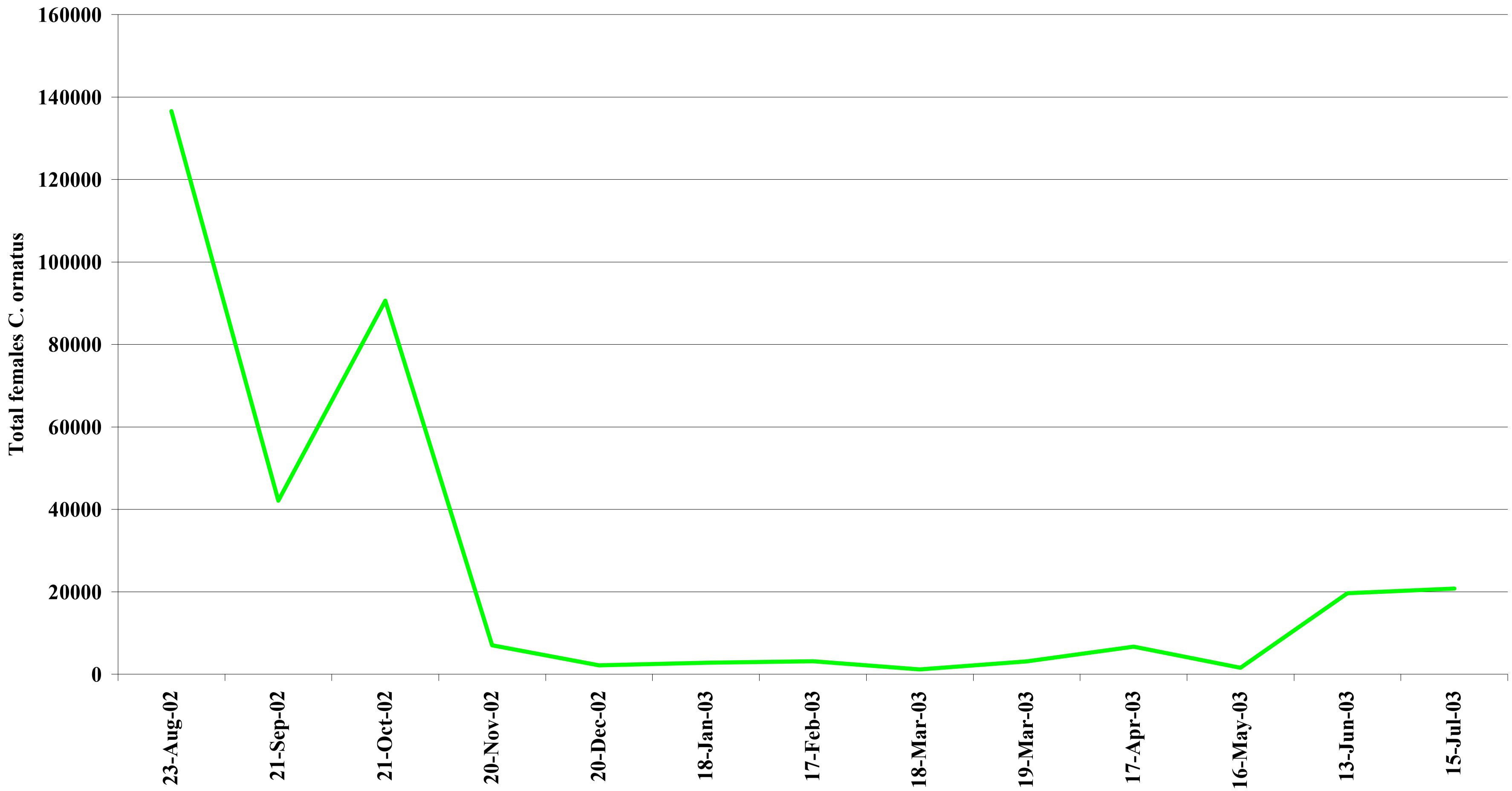
0 500 1,000 1,500 Meters Scale 1:24,000

Legend

● Adult CO_2 trap sites

Filename F:\ENTO\ento_files\gis\gis_data\Blaydin Point\Blaydin 2007 Fig 3.mxd

Figure 4 - Wickham Point Baseline Biting Insect Investigation 2003-2004. Total number of female *Culicoides ornatus* collected in carbon dioxide baited EVS traps from all 6 trap sites .



Tables

Table 1. Blaydin Point Biting Insect Assessment. Total number of female biting midges collected in CO_2 baited EVS traps on 26 October 2007 at all sites (traps set one night before full moon).

Trap location	*Culicoides (Mar grp) marksi*	*Culicoides (Orn grp) ornatus*	*Culicoides (Orn grp)* undesc. sp No 6	*Culicoides (Vic grp) bundyensis*	**Totals**	**%**
BLAY_01, Blaydin Point Baseline Study Site 1, mainland at proposed site office, south of Blaydin Point	1	18000	0	0	18001	14.88
BLAY_02, Blaydin Point Baseline Study Site 2, south edge of monsoon forest	0	10000	0	0	10000	8.26
BLAY_03, Blaydin Point Baseline Study Site 3, western edge of Blaydin Point	0	49000	1000	0	50000	41.32
BLAY_04, Blaydin Point Baseline Study Site 4, tip of Blaydin Point	0	8000	0	1	8001	6.61
BLAY_05, Blaydin Point Baseline Study Site 5, north edge of monsoon forest	0	10000	0	0	10000	8.26
BLAY_06, Blaydin Point Baseline Study Site 6, south-west corner of Blaydin Point	0	23500	1500	0	25000	20.66
Totals	1	118500	2500	1	121002	100.00
%	0.00	97.93	2.07	0.00	100.00	

Table 2. Blaydin Point Biting Insect Assessment. Total number of female biting midges collected in CO_2 baited EVS traps on the 7 December 2007 at all sites (Traps set 4 days before new moon).

Trap location	*Culicoides (Ava) obscurus*	*Culicoides (Orn grp) ornatus*	*Culicoides (Orn grp)* undesc. sp. No. 6	*Culicoides (Wil grp) austropalpalis*	*Culicoides* unidentifiable	not identified biting midges	Totals	%
BLAY_01, Blaydin Point Baseline Study Site 1,mainland at proposed site office, south of Blaydin Point	0	0	0	0	0	1	1	0.03
BLAY_02, Blaydin Point Baseline Study Site 2, south edge of monsoon forest	0	240	10	0	0	0	250	6.51
BLAY_03, Blaydin Point Baseline Study Site 3, western edge of Blaydin Point	5	2580	420	0	0	0	3005	78.21
BLAY_04, Blaydin Point Baseline Study Site 4, Tip of Blaydin Point	0	114	8	1	2	0	125	3.25
BLAY_05, Blaydin Point Baseline Study Site 5, north edge of monsoon forest	1	450	9	0	0	0	460	11.97
BLAY_06, Blaydin Point Baseline Study Site 6, south-west corner of Blaydin Point	0	0	0	0	0	1	1	0.03
Totals	6	3384	447	1	2	2	3842	100.00
%	0.16	88.08	11.63	0.03	0.05	0.05	100.00	

Table 3: Wickham Point Biting Insect Survey, Medical Entomology Branch

Summary of *Culicoides ornatus* collected at six trap sites set once monthly using CO2 baited EVS traps August 2002 to July 2003

	Full moon date													
	23-Aug-02	21-Sep-02	21-Oct-02	20-Nov-02	20-Dec-02	18-Jan-03	17-Feb-03	18-Mar-03	18-Mar-03	17-Apr-03	16-May-03	13-Jun-03	14-Jul-03	
	Date collected													
Trap location	23-Aug-02	21-Sep-02	21-Oct-02	20-Nov-02	20-Dec-02	18-Jan-03	17-Feb-03	18-Mar-03	19-Mar-03	17-Apr-03	16-May-03	13-Jun-03	15-Jul-03	Grand Total
Site 1 - At start of rocky outcrop E of narrow beach line	20000	396	14700	3185	250	53	150	52	N/C	250	41	900	2058	42035
Site 2 - East of mudflat between sand spit and land in 10m from landward vegetation edge.	8500	15000	6500	2050	138	100	185	630	N/C	4320	252	7000	1380	46055
Site 3 - In paperbark swamp 30m in from mangrove margin on Eastern side of island	24000	10560	19000	0	900	1410	1440	N/C	1500	450	57	5940	12320	77577
Site 4 - Rocky outcrop, on top of ridge S edge of island, east corner	41360	8330	4140	558	150	483	720	N/C	270	792	252	3420	3010	63485
Site 5 - At Paperbark and mangrove interface on S edge of Island	21168	2500	11000	924	495	370	205	N/C	1300	868	720	392	37	39979
Site 6 - In Peltophorum forest, S edge of island, approx. 250m from cut mangrove boat access path on south of island.	21560	5336	35280	288	210	380	450	525	N/C	42	250	2000	2000	68321
Grand Total	136588	42122	90620	7005	2143	2796	3150	1207	3070	6722	1572	19652	20805	337452

Table 4. Blaydin Point Biting Insect Assessment. Total number of female mosquitoes collected in CO_2 baited EVS traps on 26 October 2007 at all sites.

Trap location	*Aedes (Och) vigilax*	*Culex (Cux) annulirostris*	*Culex (Cux) sitiens*	*Nil mosquitoes*	**Totals**	**%**
BLAY_01, Blaydin Point Baseline Study Site 1, mainland at proposed site office, south of Blaydin Point	1	1	0	0	2	16.67
BLAY_02, Blaydin Point Baseline Study Site 2, south edge of monsoon forest	3	0	0	0	3	25.00
BLAY_03, Blaydin Point Baseline Study Site 3, western edge of Blaydin Point	0	1	0	0	1	8.33
BLAY_04, Blaydin Point Baseline Study Site 4, Tip of Blaydin Point	0	0	0	0	0	0.00
BLAY_05, Blaydin Point Baseline Study Site 5, north edge of monsoon forest	0	0	1	0	1	8.33
BLAY_06, Blaydin Point Baseline Study Site 6, south-west edge of Blaydin Point	3	2	0	0	5	41.67
Totals	7	4	1	0	12	100.00
%	58.33	33.33	8.33	0.00	100.00	

Table 5. Blaydin Point Biting Insect Assessment. Total number of female mosquitoes collected in CO_2 baited EVS traps on 7 December 2007 at all sites (traps set 10 days after November monthly high tide)

Trap location	*Aedes (Cha) elchoensis*	*Aedes (Fin) notoscriptus*	*Aedes (Mol) pecuniosus*	*Aedes (Och) vigilax*	*Aedes daliensis*	*Coquellettidia (Coq) xanthogaster*	*Culex (Cux) annulirostris*	*Culex (Cux) sitiens*	*Verrallina (Ver) funerea*	**Totals**	**%**
BLAY_01, Blaydin Point Baseline Study Site 1, mainland at proposed site office, south of Blaydin Point	0	0	0	70	0	1	9	0	1	81	26.64
BLAY_02, Blaydin Point Baseline Study Site 2, south edge of monsoon forest	0	2	0	12	0	0	8	0	0	22	7.24
BLAY_03, Blaydin Point Baseline Study Site 3, western edge of Blaydin Point	0	0	0	37	0	0	6	0	0	43	14.14
BLAY_04, Blaydin Point Baseline Study Site 4, Tip of Blaydin Point	0	0	0	37	6	0	6	1	0	50	16.45
BLAY_05, Blaydin Point Baseline Study Site 5, north edge of monsoon forest	0	5	0	25	0	0	12	0	0	42	13.82
BLAY_06, Blaydin Point Baseline Study Site 6, south-west edge of Blaydin Point	0	1	1	55	0	0	8	1	0	66	21.71
Totals	0	8	1	236	6	1	49	2	1	304	100.00
%	0.00	2.63	0.33	77.63	1.97	0.33	16.12	0.66	0.33	100.00	

Table 6: Wickham Point Biting Insect Survey, Medical Entomlogy Branch

Summary by date of female mosquitoes collected at six trap sites using CO_2 baited EVS traps set once monthly August 2002 to July 2003

Mosquito species	Date Collected																
	23-Aug-02	21-Sep-02	21-Oct-02	20-Nov-02	20-Dec-02	18-Jan-03	17-Feb-03	18-Mar-03	19-Mar-03	17-Apr-03	16-May-03	13-Jun-03	15-Jul-03	Totals	%	No. of traps	Average per trap
Ae. (Adm) alboscutellatus	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0.04	71	0.03
An. (Ano) bancroftii	0	0	0	0	0	0	0	0	0	2	0	4	1	7	0.13	71	0.10
An. (Cel) farauti s.l.	1	0	0	0	0	0	2	0	1	3	1	0	2	10	0.19	71	0.14
An. (Cel) hilli	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.02	71	0.01
An. (Cel) meraukensis	0	0	0	0	0	0	0	0	2	1	0	0	0	3	0.06	71	0.04
An. (Cel) novaguinensis	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0.04	71	0.03
Cq. (Coq) xanthogaster	0	0	0	0	0	149	0	0	0	6	0	254	131	540	10.27	71	7.61
Cx. (Cui) pullus	0	0	0	0	0	9	8	0	1	1	1	0	0	20	0.38	71	0.28
Cx. (Cux) annulirostris	3	0	1	1	17	137	302	25	9	113	2	11	59	680	12.93	71	9.58
Cx. (Cux) bitaeniorhynchus	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0.02	71	0.01
Cx. (Cux) palpalis	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0.06	71	0.04
Cx. (Cux) sitiens	0	0	2	0	17	394	82	12	6	0	0	6	1	520	9.89	71	7.32
Cx. (Cux) Vishnui group	0	0	0	0	0	0	0	0	0	1	0	1	0	2	0.04	71	0.03
Cx. (Lop) hilli	0	0	0	0	1	0	0	0	0	0	0	1	1	3	0.06	71	0.04
Ma. (Mnd) uniformis	0	0	0	0	0	0	0	0	0	4	0	4	0	8	0.15	71	0.11
mosquitoes unidentifiable (damaged)	0	0	0	0	3	0	0	0	0	0	0	0	0	3	0.06	71	0.04
Nil mosquitoes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	71	0.00
not identified mosquitoes	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.02	71	0.01
Oc. (?nr Levua) daliensis	0	0	1	1	0	1	1	0	0	1	0	1	0	6	0.11	71	0.08
Oc. (Fin) kochi	0	0	0	0	0	1	5	1	5	1	0	0	0	13	0.25	71	0.18
Oc. (Fin) notoscriptus	0	0	1	10	4	13	15	6	1	3	0	0	0	53	1.01	71	0.75
Oc. (Mac) species	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0.04	71	0.03
Oc. (Mac) species 76	0	0	1	4	0	4	13	1	0	0	0	0	0	23	0.44	71	0.32
Oc. (Mac) tremulus	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0.02	71	0.01
Oc. (Och) vigilax	3	14	290	736	1456	427	60	49	11	3	1	45	31	3126	59.45	71	44.03
Tp. (Trp) magnesianus	0	0	0	0	0	3	3	0	2	4	0	0	0	12	0.23	71	0.17
Trap failure mosquitoes	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0.00	71	0.00
Ve. (Ver) funerea	0	0	0	10	0	78	116	10	1	0	0	0	0	215	4.09	71	3.03
Ve. (Ver) reesi	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0.02	71	0.01
Totals	7	14	296	762	1499	1220	607	106	39	143	5	332	228	5258	100.00	71	74.06
%	0.13	0.27	5.63	14.49	28.51	23.20	11.54	2.02	0.74	2.72	0.10	6.31	4.34	100.00			
No. of traps	6	6	6	5	6	6	6	3	3	6	6	6	6	71			
Average per trap	1.17	2.33	49.33	152.40	249.83	203.33	101.17	35.33	13.00	23.83	0.83	55.33	38.00	74.06			

Appendix 1

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
C. ornatus	Dry season – breeds between Mean Low Water Neap (MLWN) and MHWN tide mark extensive areas of mangroves with mud substrates. Breeds in highest numbers at creek-bank habitats around Mean High Water Neap (MHWN) in association with *Avicennia* pneumatophores. Breeds in *Sonneratia* foreshore habitats associated with mud substrates. Wet season – breeds in transitional *Ceriops* zone just below Mean High Water Spring (MHWS) at back edge of creek-bank forest, and *Rhizophora* transitional zone adjacent to *Sonneratia* 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.
C. undescribed species *(Ornatus grp) No. 6 (Dyce) (formerly C. sp. near hewitti)*	Upper estuary, freshwater influenced extensive mangrove areas. Breeds in highest numbers just below MHWS.	Crepuscular. Rarely bites people.
C. marksi	Breeds in the margins of freshwater lakes and streams.	Crepuscular to diurnal; feeds on cattle and occasionally bites people; a minor pest at times.
C. narrabeenensis	Breeds at edge of fresh water.	Rarely bites people.
C. undescribed species (Victoriae grp) No. 42 (Dyce) (formerly C. ?pangkorensis)	Upper estuary.	Occasionally bites people.
C. pallidothorax	Breeds near fresh water.	NT species, rarely bites people.
C. flumineus	Similar to *C. ornatus* but at a lower level on creek banks of small upper tidal tributaries. Also breeds in crab burrows on creek banks.	Readily bites people but rarely encountered out of mangroves.
C. undescribed sp. (near *C. immaculatus*)	Possibly breeds below neap tide zone in mangrove creeks. Spring tide species.	Relatively common in lower reaches of mangrove creeks and bites viciously.

Species	Larval Ecology	Adult Ecology
C. immaculatus	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.
C. ?subimmaculatus (northern form)	Maritime sands in wave sheltered areas often with small crabs between neap and spring tide zone.	Crepuscular. A minor to moderate pest. Bites man readily near breeding sites. Pest range generally up to 0.5 km.

Adapted from information by Allan Dyce and pers. comm. 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
C. ornatus	The major human pest species within 2km of mangroves at coast. High localised populations all year round, with maximum numbers occurring in August to November and minimum in the wet season.
C. undescribed species *(Ornatus grp) No. 6 (Dyce) (formerly C. sp. near hewitti)*	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.
C. marksi	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.
C. narrabeenensis	A minor species with peak numbers in the early to mid dry season.
C. undescribed species *(Victoriae grp) No. 42 (Dyce) (formerly C. ?pangkorensis)*	A minor species. Peak numbers in mid wet season.
C. pallidothorax	A minor species. Peak populations during the early to mid wet season.
C. flumineus	An important pest species with high numbers inside mangroves only. Peaks in late dry season, early wet season.
C. undescribed sp. (near *C. immaculatus*)	A serious pest in lower reaches of mangrove creeks
C. immaculatus	A minor to rare species near rock-sand or sandy beaches only. Peak numbers in mid to late dry and early wet season.
C. ?subimmaculatus *(northern form)*	An important pest species. Moderate numbers near favoured wave-sheltered breeding sites only. Peak numbers in mid dry season tapering to late dry season.

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

Appendix 2

Personal protection from mosquitoes & biting midges in the NT

Medical Entomology
Centre for Disease Control
Department of Health and Families
Northern Territory Government
August 2009

Personal protection from mosquitoes & biting midges in the NT

P. I. Whelan
Department of Health and Families
August 2009

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 MOSQUITOES AND BITING MIDGE BITES

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

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

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

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

The place of feeding by mosquitoes or biting midges is varied. Some species, such as the brown house mosquito, readily entering houses to feed on people, while others will only bite people outdoors.

When a mosquito or biting midge bites, fine stylets sheathed in the proboscis are inserted into small capillaries in the skin. Blood is sucked up through one of the channels in the stylets, while saliva is injected down an adjacent channel. This saliva contains histamine like substances that the human body recognises as foreign and often stimulates a bite reaction. Sometimes the saliva can contain viruses or other pathogens that can cause disease.

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

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

2.0 MOSQUITO & BITING MIDGE AVOIDANCE

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

The upper high tide areas near creeks or low-lying areas, particularly near salt marsh habitats, can be significant sources of northern salt marsh mosquitoes (particularly *Aedes vigilax* and various other pest mosquitoes. The period of high salt marsh mosquito activity is usually during the late dry season and early wet season in tropical latitudes. Generally they are prevalent for one to two weeks after the highest tides of the month or 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 with small dendritic creeks or estuarine areas with muddy banks are potential sources of mangrove biting midges. These midges have seasonal and monthly population peaks with the monthly peaks usually associated with the tidal regime. When camping or choosing a permanent living site, a separation distance of at least 2 km from these areas is recommended unless specific biting insect investigations indicate there are no seasonal pest problems (Whelan 1990, Whelan, Hayes et al., 1997).

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

In residential areas, a local source of mosquitoes may be the cause of the problem. Check nearby potential artificial sources of mosquitoes such as disused swimming pools, receptacles such as tyres 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 concentrations of DEET greater than 20%. 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.

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

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 repellent effects as smoke or liniments (see Section 12, emergency biting insect protection).

7.0 ANIMAL DIVERSION

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

8.0 LIGHTING DIVERSION

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

9.0 ADULT INSECT CONTROL

If mosquitoes or biting midges have entered a screened area 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, bioresmethrin or pyrethrum. Control relies on good access, open vegetation, and light breezes in the direction of the breeding or harbouring sites. Application should only be during the peak biting insect activity period of those insects actually causing the problem, which is usually the late evening and early night.

There are some synthetic pyrethroid aerosol products available as outdoor yard or patio repellents. Control 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 to a few weeks) 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 up to 6 weeks protection (Standfast et al 2003). These residual insecticides can be applied according to label recommendations with the aid of a garden sprayer for walls and solid surfaces and back pack mechanical misters for vegetation screens. 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, Medicreme, Katers lotion, Dermocaine and Paraderm creme, and non-proprietary products such as paw paw ointment, tea tree oil, eucalyptus oil, aloe vera gel, ice, or methylated spirits.

Ice packs to the general bite site will give usually give immediate relief for painful and itchy bites and swelling or blisters from of mosquitoes and biting midges in particular. The sooner the ice pack is applied after bites or reactions, the better the relief, and can often avoid more intense reactions. Some people have had good results from the application of paw paw ointment following bite reactions in the reducing the itching and aiding the healing process.

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

12.0 EMERGENCY BITING INSECT PROTECTION

There are a number of emergency measures that can be taken when exposed to biting insects with no protection. Sheltering downwind next to smoky fires can offer considerable protection. Burning dung or aromatic and oil producing foliage from plants such as *Hyptis* (horehound), *Vitex* (black plum), *Calytrix* (turkey bush), *Melaleuca* species (paperbark) 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, warnulpu, paperbarks or tea-trees that contain volatile oils. However these are not as efficient as proprietary repellents containing DEET or picaridin. Other emergency protection measures include coating the skin with mud, or burying yourself in shallow sand with some form of head protection. If all else fails, keep running. The best forms of protection, and the most comfortable, require an awareness of the potential problems and adequate preparation.

References

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

An electronic version is available at:
http://www.health.nt.gov.au/Medical_Entomology/Publications/index.aspx

General enquiries about this publication should be directed to:
Peter Whelan, Medical Entomology
Department of Health and Families
PO Box 40596, Casuarina, NT 0811
XPhone: (08) 8999 8901
XFacsimile: (08) 8999 8820

Appendix 3

Biting Midge Pest Calendar for the Coastal Top End NT 2008

Peter Whelan and Nina Kurucz
Medical Entomology
Centre for Disease Control
Department of Health and Families
Northern Territory Government

Biting Midge Pest Periods in the Coastal Top End of the NT.

The mangrove biting midge, *Culicoides ornatus,* causes widespread pest problems around the coast of northern Australia. Areas mostly affected are extensive coastal and tidal river mangrove areas, and adjacent areas up to 2km inland from these areas. Primary breeding sites are the upper neap tide level of the mud banks of the upper reaches of small tidal creeks to the limit where the canopy closes over, and are associated with mud and *Rhizophora* and *Avicennia* mangrove pneumatophores. The more of these small mangrove creeks in an area (eg dendrite patterns of creeks) the more area of prime biting midge breeding, and the greater potential for severe pest problems. Less productive breeding sites include the muddy foreshore areas with wide and extensive areas of the woodland mangrove species *Sonneratia* present. Biting midge abundance varies greatly during the month, with highest numbers occurring around the time of the full moon and to a lesser extent around the new moon.

Biting midge numbers also vary during the year with relatively low numbers during the wet season, an increase from April to August, and highest numbers occurring between August and November. The increase in numbers each month coincides with the increase in the highest tide levels each month from the mid to late dry season.

Biting midge numbers exceeding 1000 *C. ornatus* in one CO_2 baited EVS trap per night is considered a high pest problem, with numbers exceeding 5000 per trap night indicating a severe pest problem. High primary peaks of biting midges can be expected between August and November around the full moon, with average numbers within 1.5km of extensive areas of mangroves with primary breeding sites of 15 000 to 25 000 per trap night, and high secondary peaks of 5000 to 15 000 around the new moon. Moderate primary peaks of 1000 to 5000 can be expected between December and July around the full moon, and moderate secondary peaks of 300 to 1000 around the new moon. Areas of mangroves with less prime breeding sites will experience lower pest levels.

Biting midges do not transmit diseases to humans but scratching of the bites may lead to secondary bacterial infection. *Culicoides ornatus* bite in the highest numbers in the hour before and after sunrise, and the hour before and after sunset. However, bites can also occur at other times and during the day in or adjacent to their primary breeding sites. Personal protection, such as full-length trousers, long sleeved shirts, socks and shoes, and the use of insect repellents containing DEET or Picaridin will generally be required at their prime pest times to provide protection from biting midges within 1.5 km of their prime breeding sites.

This calendar shows periods when high numbers of *C. ornatus* are expected in the Darwin area in relation to tides in Darwin Harbour and moon phases. Highest numbers will start 2–3 days before the full/new moon and last until 2–3 days after the full/new moon. Pest periods will occur in other areas around the NT coast at the same periods. The period of least *C. ornatus* biting activity is in the 9–4 days preceding full or new moons.

High pest period (August to November)

Highest primary peaks of *C. ornatus* (Full moon) (Pest rank 1)

Days highlighted in red indicate expected highest primary peaks of the pest biting midge *Culicoides ornatus* within 1.5km of extensive prime breeding sites. These extremely high biting midge pest levels can occur in the late dry season (August to November) in the days around the full moon and present a very high to severe pest problem.

High secondary peaks of *C. ornatus* (New moon) (Pest rank 2)

Days highlighted in orange indicate expected high secondary peaks of the pest biting midge *Culicoides ornatus* within 1.5km of extensive areas of prime breeding sites. These high biting midge levels can occur in the late dry season (August to November) in the days around the new moon. *Culocoides ornatus* numbers are slightly lower compared to the numbers during the primary peaks in those months but still present a high to very high pest problem.

Moderate pest period (December to July)

Moderate primary peaks of *C. ornatus* (Full moon) (Pest rank 3)

Days highlighted in yellow indicate expected moderate primary peaks of the pest biting midge *Culicoides ornatus* within 1.5km of prime breeding sites. These moderate biting midge pest levels can occur in December to July around the full moon, with highest levels around December.

Moderate to low secondary peaks of *C. ornatus* (New moon) (Pest rank 4)

Days highlighted in blue indicate expected moderate secondary peaks of the pest biting midge *Culicoides ornatus* within 1.5km of prime breeding sites. These moderate to low biting midge pest levels can occur in December to July around the new moon, with highest levels around December.

For more information on biting midges or personal protection, please contact:
Medical Entomology, CDC, DHF Darwin on (08) 89228901

Biting Midge Pest Calendar for the Coastal Top End of the NT

AUSTRALIA, NORTH COAST – DARWIN 2008

LAT 12° 28' S LONG 130° 51' E

TIMES AND HEIGHTS OF HIGH AND LOW WATERS

TIME ZONE –0930

JANUARY

Date	Day	Time	m
1	TU	0610 1159 1726 2337	2.69 5.07 3.59 5.81
2	WE	0703 1319 1843	2.72 4.93 4.04
3	TH	0022 0806 1514 2018	5.41 2.66 5.13 4.25
4	FR	0134 0915 1630 2204	5.12 2.49 5.59 4.14
5	SA	0302 1015 1718 2313	5.06 2.21 6.04 3.87
6	SU	0404 1102 1757 2352	5.23 1.91 6.42 3.60
7	MO	0449 1144 1832	5.49 1.61 6.73
8	TU ●	0023 0530 1220 1906	3.35 5.79 1.35 6.98
9	WE	0053 0607 1255 1939	3.11 6.07 1.16 7.17
10	TH	0125 0645 1328 2011	2.88 6.29 1.06 7.30
11	FR	0159 0723 1359 2040	2.67 6.43 1.08 7.36
12	SA	0236 0802 1429 2107	2.48 6.48 1.23 7.33
13	SU	0315 0845 1459 2133	2.32 6.43 1.52 7.21
14	MO	0356 0931 1530 2200	2.21 6.28 1.96 6.99
15	TU	0439 1023 1606 2228	2.14 6.05 2.52 6.68
16	WE ◑	0526 1123 1651 2300	2.13 5.76 3.15 6.30
17	TH	0618 1235 1758 2341	2.15 5.52 3.78 5.87
18	FR	0729 1417 1942	2.15 5.49 4.19
19	SA	0048 0858 1606 2134	5.46 2.01 5.90 4.16
20	SU	0241 1018 1716 2301	5.32 1.68 6.48 3.80
21	MO	0408 1121 1810	5.57 1.28 6.99
22	TU ○	0002 0510 1214 1856	3.32 5.97 0.95 7.39
23	WE	0050 0603 1258 1935	2.86 6.35 0.75 7.65
24	TH	0132 0653 1336 2010	2.46 6.63 0.74 7.75
25	FR	0212 0740 1412 2040	2.15 6.77 0.92 7.71
26	SA	0248 0822 1442 2106	1.96 6.74 1.28 7.53
27	SU	0324 0901 1507 2128	1.90 6.57 1.77 7.25
28	MO	0357 0938 1524 2145	1.95 6.27 2.31 6.89
29	TU	0428 1015 1536 2202	2.09 5.92 2.85 6.47
30	WE ◐	0500 1057 1557 2222	2.29 5.53 3.42 5.99
31	TH	0538 1150 1636 2244	2.53 5.15 4.00 5.47

FEBRUARY

Date	Day	Time	m
1	FR	0631 1314 1845 2310	2.76 4.90 4.48 4.96
2	SA	0750 1628 2305	2.88 5.18 4.49
3	SU	0200 0934 1712 2336	4.61 2.74 5.69 4.08
4	MO	0349 1047 1745 2359	4.86 2.36 6.16 3.70
5	TU	0443 1135 1818	5.29 1.92 6.59
6	WE	0022 0525 1214 1850	3.33 5.76 1.52 6.99
7	TH ●	0049 0605 1248 1921	2.93 6.21 1.20 7.33
8	FR	0120 0645 1319 1950	2.51 6.60 1.01 7.56
9	SA	0152 0725 1348 2015	2.11 6.90 0.99 7.67
10	SU	0225 0803 1415 2037	1.75 7.06 1.14 7.65
11	MO	0259 0843 1442 2059	1.48 7.08 1.47 7.51
12	TU	0333 0925 1511 2120	1.36 6.94 1.96 7.24
13	WE	0410 1009 1541 2144	1.40 6.62 2.58 6.84
14	TH ◑	0448 1059 1615 2209	1.61 6.16 3.27 6.33
15	FR	0534 1202 1710 2243	1.96 5.64 3.97 5.73
16	SA	0641 1348 1918 2345	2.34 5.33 4.48 5.09
17	SU	0838 1610 2210	2.48 5.71 4.24
18	MO	0304 1021 1715 2328	4.94 2.16 6.32 3.60
19	TU	0431 1126 1800	5.46 1.70 6.86
20	WE	0012 0530 1213 1840	2.98 6.04 1.32 7.29
21	TH ○	0048 0618 1250 1913	2.44 6.54 1.09 7.57
22	FR	0121 0700 1322 1942	1.99 6.90 1.05 7.69
23	SA	0152 0738 1351 2005	1.65 7.09 1.19 7.66
24	SU	0221 0812 1415 2024	1.46 7.11 1.49 7.51
25	MO	0249 0844 1435 2041	1.40 6.98 1.89 7.26
26	TU	0315 0914 1450 2057	1.46 6.73 2.34 6.93
27	WE	0341 0944 1503 2113	1.65 6.40 2.81 6.51
28	TH	0409 1017 1519 2128	1.94 6.00 3.32 6.02
29	FR ◐	0442 1059 1538 2137	2.32 5.54 3.85 5.49

MARCH

Date	Day	Time	m
1	SA	0528 1158 1556 2136	2.74 5.10 4.39 5.00
2	SU	0640 1630	3.09 4.93
3	MO	0839 1652 2331	3.13 5.45 4.04
4	TU	0345 1025 1718 2337	4.70 2.72 5.97 3.59
5	WE	0436 1115 1747 2359	5.29 2.20 6.48 3.08
6	TH	0518 1154 1817	5.90 1.73 6.95
7	FR	0026 0600 1229 1846	2.52 6.49 1.37 7.35
8	SA ●	0057 0640 1300 1914	1.94 7.00 1.17 7.61
9	SU	0129 0720 1328 1937	1.40 7.38 1.17 7.72
10	MO	0200 0758 1356 1958	0.98 7.59 1.35 7.69
11	TU	0233 0835 1424 2020	0.73 7.59 1.70 7.52
12	WE	0307 0914 1454 2045	0.71 7.37 2.20 7.19
13	TH	0343 0956 1526 2110	0.95 6.93 2.81 6.70
14	FR ◑	0422 1043 1601 2138	1.41 6.34 3.47 6.07
15	SA	0509 1145 1701 2214	2.02 5.71 4.11 5.35
16	SU	0622 1332 1954	2.61 5.33 4.39
17	MO	0019 0832 1552 2230	4.66 2.84 5.66 3.79
18	TU	0339 1017 1651 2316	5.04 2.51 6.20 3.10
19	WE	0443 1115 1733 2353	5.69 2.09 6.67 2.49
20	TH	0532 1156 1808	6.29 1.78 7.03
21	FR	0025 0614 1230 1836	1.99 6.76 1.61 7.25
22	SA ○	0054 0651 1258 1900	1.59 7.08 1.58 7.34
23	SU	0121 0724 1324 1920	1.30 7.26 1.68 7.32
24	MO	0147 0755 1346 1938	1.13 7.28 1.89 7.21
25	TU	0213 0824 1407 1956	1.09 7.18 2.17 7.02
26	WE	0238 0851 1428 2015	1.18 6.98 2.51 6.72
27	TH	0304 0919 1447 2035	1.41 6.68 2.89 6.33
28	FR	0333 0950 1508 2052	1.77 6.30 3.31 5.87
29	SA	0407 1028 1531 2106	2.22 5.85 3.76 5.39
30	SU ◐	0450 1118 1622 2118	2.70 5.39 4.22 4.91
31	MO	0556 1243 1941 2107	3.10 5.07 4.42 4.44

APRIL

Date	Day	Time	m
1	TU	0736 1531 2223	3.26 5.27 3.92
2	WE	0316 0933 1620 2245	4.71 2.98 5.77 3.35
3	TH	0412 1035 1656 2315	5.36 2.52 6.28 2.71
4	FR	0458 1119 1728 2348	6.05 2.09 6.75 2.03
5	SA	0542 1157 1759	6.71 1.77 7.12
6	SU ●	0023 0625 1231 1826	1.37 7.28 1.60 7.37
7	MO	0057 0707 1303 1851	0.80 7.67 1.61 7.49
8	TU	0131 0746 1334 1917	0.42 7.85 1.78 7.46
9	WE	0206 0825 1407 1946	0.28 7.78 2.08 7.27
10	TH	0243 0905 1442 2018	0.42 7.48 2.51 6.89
11	FR	0323 0947 1521 2052	0.84 6.99 3.01 6.35
12	SA	0407 1036 1610 2132	1.46 6.40 3.54 5.67
13	SU ◑	0500 1139 1743 2241	2.16 5.83 3.96 4.97
14	MO	0619 1309 2010	2.77 5.51 3.85
15	TU	0150 0809 1454 2148	4.75 3.01 5.63 3.25
16	WE	0327 0945 1601 2239	5.26 2.85 5.97 2.65
17	TH	0426 1043 1645 2317	5.83 2.59 6.30 2.14
18	FR	0514 1126 1720 2350	6.33 2.38 6.54 1.73
19	SA	0555 1200 1747	6.73 2.25 6.70
20	SU ○	0018 0631 1230 1811	1.41 7.02 2.20 6.78
21	MO	0045 0705 1256 1832	1.17 7.18 2.23 6.80
22	TU	0111 0736 1320 1856	1.04 7.21 2.32 6.74
23	WE	0137 0804 1345 1920	1.02 7.14 2.48 6.61
24	TH	0205 0831 1409 1946	1.13 6.97 2.68 6.38
25	FR	0236 0900 1436 2013	1.37 6.72 2.94 6.07
26	SA	0308 0932 1506 2039	1.72 6.41 3.25 5.69
27	SU	0345 1010 1544 2110	2.14 6.05 3.59 5.28
28	MO ◐	0428 1057 1649 2200	2.56 5.69 3.90 4.87
29	TU	0526 1202 1849 2355	2.93 5.43 3.96 4.58
30	WE	0644 1329 2040	3.14 5.39 3.58

 Bureau of Meteorology National Tidal Centre

Datum of Predictions is Lowest Astronomical Tide

Moon Symbols ● New Moon ◑ First Quarter ○ Full Moon ◐ Last Quarter

High Pest Periods

- Red: Highest primary peaks of *C. ornatus* (Full moon) (Pest rank 1)
- Orange: High secondary peaks of *C. ornatus* (New moon) (Pest rank 2)

Moderate Pest Periods

- Yellow: Moderate primary peaks of *C. ornatus* (Full moon) (Pest rank 3)
- Light blue: Moderate to low secondary peaks of *C. ornatus* (New moon) (Pest rank 4)

* This Calendar has been produced by Medical Entomology Northern Territory, using the Tidal Tables template with the authorisation of the Bureau of Meteorology. All highlights pertaining to the biting midge, *Culicoides ornatus,* are additions made by Medical Entomology.

Biting Midge Pest Calendar for the Coastal Top End of the NT

AUSTRALIA, NORTH COAST – DARWIN **2008**

LAT 12° 28′ S LONG 130° 51′ E

TIMES AND HEIGHTS OF HIGH AND LOW WATERS TIME ZONE –0930

MAY

Date	Day	Time	m	Time	m	Time	m	Time	m
1	TH	0213	4.84	0817	3.11	1450	5.64	2139	2.98
2	FR	0329	5.44	0936	2.86	1545	6.01	2224	2.30
3	SA	0426	6.11	1032	2.57	1627	6.38	2305	1.61
4	SU	0516	6.76	1119	2.33	1703	6.69	2345	0.97
5	MO ●	0605	7.29	1200	2.18	1737	6.93		
6	TU	0024	0.49	0651	7.64	1238	2.15	1811	7.06
7	WE	0103	0.21	0734	7.77	1315	2.22	1846	7.06
8	TH	0144	0.19	0816	7.67	1355	2.39	1925	6.89
9	FR	0226	0.44	0900	7.39	1437	2.65	2006	6.54
10	SA	0311	0.91	0945	6.97	1527	2.96	2052	6.05
11	SU	0400	1.53	1032	6.51	1631	3.25	2152	5.49
12	MO ◑	0457	2.18	1128	6.08	1800	3.37	2326	5.04
13	TU	0605	2.74	1230	5.77	1930	3.20		
14	WE	0122	5.00	0724	3.09	1342	5.64	2048	2.82
15	TH	0247	5.30	0845	3.20	1448	5.68	2147	2.41
16	FR	0353	5.71	0954	3.14	1542	5.80	2231	2.03
17	SA	0445	6.11	1046	3.01	1623	5.92	2308	1.72
18	SU	0530	6.46	1128	2.87	1656	6.04	2340	1.47
19	MO	0611	6.73	1202	2.76	1726	6.14		
20	TU ○	0009	1.27	0646	6.90	1231	2.69	1756	6.21
21	WE	0039	1.16	0718	6.96	1259	2.67	1826	6.24
22	TH	0109	1.14	0748	6.92	1326	2.68	1857	6.21
23	FR	0142	1.21	0818	6.82	1354	2.75	1929	6.11
24	SA	0215	1.39	0848	6.67	1427	2.87	2001	5.93
25	SU	0250	1.64	0921	6.47	1503	3.03	2037	5.68
26	MO	0327	1.95	0957	6.26	1548	3.20	2120	5.40
27	TU	0408	2.28	1038	6.03	1650	3.32	2219	5.13
28	WE ◐	0457	2.62	1126	5.83	1807	3.28	2342	4.99
29	TH	0559	2.92	1222	5.69	1925	3.00		
30	FR	0113	5.11	0713	3.12	1325	5.65	2032	2.53
31	SA	0237	5.50	0831	3.16	1428	5.74	2130	1.96

JUNE

Date	Day	Time	m	Time	m	Time	m	Time	m
1	SU	0350	6.04	0943	3.06	1525	5.93	2222	1.39
2	MO	0452	6.59	1043	2.89	1615	6.16	2311	0.88
3	TU	0548	7.06	1133	2.72	1700	6.40	2358	0.50
4	WE ●	0639	7.37	1219	2.58	1744	6.57		
5	TH	0044	0.31	0728	7.52	1305	2.49	1830	6.65
6	FR	0130	0.32	0813	7.49	1351	2.45	1916	6.58
7	SA	0217	0.55	0856	7.33	1441	2.48	2006	6.38
8	SU	0304	0.95	0938	7.06	1535	2.55	2101	6.05
9	MO	0352	1.48	1019	6.74	1634	2.62	2205	5.69
10	TU	0441	2.08	1101	6.37	1736	2.66	2316	5.37
11	WE ◑	0532	2.65	1144	6.00	1840	2.64		
12	TH	0031	5.18	0630	3.14	1230	5.67	1943	2.54
13	FR	0151	5.18	0735	3.48	1325	5.41	2044	2.36
14	SA	0309	5.38	0851	3.60	1429	5.27	2138	2.16
15	SU	0415	5.71	1006	3.53	1529	5.28	2224	1.93
16	MO	0508	6.06	1103	3.35	1616	5.39	2304	1.71
17	TU	0552	6.34	1145	3.15	1656	5.55	2342	1.52
18	WE	0630	6.55	1217	2.98	1732	5.73		
19	TH ○	0017	1.37	0706	6.67	1245	2.84	1807	5.89
20	FR	0053	1.27	0738	6.74	1315	2.73	1843	6.01
21	SA	0127	1.25	0810	6.75	1346	2.65	1918	6.06
22	SU	0201	1.30	0840	6.73	1422	2.61	1956	6.03
23	MO	0235	1.44	0910	6.67	1501	2.59	2036	5.93
24	TU	0309	1.66	0940	6.57	1546	2.59	2121	5.78
25	WE	0345	1.96	1011	6.41	1636	2.56	2215	5.61
26	TH ◐	0426	2.33	1045	6.20	1729	2.49	2318	5.47
27	FR	0515	2.76	1123	5.94	1826	2.35		
28	SA	0030	5.42	0618	3.17	1211	5.68	1930	2.13
29	SU	0150	5.52	0737	3.46	1313	5.48	2039	1.83
30	MO	0320	5.83	0903	3.52	1430	5.44	2147	1.46

JULY

Date	Day	Time	m	Time	m	Time	m	Time	m
1	TU	0437	6.29	1019	3.35	1543	5.62	2249	1.07
2	WE	0539	6.73	1122	3.07	1643	5.91	2345	0.73
3	TH ●	0634	7.10	1215	2.74	1736	6.22		
4	FR	0037	0.52	0722	7.34	1306	2.44	1828	6.45
5	SA	0126	0.47	0806	7.45	1354	2.18	1919	6.55
6	SU	0211	0.60	0845	7.42	1441	1.99	2012	6.52
7	MO	0253	0.93	0919	7.26	1527	1.91	2103	6.35
8	TU	0332	1.42	0952	6.98	1613	1.93	2154	6.06
9	WE	0409	2.00	1020	6.60	1657	2.04	2245	5.72
10	TH ◑	0444	2.61	1047	6.17	1742	2.19	2338	5.37
11	FR	0522	3.18	1115	5.71	1830	2.34		
12	SA	0042	5.11	0620	3.66	1152	5.24	1927	2.43
13	SU	0208	5.05	0743	3.94	1259	4.83	2033	2.43
14	MO	0348	5.29	0933	3.92	1442	4.69	2143	2.28
15	TU	0453	5.67	1105	3.63	1554	4.86	2240	2.04
16	WE	0539	6.01	1147	3.33	1642	5.17	2328	1.77
17	TH	0618	6.30	1218	3.06	1722	5.50		
18	FR ○	0008	1.51	0653	6.55	1245	2.81	1759	5.82
19	SA	0045	1.30	0725	6.75	1313	2.56	1836	6.08
20	SU	0118	1.17	0756	6.90	1345	2.32	1914	6.27
21	MO	0149	1.13	0823	6.99	1418	2.11	1952	6.37
22	TU	0218	1.22	0848	6.99	1454	1.93	2032	6.38
23	WE	0248	1.43	0912	6.91	1531	1.81	2115	6.31
24	TH	0318	1.76	0935	6.73	1611	1.76	2202	6.15
25	FR	0353	2.22	1000	6.46	1653	1.78	2255	5.91
26	SA ◐	0435	2.76	1029	6.09	1739	1.86	2356	5.65
27	SU	0530	3.33	1105	5.66	1838	1.95		
28	MO	0115	5.46	0655	3.79	1202	5.22	2000	1.97
29	TU	0305	5.57	0846	3.89	1355	4.96	2132	1.76
30	WE	0434	6.04	1024	3.57	1543	5.22	2246	1.38
31	TH	0536	6.55	1132	3.06	1649	5.70	2345	0.99

AUGUST

Date	Day	Time	m	Time	m	Time	m	Time	m
1	FR ●	0628	7.00	1224	2.54	1744	6.18		
2	SA	0035	0.71	0711	7.33	1307	2.06	1836	6.57
3	SU	0118	0.61	0747	7.51	1347	1.67	1925	6.80
4	MO	0156	0.72	0819	7.52	1426	1.41	2010	6.84
5	TU	0230	1.03	0847	7.37	1502	1.31	2051	6.70
6	WE	0301	1.50	0911	7.09	1537	1.37	2130	6.42
7	TH	0327	2.06	0930	6.71	1610	1.56	2209	6.05
8	FR	0346	2.63	0947	6.26	1643	1.85	2250	5.64
9	SA ◑	0409	3.19	1006	5.74	1720	2.18	2339	5.24
10	SU	0458	3.72	1029	5.18	1811	2.50		
11	MO	0048	4.93	0636	4.14	1057	4.62	1925	2.72
12	TU	0325	4.96	1100	4.10	1404	4.26	2104	2.67
13	WE	0445	5.40	1127	3.67	1553	4.60	2226	2.36
14	TH	0525	5.83	1148	3.29	1641	5.07	2316	1.97
15	FR	0558	6.22	1210	2.93	1719	5.55	2357	1.60
16	SA	0630	6.58	1233	2.56	1756	6.00		
17	SU ○	0031	1.30	0700	6.90	1300	2.16	1833	6.39
18	MO	0102	1.11	0728	7.13	1330	1.77	1911	6.69
19	TU	0131	1.07	0752	7.25	1401	1.43	1947	6.87
20	WE	0158	1.17	0814	7.25	1433	1.18	2025	6.93
21	TH	0225	1.42	0833	7.15	1507	1.06	2104	6.84
22	FR	0254	1.82	0855	6.92	1542	1.11	2146	6.60
23	SA	0327	2.34	0918	6.56	1620	1.32	2234	6.22
24	SU ◐	0404	2.95	0944	6.08	1704	1.67	2331	5.75
25	MO	0458	3.58	1016	5.51	1804	2.07		
26	TU	0054	5.36	0639	4.07	1112	4.88	1945	2.32
27	WE	0307	5.46	0915	3.96	1433	4.64	2136	2.11
28	TH	0431	5.98	1050	3.34	1607	5.23	2249	1.67
29	FR	0525	6.53	1139	2.67	1705	5.89	2342	1.27
30	SA	0608	6.98	1218	2.06	1755	6.46		
31	SU ●	0024	1.02	0645	7.29	1254	1.55	1839	6.88

 Bureau of Meteorology National Tidal Centre

Datum of Predictions is Lowest Astronomical Tide

Moon Symbols ● New Moon ◑ First Quarter ○ Full Moon ◐ Last Quarter

High Pest Periods

Highest primary peaks of *C. ornatus* (Full moon) (Pest rank 1)

High secondary peaks of *C. ornatus* (New moon) (Pest rank 2)

Moderate Pest Periods

Moderate primary peaks of *C. ornatus* (Full moon) (Pest rank 3)

Moderate to low secondary peaks of *C. ornatus* (New moon) (Pest rank 4)

* This Calendar has been produced by Medical Entomology Northern Territory, using the Tidal Tables template with the authorisation of the Bureau of Meteorology. All highlights pertaining to the biting midge, *Culicoides ornatus,* are additions made by Medical Entomology.

Biting Midge Pest Calendar for the Coastal Top End of the NT

AUSTRALIA, NORTH COAST – DARWIN

2008

LAT 12° 28' S LONG 130° 51' E

TIMES AND HEIGHTS OF HIGH AND LOW WATERS

TIME ZONE –0930

SEPTEMBER

		Time	m		
1	MO	0100 0715 1327 1920	0.95 7.45 1.17 7.10		Orange (Pest rank 2)
2	TU	0131 0742 1359 1957	1.08 7.44 0.95 7.14		Orange (Pest rank 2)
3	WE	0200 0802 1429 2031	1.36 7.29 0.90 7.00		Orange (Pest rank 2)
4	TH	0225 0821 1457 2104	1.77 7.03 1.02 6.73		
5	FR	0245 0839 1524 2136	2.23 6.68 1.28 6.37		
6	SA	0303 0856 1552 2211	2.72 6.23 1.65 5.94		
7	SU	0323 0914 1626 2252	3.21 5.71 2.11 5.49	First Quarter	
8	MO	0353 0926 1715 2350	3.72 5.14 2.59 5.06		
9	TU	0534 0919 1830	4.19 4.61 2.97		
10	WE	0139 1138 1336 2023	4.84 4.03 4.06 3.02		
11	TH	0419 1110 1556 2201	5.25 3.61 4.58 2.67		
12	FR	0452 1120 1634 2253	5.72 3.17 5.17 2.22		Red (Pest rank 1)
13	SA	0522 1140 1709 2332	6.17 2.70 5.76 1.81		Red (Pest rank 1)
14	SU	0551 1205 1745	6.59 2.18 6.31		Red (Pest rank 1)
15	MO	0006 0620 1233 1823	1.49 6.95 1.65 6.80	Full Moon	Red (Pest rank 1)
16	TU	0038 0646 1304 1900	1.31 7.21 1.16 7.16		Red (Pest rank 1)
17	WE	0106 0710 1334 1937	1.28 7.33 0.77 7.38		Red (Pest rank 1)
18	TH	0134 0731 1406 2014	1.41 7.33 0.54 7.41		Red (Pest rank 1)
19	FR	0202 0754 1439 2052	1.68 7.20 0.53 7.25		
20	SA	0234 0818 1515 2132	2.09 6.91 0.74 6.90		
21	SU	0310 0845 1554 2220	2.62 6.47 1.18 6.38		
22	MO	0350 0915 1642 2318	3.21 5.89 1.77 5.82	Last Quarter	
23	TU	0453 0953 1751	3.79 5.20 2.37		
24	WE	0046 0709 1134 1945	5.41 4.07 4.51 2.67		
25	TH	0251 0943 1511 2133	5.53 3.57 4.83 2.44		
26	FR	0406 1040 1615 2238	6.00 2.84 5.56 2.06		Orange (Pest rank 2)
27	SA	0455 1120 1706 2325	6.46 2.17 6.22 1.76		Orange (Pest rank 2)
28	SU	0533 1156 1750	6.81 1.61 6.74		Orange (Pest rank 2)
29	MO	0002 0606 1228 1830	1.59 7.05 1.18 7.10	New Moon	Orange (Pest rank 2)
30	TU	0034 0632 1257 1906	1.57 7.15 0.87 7.28		Orange (Pest rank 2)

OCTOBER

		Time	m		
1	WE	0103 0654 1325 1939	1.67 7.14 0.72 7.30		Orange (Pest rank 2)
2	TH	0130 0715 1351 2010	1.87 7.02 0.73 7.17		
3	FR	0154 0736 1417 2040	2.16 6.81 0.89 6.93		
4	SA	0216 0758 1444 2109	2.49 6.50 1.19 6.61		
5	SU	0240 0819 1513 2141	2.86 6.10 1.61 6.22		
6	MO	0305 0841 1546 2219	3.26 5.62 2.11 5.78		
7	TU	0339 0858 1633 2311	3.68 5.10 2.64 5.36	First Quarter	
8	WE	0458 0909 1745	4.08 4.59 3.09		
9	TH	0029 1029 1212 1927	5.07 4.09 4.11 3.25		
10	FR	0242 1008 1529 2111	5.18 3.58 4.61 3.02		
11	SA	0349 1030 1609 2212	5.60 3.04 5.26 2.64		
12	SU	0426 1057 1646 2255	6.03 2.45 5.92 2.26		Red (Pest rank 1)
13	MO	0459 1127 1726 2333	6.45 1.82 6.55 1.98		Red (Pest rank 1)
14	TU	0530 1159 1806	6.79 1.21 7.10		Red (Pest rank 1)
15	WE	0007 0558 1231 1845	1.81 7.04 0.69 7.50	Full Moon	Red (Pest rank 1)
16	TH	0040 0624 1304 1925	1.78 7.18 0.33 7.70		Red (Pest rank 1)
17	FR	0112 0651 1339 2002	1.89 7.19 0.18 7.69		Red (Pest rank 1)
18	SA	0145 0721 1415 2043	2.11 7.05 0.29 7.46		Red (Pest rank 1)
19	SU	0222 0754 1453 2125	2.45 6.75 0.66 7.06		
20	MO	0303 0830 1537 2214	2.88 6.27 1.25 6.54		
21	TU	0354 0911 1630 2314	3.34 5.65 1.95 6.02	Last Quarter	
22	WE	0516 1013 1745	3.71 4.96 2.59		
23	TH	0030 0723 1300 1927	5.68 3.64 4.61 2.93		
24	FR	0201 0906 1458 2102	5.69 3.09 5.11 2.88		
25	SA	0315 1005 1601 2208	5.93 2.44 5.75 2.68		
26	SU	0406 1048 1651 2256	6.21 1.87 6.31 2.49		Orange (Pest rank 2)
27	MO	0445 1125 1734 2335	6.43 1.42 6.77 2.38		Orange (Pest rank 2)
28	TU	0517 1156 1814	6.58 1.09 7.08		Orange (Pest rank 2)
29	WE	0008 0545 1224 1849	2.32 6.66 0.87 7.25	New Moon	Orange (Pest rank 2)
30	TH	0037 0610 1251 1922	2.34 6.68 0.77 7.28		Orange (Pest rank 2)
31	FR	0105 0635 1317 1952	2.42 6.62 0.80 7.20		Orange (Pest rank 2)

NOVEMBER

		Time	m		
1	SA	0131 0702 1345 2020	2.56 6.49 0.95 7.01		Orange (Pest rank 2)
2	SU	0158 0730 1414 2050	2.74 6.27 1.23 6.76		
3	MO	0227 0759 1445 2121	2.97 5.97 1.61 6.45		
4	TU	0259 0828 1518 2158	3.24 5.59 2.06 6.12		
5	WE	0340 0900 1600 2243	3.53 5.17 2.54 5.79		
6	TH	0447 0947 1659 2341	3.78 4.73 2.99 5.53	First Quarter	
7	FR	0639 1134 1819	3.81 4.41 3.29		
8	SA	0054 0821 1404 1952	5.44 3.45 4.62 3.34		
9	SU	0210 0921 1523 2110	5.56 2.89 5.23 3.17		
10	MO	0311 1004 1615 2208	5.83 2.26 5.91 2.91		Red (Pest rank 1)
11	TU	0356 1045 1701 2256	6.14 1.60 6.58 2.68		Red (Pest rank 1)
12	WE	0435 1123 1746 2338	6.44 1.00 7.15 2.51		Red (Pest rank 1)
13	TH	0511 1200 1830	6.68 0.51 7.56	Full Moon	Red (Pest rank 1)
14	FR	0016 0545 1239 1914	2.41 6.85 0.20 7.76		Red (Pest rank 1)
15	SA	0055 0622 1317 1956	2.41 6.92 0.13 7.75		Red (Pest rank 1)
16	SU	0134 0701 1359 2039	2.49 6.83 0.30 7.56		Red (Pest rank 1)
17	MO	0218 0744 1442 2123	2.66 6.58 0.71 7.23		
18	TU	0308 0830 1529 2210	2.87 6.17 1.30 6.84		
19	WE	0409 0925 1622 2301	3.09 5.65 1.98 6.44		
20	TH	0528 1045 1727 2359	3.19 5.15 2.64 6.11	Last Quarter	
21	FR	0652 1237 1845	3.07 4.95 3.13		
22	SA	0100 0812 1415 2007	5.89 2.73 5.18 3.37		
23	SU	0205 0917 1531 2122	5.80 2.30 5.62 3.40		
24	MO	0303 1009 1630 2222	5.82 1.90 6.10 3.30		
25	TU	0352 1050 1717 2309	5.90 1.57 6.52 3.17		Orange (Pest rank 2)
26	WE	0431 1125 1759 2348	6.00 1.32 6.84 3.03		Orange (Pest rank 2)
27	TH	0505 1156 1835	6.09 1.14 7.04		Orange (Pest rank 2)
28	FR	0021 0538 1225 1909	2.93 6.16 1.04 7.13	New Moon	Orange (Pest rank 2)
29	SA	0050 0610 1255 1940	2.87 6.22 1.02 7.11		Orange (Pest rank 2)
30	SU	0117 0643 1325 2009	2.86 6.21 1.10 7.02		Orange (Pest rank 2)

DECEMBER

		Time	m		
1	MO	0146 0715 1356 2039	2.88 6.14 1.28 6.88		Orange (Pest rank 2)
2	TU	0218 0749 1428 2109	2.95 5.99 1.54 6.72		
3	WE	0256 0824 1459 2142	3.06 5.76 1.88 6.52		
4	TH	0340 0903 1532 2217	3.18 5.48 2.27 6.31		
5	FR	0435 0954 1614 2257	3.27 5.17 2.69 6.09		
6	SA	0543 1106 1713 2344	3.25 4.93 3.11 5.89	First Quarter	
7	SU	0654 1236 1829	3.06 4.91 3.45		
8	MO	0040 0802 1413 1954	5.74 2.69 5.20 3.62		
9	TU	0143 0906 1535 2115	5.69 2.19 5.76 3.57		
10	WE	0247 1001 1638 2219	5.78 1.63 6.39 3.40		Yellow (Pest rank 3)
11	TH	0345 1051 1731 2314	5.98 1.10 6.96 3.18		Yellow (Pest rank 3)
12	FR	0435 1138 1821	6.24 0.65 7.40		Yellow (Pest rank 3)
13	SA	0002 0522 1224 1909	2.96 6.49 0.35 7.67	Full Moon	Yellow (Pest rank 3)
14	SU	0048 0608 1308 1954	2.77 6.67 0.26 7.77		Yellow (Pest rank 3)
15	MO	0134 0656 1352 2036	2.62 6.72 0.38 7.72		Yellow (Pest rank 3)
16	TU	0223 0745 1437 2117	2.52 6.62 0.72 7.55		Yellow (Pest rank 3)
17	WE	0315 0838 1521 2157	2.48 6.38 1.24 7.27		
18	TH	0410 0936 1605 2235	2.48 6.03 1.89 6.92		
19	FR	0507 1041 1651 2314	2.50 5.64 2.58 6.52	Last Quarter	
20	SA	0606 1151 1744 2354	2.52 5.31 3.24 6.10		
21	SU	0708 1312 1851	2.50 5.15 3.75		
22	MO	0041 0815 1446 2015	5.72 2.41 5.28 4.02		
23	TU	0145 0919 1608 2146	5.43 2.24 5.67 3.99		
24	WE	0257 1015 1704 2258	5.32 2.02 6.11 3.78		Blue (Pest rank 4)
25	TH	0356 1100 1748 2345	5.39 1.78 6.48 3.52		Blue (Pest rank 4)
26	FR	0443 1139 1827	5.55 1.57 6.76		Blue (Pest rank 4)
27	SA	0021 0522 1213 1901	3.30 5.76 1.39 6.94	New Moon	Blue (Pest rank 4)
28	SU	0050 0558 1245 1933	3.12 5.97 1.26 7.04		Blue (Pest rank 4)
29	MO	0117 0633 1316 2002	2.96 6.13 1.21 7.09		Blue (Pest rank 4)
30	TU	0145 0709 1346 2030	2.84 6.23 1.25 7.10		Blue (Pest rank 4)
31	WE	0218 0745 1415 2056	2.73 6.23 1.39 7.06		

 Bureau of Meteorology **National Tidal Centre**

Datum of Predictions is Lowest Astronomical Tide

Moon Symbols ● **New Moon** ◑ **First Quarter** ○ **Full Moon** ◐ **Last Quarter**

High Pest Periods

- Red: Highest primary peaks of *C. ornatus* (Full moon) (Pest rank 1)
- Orange: High secondary peaks of *C. ornatus* (New moon) (Pest rank 2)

Moderate Pest Periods

- Yellow: Moderate primary peaks of *C. ornatus* (Full moon) (Pest rank 3)
- Light blue: Moderate to low secondary peaks of *C. ornatus* (New moon) (Pest rank 4)

* This Calendar has been produced by Medical Entomology Northern Territory, using the Tidal Tables template with the authorisation of the Bureau of Meteorology. All highlights pertaining to the biting midge, *Culicoides ornatus,* are additions made by Medical Entomology.