Northern Territory Government
Department of Health and Community Services

BITING INSECT REPORT
for the
DARWIN CITY WATERFRONT REDEVELOPMENT

April 2004

by
Allan Warchot & Peter Whelan
Department of Health & Community Services

Study undertaken on behalf of URS Australia Pty Ltd

For more information contact:

Allan Warchot
Medical Entomology Branch
Centre for Disease Control
Department of Health and Community Services
PO Box 40596
CASUARINA NT 0811

Telephone: (08) 8922 8337
Fax: (08) 8922 8820
Email: allan.warchot@nt.gov.au

CONTENTS

List of figures

List of tables

1.0 Objectives and Scope

1.1 Objectives

The objectives of the biting insect assessment of the proposed Darwin City Waterfront Redevelopment area is to outline actual and potential biting insect problems within the redevelopment area, and to provide mitigation strategies to prevent or minimise biting insect problems. As with most coastal areas in the NT, the proposed development area is potentially subject to mosquito and biting midge pest problems, and potential mosquito borne disease problems.

The objectives of the biting insect assessment were to;

1) Conduct a limited adult biting insect trapping survey to assess any potential biting midge problem in the redevelopment area. The trapping was to coincide with the peak seasonal abundance of biting midges and to assess the salt marsh mosquito numbers expected after a monthly spring tide.

2) Assess routine weekly Quarantine adult mosquito trap results from the port area nearest to the redevelopment area.

3) Conduct ground surveys to locate any actual and potential mosquito breeding sites.

4) Assess previous mosquito larval surveys in the redevelopment area to locate actual mosquito breeding sites.

5) Assess the location of biting midge breeding sites that may affect the redevelopment area.

6) Outline mitigation measures to reduce the current biting insect population and to avoid creating new mosquito breeding sites.

The outcome of the study was to provide information on the actual and potential biting insect problem in the redevelopment area.

Biting midges can be considerable pests within a few kilometres of the coast in the NT (Whelan 1991). These pests can affect the amenity of the area by causing direct effects due to their painful bites, and indirect effects due to secondary infection and loss of a sense of well being.

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

The results of the biting insect trapping, ground surveys and desktop assessments would be used to outline mitigation strategies to reduce the impact of biting insects in the proposed development area, and to prevent the future development of the area from exacerbating existing or creating new mosquito problems.

1.2 Scope

Sampling for adult biting midges in the proposed development area would be conducted for three nights around the full moon in early November. Sampling would be conducted using carbon dioxide (CO_2) baited encephalitis virus surveillance (EVS) type traps (Rohe & Fall 1979). Traps would be set between 1500 and 1800 hours and collected the following morning between 0800 and 1000 hours. The

timing of sampling was designed to monitor likely peak season numbers of the estuarine biting midge species *Culicoides ornatus.* High abundance of this species occurs in the late dry season (between August and November) (Shivas and Whelan 2001), although high early wet season rainfall can surpress numbers of this species. A desktop assessment would be made to locate potential sources of *C. ornatus* to the redevelopment area, using aerial photography and the biology of the species.

The timing of adult biting midge sampling would also coincide with peak abundance of the salt marsh mosquito *Ochlerotatus vigilax*, with the traps being set from 12 days after the October monthly high tide. Adult mosquitoes would be collected in the same traps used for adult biting midge sampling.

In addition to the three day trapping in November, an assessment would be made of the quarantine weekly routine adult mosquito trapping at the Grey Collar Club, which is located on the northwest boundary the proposed development area. This trapping would provide information on the seasonal abundance and diversity of mosquito species in the redevelopment area.

In addition to adult mosquito trapping, larval surveys would be conducted during the wet season to locate any actual and potential mosquito breeding sites. Information from previous surveys of certain sites in the proposed development area would also be used to highlight any particular mosquito breeding problem.

2.0 Acknowledgments

Adult trap sites were located by Jane Carter, Jennifer Grigg and Leah Stratford from the Medical Entomology Branch. The above three officers conducted the adult biting insect trapping.

All biting insects were identified by the Medical Entomology Branch. Mosquitoes were identified by Jane Carter and Leah Stratford, and biting midges were identified by Jane Carter and Nina Kurucz.

Larval mosquito surveys were conducted by officers from the Medical Entomology Branch (MEB) and Darwin City Council (DCC).

Figures and tables were prepared by Allan Warchot. Text by Allan Warchot and Peter Whelan.

3.0 Methods

3.1 Field inspection

3.1.1 Habitat inspection

Field inspections for mosquito breeding in depressions have previously taken place within and nearby to the redevelopment area, as part of routine inspections during the wet season by MEB and DCC officers. Drains in and nearby the development area have been inspected sporadically over a number of years for exotic mosquito breeding.

Routine field inspections of depressions within and nearby to the redevelopment area were again conducted throughout the wet season of 2003/2004, with a further field inspection of drains within the redevelopment boundary also conducted in the wet season of 2003/2004.

Actual mosquito breeding was determined by sampling habitats with water using a standard 270ml volume ladle. Potential mosquito breeding sites were assessed by field observations of the presence of localised depressions and poorly draining areas, and the vicinity of these sites to the coast.

Potential problem biting midge breeding sites within and nearby to the redevelopment area was assessed from aerial photographs (see Figure 1).

3.1.2 Trap site selection

The biting insect trap locations were evaluated from aerial photography and a consideration of the potential breeding sites of both mosquitoes and biting midges, and the likely flight range and activity of these insects.

Nine adult biting insect trap sites were selected during an initial field inspection. Trap site positions were stored using a hand held Garmin GPS unit, with all trap sites marked with flagging tape to enable traps to be set in the same position on each trap night. Adult biting insect trap sites are indicated in Figure 2. Sites were generally in or near vegetation and well away from competing light sources and human or machine activity.

3.2 Survey dates

Trapping for adult biting insects commenced in the mid afternoons (between 1500 and 1800 hours) and collected the following mid-morning (between 0800 and 1000 hours) to collect late afternoon, evening, night and early morning contributions to total biting insect numbers.

Adult biting insect traps were set on the nights of November 8, 9 & 10, with November 9 being the full moon night. The timing of adult biting insect trapping was to coincide with peak abundance of the salt marsh mosquito *Ochlerotatus vigilax*, with the traps being set from 12 days after the October monthly high tide. Adult mosquitoes would be collected in the same traps used for adult biting midge sampling. The timing of biting insect trapping was to also coincide with peak numbers of the mangrove biting midge *Culicoides ornatus,* with peak numbers of this species generally occurring around the time of the full moon.

Mosquito habitat surveys within and nearby to the redevelopment area was to occur from three to seven days after rainfall periods during the wet season of 2003/04.

3.3 Biting midge trapping

Trapping for the presence and relative abundance of biting midges was carried out overnight using carbon dioxide (CO_2) baited encephalitis virus surveillance (EVS) type traps. The traps consisted of an insulated billy can with four holes drilled into the bottom and loaded with approximately 1kg of dry ice, a suction fan motor compartment powered by two "D" cell batteries, a grain of wheat light source, and a modified 4 litre catch container fitted with a muslin sleeve and very fine wire mesh vents. The traps were set around chest height between 1500 and 1800 hours and collected the following morning between 0800 and 1000 hours. Biting midges were collected from all traps set on the above trap nights.

All trap collections were transported to the Medical Entomology Branch laboratory for sorting. Trap collections were killed by freezing, and mosquitoes and midges separated using a sieve. Biting midges collections were stored in 70% alcohol in small vials. For biting midge collection under 50 individuals, all individuals were identified. For biting midge collections over 50 individuals, subsamples of 50 individuals were taken and identified, with the entire remaining bulk counted to provide total numbers and scanned for species not identified in the subsample. Biting midges were identified with the aid of stereo microscopes using taxonomic references and wing photos.

3.4 Biting midge population and seasonal trends

The seasonal trend in biting midge abundance at the redevelopment area could not be determined because trapping was conducted for only one full moon event. General seasonal trends in biting midge populations of the mangrove biting midge species *Culicoides ornatus* were inferred from the Fairway Waters (Palmerston) study (Whelan et al 1998). Trapping for this study was carried out on the night of the full moon and provides a reasonable indication of expected seasonal variations of *C. ornatus* numbers in the redevelopment area.

3.5 Mosquito trapping

Mosquitoes were sampled by the same traps used above for biting midge sampling. Once separated from the biting midges, mosquitoes were emptied onto a filter paper lined petri dish for identification, with all mosquitoes trapped during the study being identified. Mosquitoes were identified with the aid of stereo microscopes using taxonomic references.

3.6 Mosquito population and seasonal trends

The probable maximum numbers and relative numbers of all species of mosquitoes over a complete year in the redevelopment area can be inferred from the results of the limited mosquito trapping for this study, and a comparison of the weekly quarantine adult mosquito trapping at the Grey Collar Club, located near the northwest boundary of the redevelopment area (Figure 2).

4.0 Results

4.1 Habitat survey

The land in the redevelopment area is within the vicinity of the sea. Due to a steep shoreline, there is only a small area of land subject to intertidal inundation. This includes a small creek associated with a drain pipe outfall. Sea spray is likely to affect areas within close proximity to the shoreline. There are several poorly draining areas in the redevelopment area that pond water during the wet season. Most of the proposed land development area is relatively flat, except for Stokes Hill, which is located in the eastern section of the development area. To the north of the redevelopment area is Darwin City, which is located on the escarpment bordering the redevelopment area. The redevelopment area also contains stormwater drains that pond water.

Potential biting midge habitats assessed from air photos were the extensive dendritic and foreshore mangrove areas associated with Sadgroves Creek (Figure 1).

The results of the various mosquito larval surveys at selected sites within and nearby the redevelopment area are presented in Table 11.

4.2 Biting midge trapping

The summary of biting midge trapping over three nights from November 8 to November 10 at all sites is presented in Table 6. The individual trap results for biting midges at all sites for each trap night are presented in Tables 8-10.

4.2.1 Species present

A total of four species of biting midges were trapped over three nights around the full moon in November 2003, for a total of 608 female biting midges (Table 6). The majority of biting midges collected were *Culicoides ornatus*, representing 92% of all the biting midges recovered (Table 6).

4.2.2 Spatial abundance

Culicoides ornatus was most abundant at Trap Site 9 (309), followed by Trap Site 8 (98) and Trap site 4 (44) (Table 7). All other sites recorded very low numbers of *C. ornatus*. Very low numbers of other biting midge species were recorded during the trapping.

For individual collections of *C. ornatus,* the highest single number of females recorded during the trapping was 300 at Trap Site 9 on November 8 (Table 8). All other trap sites on all trap nights recorded low numbers of *C. ornatus* (Tables 8 – 10).

4.2.3 Seasonal abundance

Culicoides ornatus numbers are generally highest in the late dry season months of August to November (Shivas & Whelan 2001, Figure 5). Trapping was only conducted in November 2003 for this study. The seasonal abundance of *C. ornatus* during 2003 at the study site will be similar in trend to that recorded in the Fairway Waters (Palmerston) study (Figure 5).

For the Fairway Water study in 1996-1997 (Figure 5), highest numbers of *C. ornatus* occurred in August and September, followed by a sharp decline in October and a moderate rise again in November. Lower numbers were recorded for the remaining months of the 12 month study.

4.2.4 Biting midge breeding sites

An assessment of probable biting midge breeding sites was made from aerial photography and an assessment of the results of the current trapping. There appears to be no significant *C. ornatus* breeding sites within and adjacent to the redevelopment area, with minimal mangrove areas close nearby to provide extensive breeding habitat. The small mangrove area located on the shoreline in the redevelopment area (Figure 1) would not be a likely source of *C. ornatus*. The rocky *Sonneratia* foreshore to the northwest of the redevelopment area (Figure 1) would not be a likely source of *C. ornatus* to the redevelopment area. It appears *C. ornatus* are dispersing to the redevelopment area from the dendritic mangrove creek and foreshore *Sonneratia* areas associated with Sadgroves Creek, and the *Sonneratia* foreshore east and northeast of the redevelopment area (Figure 1).

4.3 Mosquito trapping

The summary of mosquito trapping over three nights from November 8 to November 10 at all sites is presented in Table 1. The trap results for mosquitoes at all sites for each trap night are presented in Tables 3-5.

1.4.3.2 Species present

A total of eleven (11) mosquito species were collected over the three nights of trapping around the full moon in November 2003, for a total of 713 female mosquitoes (Table 1). The majority of mosquitoes trapped were *Oc. vigilax,* accounting for 79% of total mosquitoes (Table 1). The next most abundant mosquito species trapped were *Cx. annulirostris* (9.8%) and *Oc. notoscriptus* (4.8%) (Table 1).

1.4.3.3 Spatial abundance

Most mosquitoes were collected at Trap Site 8 (151 females, 21.2%) (Table 2). All other trap sites recorded below 100 female mosquitoes, with a fairly even spread of mosquitoes throughout the remaining trap sites, except for Trap Site 5, which had considerably lower numbers compared to the other trap sites (25 females) (Table 2).

The highest total number of *Oc. vigilax* was recorded at Trap Site 8 (98), followed by a fairly even spread of *Oc. vigilax* at the remaining trap sites, except for Trap Site 5 which had considerable lower numbers than the remaining trap sites (23 females) (Table 2). Trap Site 8 also recorded the highest number of *Cx. annulirostris* (32 females), with very low numbers at the remaining trap sites (Table 2).

Trap Site 2 recorded the highest number of *Oc. notoscriptus* (15 females), followed by Trap Site 8 (13 females) (Table 2). All other trap sites recorded nil to very low numbers of *Oc. notoscriptus.*

1.4.3.4 Seasonal abundance

The seasonal abundance of mosquitoes in the proposed development area can be inferred from weekly trapping at the Grey Collar Club located on the northwest boundary of the proposed development area (Figure 4). The weekly trap results for the year of 2003 have been combined to provide monthly total numbers. The trap results from the Grey Collar Club indicate low numbers of mosquitoes for most months of the year, except for the rise in *Oc. vigilax* numbers in the month of December.

4.4 Larval mosquito surveys

The results of larval mosquito surveys in and nearby the redevelopment area are presented in Table 11. The location of actual and potential mosquito breeding sites are presented in Figure 3. Larval mosquito breeding in and nearby to the redevelopment area occurred in poorly draining areas and stormwater drains.

4.4.1 Poorly draining areas (see Figure 3)

A1. This site was within the redevelopment area. This site includes a poorly draining grassy area and drainage line south-west of the tram eatery, and a poorly draining dirt area adjacent to and west of the poorly draining grassy area. Water is unable to drain adequately in these areas due to the presence of depressions and the concrete seawall that has a lip higher than the natural surface level of the area. *Culex annulirostris* and *Ochlerotatus vigilax* breeding has been located in this area in the past two wet seasons after the site was discovered. The total area of breeding has been up to 20m^2 at times, with larval concentrations of up to 4 larvae per ladle dip recorded.

A2. This site was within the redevelopment area. This site was a poorly draining area located in the vacant land east of the Shell Bitumen Plant. The depression is partly vegetated with grass. This site was surveyed once only in December 2003, with *Ochlerotatus vigilax* breeding found at 0.5 larvae per ladle dip. The total area breeding was approximately 30m^2, with larvae restricted to the grassy areas. Total area of water pooling at the time of the survey was approximately 60m^2.

A3. This site was located outside of the redevelopment area, approximately 110m north of the redevelopment boundary, adjacent to McMinn Street. This site included several grassy depressions as well as poorly draining areas associated with the gas pipeline. The area was surveyed in December 2003, with *Culex annulirostris* found breeding at 1 larvae per ladle dip. Total area of water pooling at the time of the survey was approximately 30m^2.

P1. This site was within the redevelopment area. This site was a poorly draining disturbed area, partly vegetated with grass, located near the northern boundary fence of the sulphuric acid tank. This site was surveyed in December 2003 only, with no breeding found, but was highlighted as a potential mosquito breeding site. Total area of water pooling at the time of the survey was approximately 20m^2.

P2. This site was within the redevelopment area. This site was a poorly draining area with leaf litter from overhanging trees, located between two open concrete lined drains near the corner of McMinn Street and Kitchener Drive. This site was surveyed in February 2004. No mosquito breeding was found, but this site was highlighted as a potential mosquito breeding site. Total area of water pooling at the time of the survey was approximately 15m^2.

P3. This site was within the redevelopment area. This site was a poorly draining area partly vegetated with grass, located north of the northern boundary fence of indo-pacific marine. This site was not surveyed due to access restriction, but was highlighted as a potential mosquito breeding site. The total area of water pooling was approximately 15m^2.

4.4.2 Stormwater drains

D1. This drain was within the redevelopment area. A previous survey in June 2001 has indicated this open concrete drain at the base of Stokes Hill is subject to the dry season low flows of water and heavy silt loading and leaf litter. Mosquito breeding has occurred in the drain during the dry season when low flows of water occur, and in the wet season after rainfall (as located in February 2004). Mosquito species found breeding in the drain were *Culex annulirostris* and *Culex quinquefasciatus*, at densities of up to 3 larvae per ladle dip. Total area breeding has been found to be up to 10m^2. One section of the concrete invert has been lifted by tree root growth, minimising the effectiveness of the drain to convey low flows of water and allowing water to pool.

D2. This drain was located just north of the redevelopment boundary. This open concrete drain conveys water from the corner of McMinn St Bennett Street to a letterbox pit near the corner of McMinn Street and Kitchener Drive. A previous survey in May 2003 has indicated this drain is subject to the dry season low flows of water and moderate silt loading in the lower section of the drain near

the development boundary. *Culex quinquefasciatus* were found breeding at 5 larvae per ladle dip in May 2003, with the total area breeding approximately $5m^2$.

D3. This drain was within the redevelopment area. This open concrete drain at the north western corner of Kitchener Drive conveys water in both directions, to a letter box pit at the corner of McMinn St and Kitchener Drive, and to a small inlet pipe opposite the P & O Ports office compound. The drain is subject to the dry season low flows of water and moderate silt loading and grass growth, and breeds mosquitoes when silt and vegetation prevents the free flow of water. The letterbox pit pools water due to the bottom of the pit being lower than the outlet pipe. The open section of drain breeds mosquitoes when silt and vegetation prevents the free flow of water.

Culex annulirostris was found breeding in the letterbox pit at 1 larvae per ladle dip in June 2001, with the total area breeding being $5m^2$. *Culex quinquefasciatus* were found breeding at 5 larvae per ladle dip, and *Cx. annulirostris* were found breeding at 4 larvae per ladle dip in May 2003, with the total area breeding being $5m^2$.

D4. This drain was within the redevelopment area. This open concrete drain is located along Kitchener Drive north of the Shell Bitumen Plant near the gas pipeline, and conveys water from a subsoil pipe to a letterbox pit. This drain is subject to heavy silt loading and dry season low flows of water. *Culex quinquefasciatus* were located breeding at 50 larvae per ladle dip in June 2001, with the total are unknown as water pooling extended inside the subsoil pipe. *Culex annulirostris* were located breeding at 0.5 larvae per ladle dip in May 2003, with the total breeding area being $0.2m^2$.

D5. This drain was located outside of the redevelopment area, north of the Grey Collar Club. The drain is open and unlined and pools water, and is subject to the dry season low flows of water. *Culex annulirostris* and *Culex quinquefasciatus* were found breeding at 1 larvae per ladle dip in June 2001, with the total area breeding being $30m^2$.

D6. This drain was a concrete lined open drain located within the redevelopment area, south of the Grey Collar Club in between two sheds. The drain was surveyed in March 2004, no mosquito breeding was found but water was pooling for almost the entire length of the drain, indicating a potentially significant mosquito breeding site.

D7. This area consists of old underground stormwater drains and pits constructed from previous developments, in the old powerhouse area. Pooling occurs in the underground drainage system, and in a square concrete pit adjacent to the two large fuel and water storage tanks (Lamche pers. comm. 2004). The entire drainage system in this area provides potential mosquito breeding sites.

D8. This drain was an outlet pipe to a small creek to the sea. Water was flowing out of the pipe at the time of the survey in March 2004. Silt build up at the pipe outlet prevents the free flow of water from the pipe. This site may be a potential mosquito breeding site in the dry season when water pools up the outlet pipe.

D9. This drain was an unformalised area draining water to a letterbox pit. Water drains from the surrounding areas associated with the gas pipeline. The letterbox pit was heavily silted to a point where the outlet pipe was almost completely obstructed. The letterbox pit was dry during a site inspection in April 2004.

D10. This drain was an unformalised area, and inlet pipe from the WWII tunnels, draining water to a letterbox pit. Water was flowing from the inlet pipe from the WWII tunnels during a site inspection in April 2004, and subsequently no mosquito breeding was located.

D11. This drain was an open unlined drain that conveys water to drain D2. This drain has not recently been surveyed for mosquito breeding, but is a potential mosquito breeding site if water is allowed to pool in the drain.

There are also several pipe drain outfalls from the Esplanade escarpment to the area north of Kitchener Drive. These drain outfalls were not surveyed for mosquito breeding, but could be potential mosquito breeding sites if water is allowed to pool at the pipe outfalls.

5.0 Discussion

5.1 Biting midges

5.1.1 Problem species in the redevelopment area

There is likely to be only one biting midge species with the potential to cause a pest problem in the development area, namely the mangrove biting midge species *Culicoides ornatus.*

Another biting midge species that breeds in freshwater and has been known to be a minor human pest at times is *Culicoides marksi*, but this species is unlikely to be present in pest numbers at the redevelopment site, due to the absence of freshwater lakes and streams.

Culicoides undescribed sp. (nr. *C. immaculatus*) is relatively common only in the lower reaches of mangrove creeks, and bites viciously. It possibly breeds below the neap tide zone in mangrove creeks, and it is unlikely to cause a pest problem in the redevelopment area. This species was not trapped during the study.

Culucoides flumineus is an important pest species, with high numbers inside mangroves only. This species was not trapped during the study, and is not likely to be present in the redevelopment area due to the absence of creekbanks associated with small upper tidal tributaries, which are its preferred breeding sites.

5.1.2 Culicoides ornatus

Culicoides ornatus is a widespread species causing major pest problems throughout coastal areas of northern Australia and along the east coast of Queensland (Shivas and Whelan 2001). This midge species breeds in mangrove areas and the females migrate landward after emergence, with the bulk of dispersing females moving up to 1 to 2km inland of the mangrove margin (Shivas and Whelan 2001). Lower numbers can be encountered for at least 3.5km from the mangrove margin (Shivas and Whelan 2001). Higher numbers of this species are generally found on escarpment areas facing mangroves (Shivas and Whelan 2001). The dispersal characteristics of this species ensure that it is an important human pest biting midge species in coastal areas around Darwin and Palmerston. This midge species and other midge species in Australia are not vectors of human disease.

Peak dispersal of *C. ornatus* generally occurs around the time of the full or new moon, with peak dispersal occurring one day before the full moon in the warmer months (Shivas and Whelan 2001). This generally correlates with dispersal from the more productive upper tidal creek breeding sites (Shivas and Whelan 2001). Peak dispersal from foreshore *Sonneratia* breeding sites occurs about four days before the upper tidal creek dispersal peak (Shivas and Whelan 2001).

5.1.3 Breeding sites for Culicoides ornatus

Investigations of breeding sites in Darwin Harbour have located the breeding sites of *C. ornatus* by adult emergence trapping (Shivas et. al. 1997, Shivas 1999). The midge breeds in the dry season in the mangrove mud in the creek banks of upper tidal tributaries between Mean Low Water Neap (MLWN) and Mean High Water Neap (MHWN). Larval sampling has revealed significant breeding at tidal elevations of 4.7m ACD to 5.5m ACD at creekbank habitats (Shivas 1999). The prime breeding sites are in a narrow zone in the upper section of narrow creek banks associated with the occurrence of pneumatophores of the mangrove species *Avicennia marina*. The prime dry season breeding site has an upper limit where the *Avicennia* reduces in height and predominance, and a lower limit where the creek opens out from the overhanging *Avicennia* canopy (Shivas 1999, Whelan 2003). Breeding also

occurs in a broad band centred around the edge of the vegetation line on the upper part of the creekbank i.e just above MHWN (Shivas 1999, Shivas 2001).

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

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

There appears to be no productive *C. ornatus* breeding sites within or adjacent to the redevelopment area. The small mangrove creek area associated with drain D8 (Fig. 3) has a rocky substrate, not a mud substrate which *C. ornatus* prefer. The same applies to the narrow *Sonneratia* mangrove foreshore to the north-west of the redevelopment area, which also has a rocky substrate.

5.1.4 Culicoides ornatus breeding sites affecting the redevelopment area

The *C. ornatus* breeding site affecting the proposed development area are most likely the extensive *Sonneratia* mangrove foreshore to the east, northeast and north of the redevelopment area (Areas A & D, Fig. 1), and the dendritic upper tidal creek mangrove areas associated with Sadgroves Creek (Areas B & C). Highest numbers recorded in the Stokes Hill area indicates the elevated landform of Stokes Hill is a preferred area for *C. ornatus* females to disperse to. Light early morning SE, ENE and ESE winds recorded in the week leading up to the full moon (Bureau of Meteorology data) would have aided dispersal to the Stokes Hill vicinity.

Low numbers at the remaining areas of the redevelopment site indicate the narrow *Sonneratia* foreshore located northwest of the redevelopment area, parallel with the esplanade road (Fig. 1), is not a productive *C. ornatus* breeding site, most likely due to the rocky nature of the shoreline. The small mangrove area associated with stormwater drain D8 (Figs. 1 & 3) within the redevelopment area would not be a productive breeding site, due to the rocky substrate associated with the creek.

The highest numbers of *C. ornatus* recorded during the study were recorded one day before the full moon, with very low numbers for the following two trap nights (Table 6). The lower numbers of *C. ornatus* for the following two nights may have been a result of rainfall occurring on the evening of the full moon night (9th November), which would have surpressed midge activity and perhaps caused some adult mortality. *Culicoides ornatus* numbers rose slightly on the night after the full moon, when no rainfall was recorded. The almost halving of mosquito numbers (Table 1) from the night before the full moon to the full moon night indicates rainfall on the full moon night was most likely a factor in the reduction of biting midge numbers from the full moon night onwards.

Due to the distance of the redevelopment area from productive *C. ornatus* breeding sites, the timing of peak abundance around full moon and new moon periods may vary slightly when compared to areas closer to mangrove breeding sites. Also, the three day trap results from the study may not indicate peak abundance likely to be encountered in the redevelopment area, due to seasonal and annual variations in productivity, and climatic factors such as wind and rain. Also, the three day trapping would not have indicated peak numbers to arise from the low to medium productivity *Sonneratia*

foreshore breeding habitats, as trapping would have been required up to three days before the full moon to assess the foreshore breeding component affecting the redevelopment area.

5.1.5 Pest and public health significance in the redevelopment area

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

Investigations near Darwin have suggested an approximate relationship between the numbers of biting midges collected in a carbon dioxide trap and the number of bites that can be expected at the peak biting period (Whelan et. al. 1997a). The number of bites in an hour on an exposed leg at the peak biting time around sunset is approximately a quarter of the number collected in a CO_2 trap over one night at the same position (Whelan et. al. 1997a). For example if there were 400 *C. ornatus* in a CO_2 trap this would equate to 100 bites per hour.

The highest individual collection of *C. ornatus* during the study was 300 females collected at Trap Site 9 on November 8 (Tables 8-10). This equates to 75 bites per hour, which would constitute a minor to moderate pest problem at the Stokes Hill area. All other collections for all trap sites and trap nights recorded less than 80 female *C. ornatus* per trap per night (Tables 8-10), indicating a minor to very minor pest problem for the remaining areas of the proposed development site at the time of the study.

Early wet season rainfall can supress numbers of *C. ornatus.* It is possible that rainfall in October and early November 2003 (see Fig.4), including rainfall on the night of the full moon, may have surpressed numbers of *C. ornatus*, therefore adult trapping in early November may have missed the peak abundance of *C. ornatus* in the redevelopment area. When comparing peak abundance of *C. ornatus* from the Fairway Waters study (Fig. 5), it showed the numbers collected in November were less than half of that collected in the peak month of August for that year. The same scenario may not apply to this study due to different rainfall patterns in October and November for those years, but is should be considered that peak season numbers of *C. ornatus* at the proposed development area may be higher than those recorded in the November trapping during this study.

In the event that peak season numbers in the proposed development site were double what was recorded in November, the pest problem at the Stokes Hill vicinity would still be minor to moderate, with a very minor to insignificant problem at the remaining areas of the redevelopment site. Due to the distance of the redevelopment site from any extensive mangrove breeding sites, it is not likely that numbers large enough to cause a high to severe pest problem would disperse to the redevelopment area.

Biting midges do not currently transmit human disease in Australia, but can impact on humans due to painful and irritable bites, and secondary infection and scarring due to scratching. The numbers trapped during the study indicate that low numbers of *C. ornatus* will be present in the development area, with a low to moderate pest problem likely in the Stokes Hill vicinity, and insignificant numbers at the remaining areas of the proposed development site. Highest numbers of *C. ornatus* would occur for around four or five days during the full and new moon periods in the months of August to November. Numbers of this species are likely to be very low or insignificant during the other months of the year. *Culicoides ornatus* pest problems are usually greatest around full moon periods, with a lesser problem occurring around new moon periods.

5.2 Mosquitoes

5.2.1Potential problem species in the redevelopment area

The main mosquito species likely to cause a problem in the redevelopment area is the salt marsh mosquito *Ochlerotatus vigilax. Ochlerotatus vigilax* breed in coastal areas in tidal and brackish water. Favoured breeding sites are brackish reed swamps, disturbed upper tidal areas, upper tidal creek extremities, tidally or sea spray affected rock pools and depressions, and depressions in coastal sand dunes and vegetated areas above the tidal limit. This mosquito species is a vector of Ross River virus (RRV) and Barmah Forest virus (BFV) diseases, and can be a severe pest due to its persistent biting habits and its willingness to bite during the daytime. *Ochlerotatus vigilax* can travel up to 60km in pest numbers from their coastal breeding sites, and can breed in very high numbers in small areas of water. *Ochlerotatus vigilax* were trapped in minor pest numbers in the redevelopment area, but has the potential to breed in substantial numbers in the redevelopment area.

The relatively even spread of *Oc. vigilax* throughout the redevelopment area from the November full moon trapping indicate probable dispersal from breeding sites outside of the redevelopment area.

Another important pest and vector mosquito species trapped in the redevelopment area was *Culex annulirostris. Culex annulirostris* breed in extensive reed swamps with *Eleocharis* or *Typha* reeds, temporary flooded grasslands, sewage effluent and organic waste water, and stormwater drains. *Culex annulirostris* can breed in very high concentrations in organic water. This mosquito species is a vector of RRV, BFV, Murray Valley encephalitis virus (MVEV) and Kunjin virus (KUNV). *Culex annulirostris* was trapped in low numbers, but has the potential to breed in pest numbers in the redevelopment area. Highest numbers of this species collected from Trap Site 8 indicate probable breeding would have been occurring in a nearby drain associated with the old powerhouse area.

Of the other mosquito species trapped, *Culex quinquefasciatus* has the potential to cause a pest problem in the redevelopment area. *Culex quinquefasciatus* breed in stormwater drains, artificial containers, septic tanks, sewage effluent and wastewater pools. *Culex quinquefasciatus* can breed in very high concentrations in organic water, such as that found in stormwater drains. *Culex quinquefasciatus* were trapped in very low numbers in the redevelopment area, however numbers of this species are generally underestimated in CO_2 baited EVS traps. *Culex quinquefasciatus* numbers may actually be higher that that recorded during the three day trapping at the nine selected sites. Monthly numbers of *Cx. quinquefasciatus* recorded from the weekly quarantine trapping at the Grey Collar Club were very low, indicating only a relatively low amount of breeding in that vicinity.

Ochlerotatus notoscriptus were trapped in very low numbers in the redevelopment area. *Ochlerotatus notoscriptus* breed in tree holes and artificial containers or receptacles, and has the potential be breed in pest numbers if the number of artificial and natural containers increases in the redevelopment area. Highest numbers were trapped at Trap Sites 2 & 8, indicating breeding would have been occurring in nearby artificial receptacles.

5.2.2Potential exotic mosquito species in the redevelopment area

The redevelopment area is susceptible to the introduction of exotic species of mosquitoes, the most important species being the dengue vector mosquito species *Aedes aegypti* and *Aedes albopictus*. Both mosquito species breed in artificial and natural receptacles, and can be brought into the area on visiting ships or cargo from overseas where these species are endemic. *Aedes aegypti* can also be brought into the area from vessels and road transport from Queensland, where this species is endemic, and possibly from Tennant Creek, where this species has recently been detected (Whelan et al 2004).

Aedes aegypti are generally found in domestic situations, breeding in artificial receptacles (such as tyres, any type of water holding container and pot plant drip trays) and natural receptacles (such as tree holes, bamboo stumps and leaf axils), rarely far away from human habitation and with a preference for

artificial receptacles (Lee et al 1987). This species also breeds in underground pits that contain water, such as side entry pits and telstra pits. This mosquito species has been the vector in the recent dengue epidemic in North Queensland.

Aedes albopictus also breed in artificial containers as well as natural breeding sites such as tree holes, bamboo stumps, leaf axils and fallen palm fronds (Lee et al 1987). This species is not as domesticated as *Ae. aegypti* and does not show any marked preference for either artificial or natural breeding sites (Lee et al 1987).

5.2.3Breeding sites for the potential problem mosquito species in the redevelopment area

During routine larval mosquito surveys in the redevelopment area, *Ochlerotatus vigilax* breeding has been located in Areas A1 and A2 (Figure 3), with moderate concentrations of breeding found. Any other depressions or poorly draining areas close to the shoreline can be potential *Oc. vigilax* breeding sites eg. (areas P1 & P3, Fig. 3), due to sea spray providing ideal salinity conditions for *Oc. vigilax* breeding.

During routine larval mosquito surveys in the redevelopment area, *Cx. annulirostris* have been found breeding in two stormwater drains (drains D1& D3, Fig 3, Table 11) and also the grassy depressions south-west of the tram (area A1), in moderate to low concentrations. This species is also likely to breed in the large depression to the east of the Shell Bitumen Plant (area A2), and also at areas P2 & P3, and any other poorly draining grassy areas within the redevelopment area.

Culex quinquefasciatus has been found breeding in high concentrations in several drains in the redevelopment area (drains D1, D2, D3 & D4), during routine larval mosquito inspections. This species could also breed in any artificial containers in the redevelopment area.

Ochlerotatus notoscriptus has the potential to breed in any artificial receptacles located within the redevelopment area.

Due to the presence of artificial receptacles in and nearby to the redevelopment area, and the presence of natural tree holes, there is a risk that exotic *Aedes* species such as *Ae. aegypti* and *Ae. albopictus* may be introduced into the area from visiting ships from overseas and Queensland. The presence of the container breeding mosquito species *Oc. notoscriptus* in the adult monitoring traps indicates container mosquito breeding occurs in or nearby to the redevelopment area, representing a risk for the introduction of exotic container breeding mosquito species.

The redevelopment area is also susceptible to the introduction of a number of other exotic mosquito species, due to current wet season flooded depressions providing nearby available habitat for any exotic groundwater breeding mosquito species that may fly off a visiting ship.

In general, due to the drainage system in the redevelopment area being very old and disrupted due to previous development or clearing, it is likely that there are areas of the underground drainage system that hold water. All of the underground drainage system was not surveyed during the assessment of the redevelopment area. As can be seen with drain D3, the letterbox pit pools water, so it is likely that other letterbox pits and also side entry pits in the proposed development area have the ability to pool water and breed endemic and exotic mosquito species. Any part of the drainage system in the redevelopment area that has the capacity to pool water has the capacity to breed mosquitoes.

The stormwater drainage system in the old power house area (Figure 3, D7) has not recently been surveyed for mosquito breeding. Due to the ponding of water occurring in this stormwater drainage system, there is the potential for this stormwater drainage system to breed both endemic and exotic mosquito species.

There are several pipe drain outfalls from the Esplanade Road escarpment to the area north of Kitchener Drive. These drain outfalls have the potential to breed mosquitoes if the ponding of water is allowed to occur at the drain outfalls.

All current drainage systems within the redevelopment area have the capacity to breed mosquitoes if not upgraded or maintained regularly.

5.2.4Breeding sites outside the redevelopment area that may affect the redevelopment area

Poorly draining areas associated with the vacant block of land east of Stella Maris Seafarers Centre, and south-east of the Harbourview building (area A3), breed moderate numbers of *Cx. annulirostris* during the wet season. This includes several grassy depressions as well as poorly draining areas associated with the gas pipeline on the western boundary of the vacant block.

The section of drain D2 opposite Stella Maris Seafarers Centre on McMinn St breeds high levels of *Cx. quinquefasciatus* when silt prevents the free flow of water.

The open unlined drain (drain D5) alongside the road to the deckchair cinema is subject to dry season low flows of water. Water pools in the drain due to no low flow facilities, and breeds moderate levels of *Cx. annulirostris* and *Cx. quinquefasciatus.*

The moderate numbers of *Oc. vigilax* collected during the November full moon trapping indicates dispersal to the redevelopment area from tidally affected areas outside of the redevelopment area. No significant rainfall occurred in the 9 days before the trapping, which indicates the rain filled breeding sites in the redevelopment area would not have produced mosquitoes for that trap event. A possible nearby source may have been tidally affected areas near the railway dam (Area 1, Fig. 1), from the October 27 monthly high tide. A survey will be conducted after monthly high tides in the coming late dry season at the tidal areas near the railway dam this year, to locate any potential and actual salt marsh mosquito breeding sites. Other possible nearby breeding sites for *Oc. vigilax* (Areas 2 & 3, Fig. 1) are routinely inspected and controlled by MEB, so would not have contributed numbers to the November full moon trapping results.

It is possible that some of the *Oc. vigilax* trapped had dispersed to the proposed development area from the tidal areas of Darwin Harbour, and possibly from the Leanyer/ Holmes Jungle/Shoal Bay Swamps. There were very high numbers of *Oc. vigilax* in the MEB routine weekly adult mosquito monitoring traps bordering these swamps in the weeks prior to trapping at the redevelopment area. This species can disperse in pest numbers from their breeding sites for very long distances (up to 50km).

5.2.5Pest and public health significance in the redevelopment area

Currently the mosquito problem at the redevelopment area is minor compared to other areas of the Darwin Urban area. The potential public health issue arising from mosquitoes in the redevelopment area is currently low, due to low numbers of mosquitoes and the general absence of animal hosts in and nearby to the redevelopment area. The potential public health issue would be higher if new mosquito breeding sites are created by construction activities and if exotic mosquito species are imported into the area. Currently the main periods for increased mosquito activity in the redevelopment area would be the late dry and early wet seasons when rainfall and high tides flood *Oc. vigilax* breeding sites, and the early mid wet season when rainfall floods *Cx. annulirostris* breeding sites. Increased mosquito activity would also occur during periods of the dry season when low flows of water encourage mosquito breeding in drains.

5.3 The proposed development

5.3.1 Stormwater drainage

The stormwater drainage of the area is likely to be changed by development processes. Stormwater drainage systems have the capacity to breed mosquitoes if not appropriately designed to freely drain water to a suitable end point such as the nearby sea, and/or are not maintained regularly. Some of the old drainage systems will need to be upgraded to effectively drain water to prevent potential health impacts due to mosquito breeding.

All new stormwater drainage in the area should discharge to a suitable end point, which will be an existing formalised drain, or discharge directly to the sea. All letterbox pits and side entry pits should be flush with the invert of the outlet pipe to prevent the ponding of water in stormwater pits. Any new open drain should be constructed with concrete low flow inverts, and roadside drainage should be adequate enough to prevent water pooling along the sides of roads. All new drains in the proposed development area should convey water in a manner that does not lead to ponding in the drains.

Appropriate landscaping would be required in the proposed development area to prevent the creation of, and eliminate any areas that are capable of ponding water for more than three days. This will include appropriate contouring of landscaped surfaces to allow efficient runoff of stormwater into nearby drains, and the rectification of existing poorly draining areas in the redevelopment area. The redevelopment of the area must not result in the creation of areas capable of holding water and breeding mosquitoes, such as depressions or machinery disturbed areas.

5.3.2 Landscaping

Appropriate vegetation should be chosen to minimise the potential for natural receptacle mosquito breeding sites, that could become breeding sites for exotic *Aedes species* imported in the wharf areas. The current bamboo forest alongside Hughes Ave should be replaced with other plant species that are not capable of holding water. Plants to avoid using are those with leaf axils that hold water, such as *Bromeliad species*, and coconut trees, with fallen coconuts having the capacity to hold water.

Shrub type vegetation should be used around any public areas, to allow the potential use of barrier spraying with insecticides to reduce adult biting insect populations. Shrub type vegetation provides suitable harbouring site for biting insects. Barrier sprays with the active ingredient befenthrin can be sprayed onto shrub vegetation, which then kills biting insects that rest on the treated vegetation.

5.4 Potential impacts of the proposed development

5.4.1 Mosquito breeding

Any proposed development has the potential to create mosquito breeding sites, especially near tidal areas. On-site pest and potential health impacts may arise from the creation of mosquito breeding sites caused by disturbance to land that leads to water ponding. Due to the long flight range of the salt marsh mosquito, any breeding sites for this species created in the proposed development area also have the potential to impact on nearby Darwin City. Other mosquito species that may breed in poorly draining areas at the proposed development site may also have potential health and pest impacts on-site and off-site at nearby Darwin City.

Inappropriate design of stormwater drains can also lead to mosquito breeding that will have potential on-site and off-site pest and potential health impacts, and provide breeding sites for exotic mosquito species. Poor drainage of landscaped areas can also lead to mosquito breeding, with associated negative impacts on pubic health and amenity. Activities involving artificial receptacle use in and

nearby to the redevelopment area should be conducted in a manner to prevent mosquito breeding, such as storing artificial receptacles away from rain, or routinely treating the receptacles with chlorine or an appropriate insecticide.

5.4.2 Biting midge breeding

Development activities are not likely to create or impact on any existing significant biting midge breeding sites affecting the proposed development area.

6.0 Conclusions

6.1 Mosquito breeding

6.1.1 Groundwater depressions

The current potential and actual mosquito breeding depressions (Areas A1-A3 & P1-P3) in the redevelopment area requires rectification by filling, draining or re-contouring.

No new depressions or poorly draining areas capable of holding water for more than three days should be created by development activities.

The depressions outside of the proposed development area will be targeted for rectification by MEB and the Darwin City Council.

6.1.2 Stormwater drains

D1 – This drain requires annual desilting at the end of each wet season. The section of drain that has been lifted by tree root growth should be replaced to restore the correct levels in the drain. The drain should be redesigned to be self cleansing, by increasing the fall of the drain if possible.

D2 – This drain is outside of the proposed development area. Annual maintenance of this drain is conducted by Darwin City Council. The drain should be redesigned to be self cleansing, by increasing the fall of the drain if possible.

D3 – This drain requires annual desilting at the end of each wet season. The bottom of the letterbox pit should be raised to the level of the outlet pipe to prevent the ponding of water in the pit. If possible, the drain should be redesigned to be self cleansing, by increasing the fall of the drain.

D4 – This drain requires annual desilting at the end of each wet season. Ideally the subsoil pipe should be continued to the drain outlet, to eliminate the open section of drain currently subject to silt loading and mosquito breeding.

D5 – This drain is outside the disturbance envelope and should be upgraded with a concrete low flow invert by the appropriate authority, to prevent water ponding and subsequent mosquito breeding.

D6 – This drain requires annual desilting at the end of each wet season, otherwise the drain should be redesigned to be self cleansing by increasing the fall of the drain, if possible.

D7 – The entire underground drainage system in this area requires either decommissioning or upgrading to prevent water from pooling in the underground drainage system.

D8 – The area of drain at the outlet pipe should be desilted for approximately 30m to prevent water from pooling in the outlet pipe.

D9 – The letterbox pit requires annual desilting. If the floor of the letterbox pit is lower than the invert of the outlet pipe, it would need to be raised to the level of the outlet pipe to prevent water from pooling in the pit.

D10 – The letterbox pit requires annual desilting.

All new stormwater drainage in the area should discharge to a suitable end point, which will be an existing formalised drain, or discharge directly to the sea. All letterbox pits and side entry pits should be flush with the invert of the outlet pipe to prevent the ponding of water in stormwater pits. Any new open drain should be constructed with concrete low flow inverts, and roadside drainage should be adequate enough to prevent water pooling along the sides of roads. All new drains in the proposed development area should convey water in a manner that does not lead to ponding in the drains.

Areas of the old underground drainage system in the redevelopment area not mentioned in the above report are probably also capable of ponding water. This may include all letterbox pits and side entry pits within the redevelopment area. Any letterbox pits and side entry pits that have a floor lower that the invert of the outlet pipe should be raised to the level of the outlet pipe to prevent water ponding and mosquito breeding. Any section of the underground drainage system susceptible to silt accumulation and consequent water pooling should be re-evaluated for upgrade works. A review of the entire underground drainage system in the redevelopment area is required to locate and rectify any part of the underground drainage system capable of ponding water.

The pipe drain outfalls from the Esplanade escarpment to the area north of Kitchener Drive should be reviewed for upgrade or maintenance works. Erosion prevention structures may need to be constructed or upgraded at the pipe outfalls, or water from pipe outfalls should be connected to an underground pipe system via a stormwater pit, which then conveys the water directly to the sea. If a stormwater pit were to be constructed, the invert of the pit would need to be flush with the invert of the outlet pipe, to prevent water from pooling in the pit.

6.1.3 Artificial receptacles

A general clean up of the redevelopment area should be conducted to remove or appropriately store any artificial receptacles that can fill with water and breed mosquitoes. Any new activities should be conducted in a manner that does not lead to an increase in artificial receptacles capable of mosquito breeding, such as storing receptacles away from rain or routinely treating the receptacles with chlorine or an appropriate insecticide.

6.1.4 Landscaping

Shrub type vegetation should be considered around any proposed public areas, to allow the use of bifenthrin insecticide barrier treatment to control adult biting mosquitoes.

Consideration should be given to removing the bamboo forest alongside Hughes Ave, as cut bamboo can provide a habitat for endemic and exotic container breeding mosquitoes.

Plants to avoid using include those with leaf axils capable of holding water, such as *Bromeliad species,* and coconut trees, with fallen coconuts capable of holding water. This is to prevent natural receptacle mosquito breeding in the redevelopment area.

6.1.5 Public health risk

The present mosquito problem is very minor compared to other suburbs of Darwin within the vicinity of coastal areas, due to the lack of any extensive nearby breeding sites. Minor numbers of mosquitoes represent a minor public health risk. The proposed development should remove current mosquito breeding sites, therefore further reducing mosquito numbers in the area.

6.1.6 Exotic mosquitoes

There is a risk of exotic mosquito importation into the redevelopment area. Therefore it is important to eliminate all mosquito breeding sites within the proposed development area, and prevent the creation

of new mosquito breeding sites. In the event of an exotic mosquito incursion, health and quarantine officials would require unrestricted access throughout the proposed development area to conduct eradication procedures, such as insecticide spraying and fogging. Particular risk areas in the redevelopment area would be any part of the underground stormwater drainage system that could pond water, such as letterbox pits and side entry pits. The underground drainage system requires surveying, and any part of the underground drainage system that could pond water needs to be rectified. These Any artificial receptacle capable of holding water can also breed exotic mosquitoes.

6.1.7 Personal protection from mosquitoes

Bifenthrin barrier treatments would be a form of personal protection from mosquitoes. Other strategies can also be implemented to reduce any potential pest problem from mosquitoes (Whelan 2003b). This will include using yellow lighting around any human activity area, to prevent attracting mosquitoes to these areas. White fluorescent or ultra-violet lights can be used in areas away from human activity, to divert mosquitoes to some extent away from human activity areas.

The personal use of repellents containing DEET or Picaridin may be required if mosquito numbers become high in the redevelopment area. Protective loose long sleeve can also minimise mosquito bites. Publicity concerning the presence of pest and disease carrying mosquitoes in the redevelopment area, the potential for minor pest levels of mosquitoes and the potential for exotic mosquito introduction should form part of an information package to developers and potential landholders and businesses in the redevelopment area.

6.2 Biting midges

Only one species of biting midge (*C. ornatus*) is likely to cause a pest problem in the redevelopment area. This midge is likely to be dispersing to the proposed development area from the extensive *Sonneratia* foreshore located to the east and northeast of the redevelopment area, and the dendritic mangrove areas of Sadgroves Creek. This midge species is likely to cause a minor to moderate pest problem only, with highest numbers occurring in the development area in the months of August to November around the time of the full moon, and to a lesser extent around the time of the new moon in these months. The pest problem is likely to be insignificant for the remaining months of the year. Highest numbers would be noticed in the Stokes Hill area. Information concerning these likely pest problems and periods, and personal protection measures (see Section 6.1.7) should form part of an information package to developers and potential landholders and businesses in the redevelopment area.

Shrub type vegetation should be considered around any proposed public areas, especially at Stokes Hill, to allow the use of bifenthrin barrier treatment to control adult biting midges.

7.0 References

Cilek, J. E., Kline, D. L., and Hallmon, C. F., (2003), 'Evaluation of a novel removal trap system to reduce biting midge (Diptera: Ceratopogonidae) populations in Florida backyards', *Journal of Vector Ecology* 28 (1): 23-30.

Debenham, M. L., (1983), 'Australasian species of the blood feeding Forcipomyia subgenera Lasiohelea Dacnoforcipomyia (Diptera:Ceratopogonidae)', *Australian Journal of Zoology Supplementary Series* 95, pp. 1 - 66.

Department of Health & Community Services and Darwin City Council, Task Force Review (1989), *Mosquito control measures in Darwin*, DH&CS Darwin, NT.

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.

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.

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

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.

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.' PHD. Faculty of Science, Northern Territory University Darwin.

Shivas, M. (2001), 'Hervey Bay Biting Midge Review 2001. Previous studies and research priorities.' Prepared for the Hervey Bay City Council, QLD.

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.

Whelan, P. I. (1988a), 'Common mosquitoes in the NT', NT Department of Health & Community Services.

Whelan, P. I. (1988b), 'Construction practice near tidal areas in the NT. Guidelines to prevent mosquito breeding', NT Coastal Management Committee.

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

Whelan, P. I. (1998a), 'Summary of the Biology of Selected Culicoides Species in the Top End of the Northern Territory.' Medical Entomology Branch Handout, Territory Health Services.

Whelan, P. I. (1998b), 'Seasonal Prevalence of Selected Culicoides Species in the Top End of the NT.' Medical Entomology Branch Handout, Territory Health Services.

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

Whelan, P. I. (2003b), 'Personal Protection from Mosquitoes and Biting Midges in the NT', 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.I., Love, B., Montgomery, B., Nowland, R., Carter, J., Hayes, G., (1998), 'Durack (Fairway Waters) Development and Biting Insects May 1996 - April 1997.' (Study undertaken on behalf of Department of Lands, Planning and Environment). Territory Health Services.

Whelan, P.I., & Warchot, A. (2003), 'Biting midge investigation Archer Sporting Complex, Palmerston August 2003.' Study undertaken for Palmerston City Council, Department of Health and Community Services.

Whelan, P.I., Krause, V., Lamche, G. & Kurucz, N. (2004), '*Aedes aegypti* mosquitoes, vectors for dengue, found in Tennant Creek-Elimination Campaign in Progress.' *NT Disease Control Bulletin Vol 11,1, March 2004.*

Wightman, G.M. (1989), 'Mangroves of the Northern Territory', *Northern Territory Botanical Bulletin No. 7* (Conservation Commission, Palmerston, NT, now Parks & Wildlife Commission of the NT).

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

Table 6 - Darwin City Waterfront Redevelopment Proposal Biting Midge Trapping, November 8 to November 10, 2003					
Total number of female biting midges collected per trap night at all sites using CO2 baited EVS traps					
	Date collected				
Insect species	8-Nov-03	9-Nov-03	10-Nov-03	**Total**	**% of total**
C. (Orn grp) cordiger	1	0	0	1	0.2
C. (Orn grp) ornatus	471	14	75	560	92.1
C. (Orn grp) undescribed sp No 6	1	0	1	2	0.3
Culicoides unidentifiable	24	8	12	44	7.2
Lasiohelia sp.	0	1	0	1	0.2
Total	497	23	88	608	100.0
% of total	81.7	3.8	14.5	100.0	

Table 7 - Darwin City Waterfront Redevelopment Proposal Biting Midge Trapping Total number of female biting midges collected over three nights at each individual trap site using CO2 baited EVS traps								
	Biting midge species							
Trap location	*C. (Orn grp) cordiger*	*C. (Orn grp) ornatus*	*C. (Orn grp) undescribed sp No 6*	*Culicoides unidentifiable*	*Lasiohelia sp.*	*Nil Biting midges*	**Total**	**% of total**
Site 1 - S of New Deckchair Cinema Carpark against fenceline, Lameroo Beach area	0	3	0	1	1	0	5	0.8
Site 2 - Top of escarpment on Hughes Ave. approx 20m from the NW corner of Government house fenceline	0	66	0	20	0	0	86	14.1
Site 3 - Open area S of Kitchener Dve, opposite WWII tunnels entrance	0	19	0	1	0	0	20	3.3
Site 4 - Below escarpment in dense forest vegetation on Kitchener dve approx 100m E of WWII tunnels entrance	0	11	0	0	0	0	11	1.8
Site 5 - Frangipanii tree on the top of escarpment opposite Hughes Ave/Smith St intersection	0	9	0	0	0	0	9	1.5
Site 6 - In coffee bush 100m W of Rail way Carriage eatery area, Stokes Hill Wharf	0	8	0	11	0	0	19	3.1
Site 7 - Approx 50m from the base of the escarpment near the open area N of Indo Pacific Marine building.	0	37	1	2	0	0	40	6.6
Site 8 - Opposite small wharf, in coffee bush approx 50m from entrance gate to old deckchair cinema, Mavie Street	1	98	1	9	0	0	109	17.9
Site 9 - 3/4 of the way up the Escarpment east of old water fuel tanks in PAWA Compound.	0	309	0	0	0	0	309	50.8
Total	1	560	2	44	1	0	608	100.0

% of total	0.2	92.1	0.3	7.2	0.2	0.0	100.0	

Table 8 - Darwin City Waterfront Redevelopment Proposal Biting Midge Trapping Total number of Biting Midges collected using CO2 baited EVS traps 8 November 2003 at all sites						
	Insect species					
Trap location	*C. (Orn grp) cordiger*	*C. (Orn grp) ornatus*	*C. (Orn grp) undescribed sp No 6*	*Culicoides unidentifiable*	**Total**	**% of total**
Site 1 - S of New Deckchair Cinema Carpark against fenceline, Lameroo Beach area	0	2	0	1	3	0.6
Site 2 - Top of escarpment on Hughes Ave. approx 20m from the NW corner of Government house fenceline	0	44	0	9	53	10.7
Site 3 - Open area S of Kitchener Dve, opposite WWII tunnels entrance	0	7	0	1	8	1.6
Site 4 - Below escarpment in dense forest vegetation on Kitchener dve approx 100m E of WWII tunnels entrance	0	10	0	0	10	2.0
Site 5 - Frangipanii tree on the top of escarpment opposite Hughes Ave/Smith St intersection	0	5	0	0	5	1.0
Site 6 - In coffee bush 100m W of Rail way Carriage eatery area, Stokes Hill Wharf	0	6	0	11	17	3.4
Site 7 - Approx 50m from the base of the escarpment near the open area N of Indo Pacific Marine building.	0	26	0	2	28	5.6
Site 8 - Opposite small wharf, in coffee bush approx 50m from entrance gate to old deckchair cinema, Mavie Street	1	71	1	0	73	14.7
Site 9 - 3/4 of the way up the Escarpment east of old water fuel tanks in PAWA Compound.	0	300	0	0	300	60.4
Total	1	471	1	24	497	100.0
% of total	0.2	94.8	0.2	4.8	100.0	

Table 9 - Darwin City Waterfront Redevelopment Proposal Biting Midge Trapping						
Total number of Biting Midges collected using CO2 baited EVS traps 9 November 2003 at all sites (full moon night)						
	Insect Species					
Trap location	*C. (Orn grp) ornatus*	*Culicoides unidentifiable*	*Lasiohelia sp.*	*Nil Biting midges*	**Total**	**% of total**
Site 1 - S of New Deckchair Cinema Carpark against fenceline, Lameroo Beach area	1	0	1	0	2	8.7
Site 2 - Top of escarpment on Hughes Ave. approx 20m from the NW corner of Government house fenceline	1	0	0	0	1	4.3
Site 3 - Open area S of Kitchener Dve, opposite WWII tunnels entrance	3	0	0	0	3	13.0
Site 4 - Below escarpment in dense forest vegetation on Kitchener dve approx 100m E of WWII tunnels entrance	0	0	0	0	0	0.0
Site 5 - Frangipanii tree on the top of escarpment opposite Hughes Ave/Smith St intersection	3	0	0	0	3	13.0
Site 6 - In coffee bush 100m W of Rail way Carriage eatery area, Stokes Hill Wharf	1	0	0	0	1	4.3
Site 7 - Approx 50m from the base of the escarpment near the open area N of Indo Pacific Marine building.	0	0	0	0	0	0.0
Site 8 - Opposite small wharf, in coffee bush approx 50m from entrance gate to old deckchair cinema, Mavie Street	5	8	0	0	13	56.5
Site 9 - 3/4 of the way up the Escarpment east of old water fuel tanks in PAWA Compound.	0	0	0	0	0	0.0
Total	14	8	1	0	23	100.0
% of total	60.9	34.8	4.3	0.0	100.0	

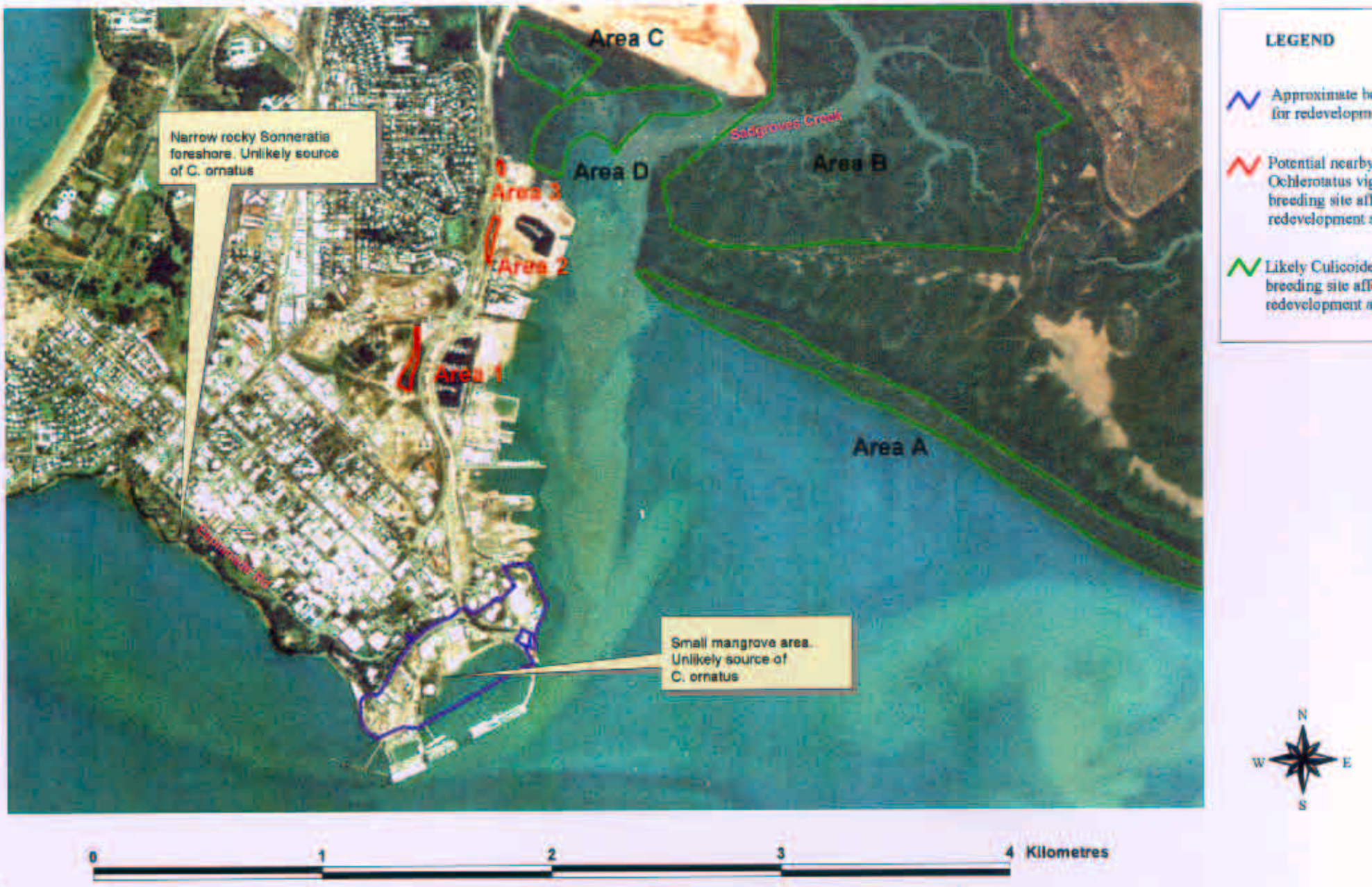
Table 10 - Darwin City Waterfront Redevelopment Proposal Biting Midge Trapping						
Total number of Biting Midges collected using CO2 baited EVS traps 10 November 2003 at all sites						
	Insect species					
Trap location	*C. (Orn grp) ornatus*	*C. (Orn grp) undescribed sp No 6*	*Culicoides unidentifiable*	*Nil Biting midges*	**Total**	**% of total**
Site 1 - S of New Deckchair Cinema Carpark against fenceline, Lameroo Beach area	0	0	0	0	0	0.0
Site 2 - Top of escarpment on Hughes Ave. approx 20m from the NW corner of Government house fenceline	21	0	11	0	32	36.4
Site 3 - Open area S of Kitchener Dve, opposite WWII tunnels entrance	9	0	0	0	9	10.2
Site 4 - Below escarpment in dense forest vegetation on Kitchener dve approx 100m E of WWII tunnels entrance	1	0	0	0	1	1.1
Site 5 - Frangipanii tree on the top of escarpment opposite Hughes Ave/Smith St intersection	1	0	0	0	1	1.1
Site 6 - In coffee bush 100m W of Rail way Carriage eatery area, Stokes Hill Wharf	1	0	0	0	1	1.1
Site 7 - Approx 50m from the base of the escarpment near the open area N of Indo Pacific Marine building.	11	1	0	0	12	13.6
Site 8 - Opposite small wharf, in coffee bush approx 50m from entrance gate to old deckchair cinema, Mavie Street	22	0	1	0	23	26.1
Site 9 - 3/4 of the way up the Escarpment east of old water fuel tanks in PAWA Compound.	9	0	0	0	9	10.2
Total	75	1	12	0	88	100.0
% of total	85.2	1.1	13.6	0.0	100.0	

Table 11: Mosquito larval surveys in and nearby the Darwin City Waterfront Redevelopment Area (Positive breeding only)				
Site location	**Date of survey**	**Average number of larvae per ladle dip**	**Mosquito Species**	**Area breeding (m^2)**
A1 - poorly draining grassy and dirt areas south-west and west of tram eatery	14/01/2003	1	*Ochlerotatus vigilax*	5
	22/01/2003	0.5	*Ochlerotatus vigilax*	2
	5/02/2003	0.5	*Culex annulirostris*	6
	7/02/2003	2	*Ochlerotatus vigilax*	8
	12/02/2003	0.5	*Ochlerotatus vigilax*	15
		0.5	*Culex annulirostris*	
	19/02/2003	0.25	*Ochlerotatus vigilax*	2
		0.25	*Culex annulirostris*	
	19/11/2003	4.17	*Ochlerotatus vigilax*	3
		0.83	*Culex annulirostris*	
	2/12/2003	1	*Ochlerotatus vigilax*	6
	15/12/2003	1	*Ochlerotatus vigilax*	2
	22/12/2003	3	*Ochlerotatus vigilax*	10
	9/01/2004	4	*Ochlerotatus vigilax*	20
	4/02/2004	4	*Ochlerotatus vigilax*	14
	26/02/2004	1	*Ochlerotatus vigilax*	5
A2 - Poorly draining grassy/bare area in vacant land east of Shell Bitumen Plant	22/12/2003	0.5	*Ochlerotatus vigilax*	30
A3 - Pooling on vacant propoerty east of Stella Maris Seafarers Centre	19/11/2003	1	*Culex annulirostris*	30

Table 11 Cont'd

Site location	Date of survey	Average number of larvae per ladle dip	Mosquito Species	Area breeding (m^2)
D1 - Open concrete drain at base of Stokes Hill	22/06/2001	2	*Culex annulirostris*	10
	26/02/2004	3	*Culex quinquefasciatus*	5
		3	*Culex annulirostris*	
D2 - Open concrete drain, opposite Stella Maris Seafarers Centre	14/05/2003	5	*Culex quinquefasciatus*	5
D3 - Open concrete drain, corner Kitchener Drive and McMinn Street, indcludes letterbox pit.	22/06/2001	1	*Culex annulirostris*	5
	14/05/2003	4	*Culex annulirostris*	5
		5	*Culex quinquefasciatus*	
D4 - Open concrete drain from outlet pipe, alongside Kitchener Drive, north of Shell Bitumen Plant	22/06/2001	50	*Culex quinquefasciatus*	Unknown (water pooling in outlet pipe due to silt blockage)
	14/05/2003	0.5	*Culex annulirostris*	0.2
D5 - Open unlined drain at base of hill, near Deckchair Cinema	22/06/2001	1	*Culex annulirostris*	30
		1	*Culex quinquefasciatus*	

Figure 1: Darwin City Waterfront Redevelopment. Probable Culicoides ornatus and Ochlerotatus vigilax breeding sites outside the redevelopment area that are likely to affect the redevelopment area.



C:\Documents and Settings\w4e\wharf redevelopment\layouts\figure 1

Medical Entomology Branch QHCS

Figure 2: Darwin City Waterfront Redevelopment. Adult biting insect trap locations

C:\Documents and Settings\w4s\wharf redevelopment\layouts\figure 2

Medical Entomology Branch DHCS

Figure 3: Darwin City Waterfront Redevelopment. Location of open drains, and actual and potential mosquito breeding areas

Figure 4 - Total monthly number of female mosquitoes from Grey Collar Club routine weekly monitoring site, and total monthly rainfall (mm) for 2003.

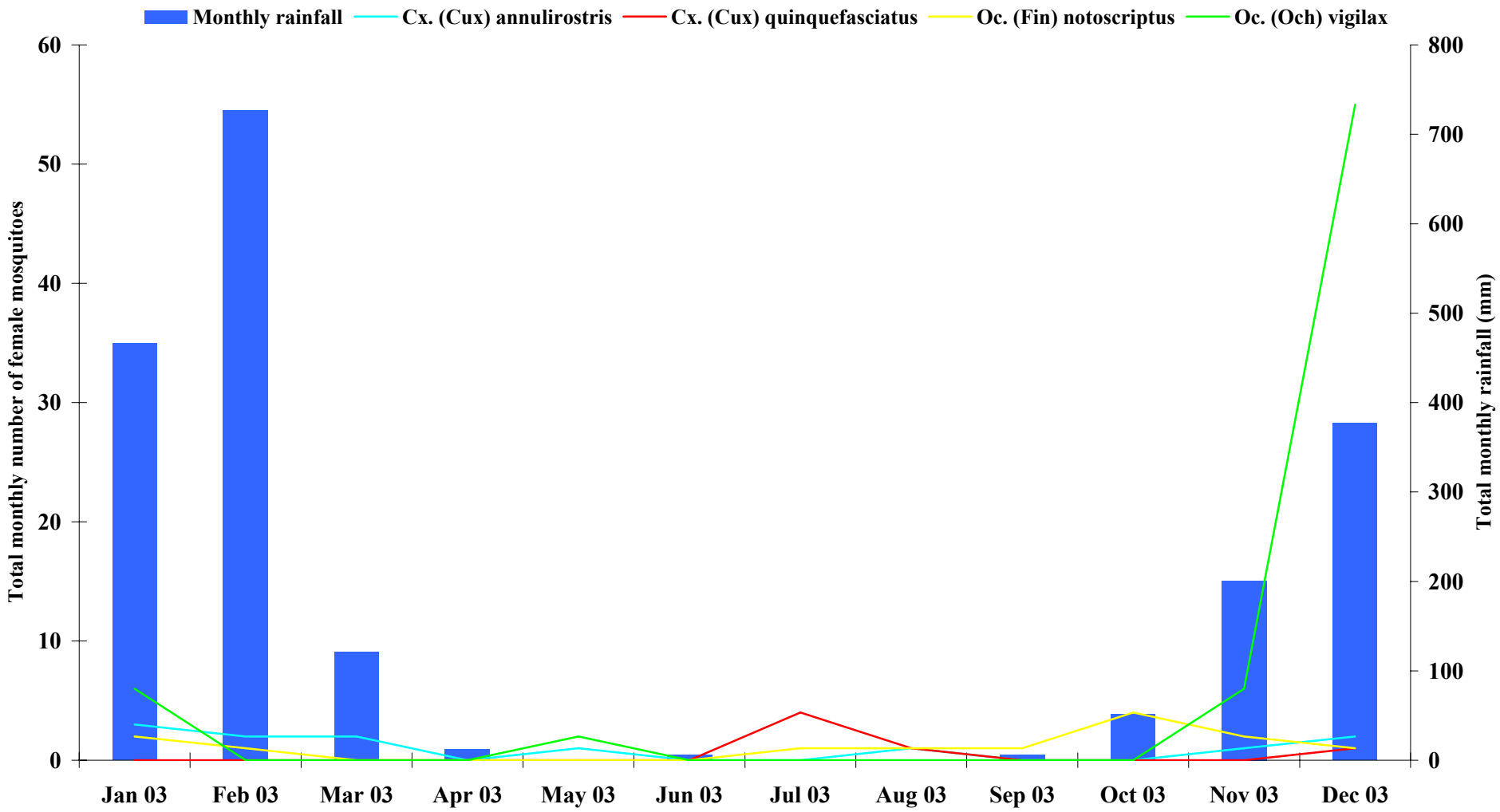


Figure 5 - Biting midge investigations "Fairway Waters" Palmerston May 1996 to April 1997
Seasonal trend of *C. ornatus* and *C. marksi* collected from all sites on all monthly trap nights, and total monthly rainfall.