Appendix K

Biting Insects Assessment Report

NOONAMAH RIDGE

INTRAPAC

Northern Territory Government

DEPARTMENT OF HEALTH

Noonamah Ridge Estate biting insect assessment.

Final Report June 2015

Study undertaken for EcOz Environmental Consultants on behalf of Intrapac Projects

Medical Entomology
Centre for Disease Control
NT Department of Health
June 2015

Noonamah Ridge Estate biting insect assessment

Final Report June 2015

Study undertaken for EcOz Environmental Consultants on behalf of Intrapac Projects

Allan Warchot & Nina Kurucz
Medical Entomology
Centre for Disease Control
NT Department of Health
June 2015

List of Tables

List of Figures

1.0 Introduction

The proposed residential sub-division of Noonamah Ridge Estate is located approximately 36km southeast of the Darwin CBD, bounded by Townend Road to the south, and bounded by rural residential lots on the southern side of Goode Road. The proposed development site contains and is within proximity to seasonally inundated areas that could be potential breeding sites for pest and disease carrying mosquitoes. Previous baseline studies have been carried out in the 1980's around seasonally flooded areas associated with the Elizabeth River to the west of the project site, which recorded seasonal levels of pest and disease carrying mosquitoes. However, baseline mosquito data was not available for most of the proposed Noonamah Ridge Estate.

Due to the absence of mosquito data from the proposed estate, and the potential for swamps previously targeted for baseline trapping to have changed in nature since the 1980's, EcOz Environmental Services on behalf of Intrapac Projects commissioned Medical Entomology, Department of Health to carry out a biting insect assessment of the proposed Noonamah Ridge Estate, to gain current knowledge of the mosquito abundance and diversity in the area.

The biting insect assessment consisted of:

- Biting insect trapping during peak abundance periods (January, February, May and June 2015).
- An evaluation of the mosquito trapping results, with regard to pest and potential mosquito borne disease transmission and the likely sources of mosquito vectors.
- An evaluation of previous baseline trapping results from seasonally flooded areas to the west of the proposed development site.
- Recommendations on engineering and mosquito control measures required to reduce the impact of mosquitoes on the proposed urban areas of Noonamah Ridge Estate.
- Recommendations on stormwater drainage design, to prevent future urban development from creating or exacerbating mosquito breeding in the area.

2.0 Aims

2.1 Mosquitoes

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 other diseases caused by Kunjin virus (KUNV), Ross River virus (RRV) and Barmah Forest virus (BFV).

For this study, traps were set around the time of the full moon during months of likely increased mosquito abundance, and also around three weeks after the end of the first monsoon burst. The mid wet season month of January was chosen for post

monsoon trapping. The early dry season months of May and June were also chosen, due to these months usually being the peak season for most freshwater mosquitoes in the Darwin Region. An extra trapping event was also carried out in mid February, due to the high mosquito numbers collected in late January.

Development can lead to the creation of new breeding sites for pest and disease vector mosquito species through the inappropriate storage or disposal of stormwater, and in particular dry season flows in stormwater drains. Leanyer Swamp was a leading example of mosquito issues that can arise from dry season urban stormwater runoff being directed into low lying areas. Stormwater treatment systems could also become breeding sites for pest and disease carrying mosquitoes, if they are not designed to be free draining or free from potential mosquito breeding habitat. Therefore, a further aim was to provide advice on potential stormwater design requirements to minimise development from exacerbating or creating new mosquito breeding sites.

2.2 Biting midges

Biting midges can be considerable pests within a few kilometres of the coast in the NT, with highest numbers occurring up to 1.5km from the mangrove margin. These pests can cause problems due to their painful bites, while some people experience secondary effects such as intense itching and skin infections from scratching, and a loss of a sense of wellbeing. Biting midges however are not known to transmit human disease in Australia.

The entire area of Noonamah Ridge Estate is considered too far from tidal mangrove areas for biting midges to cause any development constraints, although there are freshwater biting midges that could cause occasional nuisance issues. Therefore, biting midges were still collected and stored for identification at a later date, but are not discussed in this report.

3.0 Methods

3.1 Trapping

A total of 10 trap sites were chosen for the baseline trapping program, at locations nearby to potential mosquito breeding areas, as well as along the fringes of the estate and towards the proposed village centre. Trap sites are shown in Figure 1.

The traps used were carbon dioxide baited EVS traps (Rohe and Fall 1979). The traps consisted of an insulated bucket, a suction fan powered by two ‘D’ cell batteries, a ‘grain of wheat’ light, and a rigid collection container (4 litre, 220 mm in diameter) fitted with a muslin sleeve and very fine wire mesh vents. The traps were set around chest height and baited with approximately 1kg of dry ice. Traps were set in the late afternoon before sundown and collected the following morning after 8am. Navigation to the trap sites was by 4WD vehicle and 4WD quad bikes.

3.2 Mosquito processing

Collected mosquitoes were stored in a petri dish in a freezer (-10^{0}C) on the day of collection for later identification. For catches less than 300 mosquitoes, each individual mosquito was identified. For catches over 300 mosquitoes, a sub sample of around 300 mosquitoes was obtained from the bulk sample, with all mosquitoes in the sub sample identified and the bulk scanned for species not present in the sub sample. A multiplication factor was calculated by dividing the weight of all mosquitoes by the weight of the sub sample, which was then applied to the sub sample results to get an overall count of each species. 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). All species and totals for each individual collection were then entered into an access database for evaluation.

3.3 Mosquito field surveys

Brief larval mosquito sampling was carried out on the 28th of January 2015, along the creekline where traps NR7 and NR8 were set. However, adverse weather conditions prevented a more thorough survey of this creekline.

A brief survey was also carried out on the 27th of April 2015, to determine potential mosquito breeding sites during this period of the year in areas close to the proposed village centre. Survey points are shown in Figure 1.

4.0 Results

4.1 Mosquitoes

4.1.1 Species present

There were a total of 26,662 adult female mosquitoes collected during the four trapping events at the 10 sites, representing a total of 28 species (Table 1). The most abundant mosquito was the common banded mosquito *Culex annulirostris,* which accounted for 74.19% of all mosquitoes collected. This was followed by the golden mosquito *Coquillettidia xanthogaster,* which accounted for 19.05% of all mosquitoes collected. All other mosquito species individually accounted for less than 2% of all mosquitoes.

4.1.2 Spatial abundance

The most productive trap site was Trap Site NR7, which recorded 15.54% of all adult female mosquitoes, at an average of 1036 per trap night (Table 1). This was closely followed by NR9, which recorded 14.73% of all mosquitoes, at an average of 982 per trap night. Trap Site NR2 was the third most productive trap site (13.39%, ave. per trap night of 892), followed by NR1 (10.49%, ave. per trap night of 699). All other trap sites, with the exception of NR6B, recorded over 478 adult female mosquitoes per trap night.

Trap Sites NR6A and NR6B were set relatively close to each other (about 40m), but not close enough to scientifically incorporate the results together. However, if the results were incorporated together, it would indicate that this area has a similar seasonal mosquito abundance compared to NR1.

Culex annulirostris was most abundant at Trap Site NR2, with a total of 3255 adult females collected over four trap nights (Table 1). Trap Sites NR9, NR1 and NR7 were the next most productive trap sites for this mosquito, recording 2618, 2535 and 2455 adult females respectively over the four trap nights. This was followed by NR6a (2064 adult females from one trap night), NR5 (1773 over 4 trap nights), NR4 (1415 over 4 trap nights) and NR3 (1384 over 4 trap nights).

Coquillettidia xanthogaster was most abundant at Trap Site NR7, with a total of 1337 adult females collected over four trap nights (Table 1). The next most productive trap sites for this mosquito were NR9 (956 over four trap nights), NR3 (715 over four trap nights), and NR8 (633 over four trap nights).

Mansonia uniformis and *Anopheles bancroftii* were most abundant at Trap Site NR7, recording 132 and 97 adult females respectively over the four trap nights (Table 1). *Anopheles farauti s.l.* was most abundant at Trap Site NR8, with 68 adult females collected over four trap nights (Table 1).

4.1.3 Seasonal abundance

January was the most productive month for mosquitoes, recording 47.91% of all mosquitoes collected during the baseline trapping (Tables 2 & 3), at an average of 1277 per trap (Table 3). June was the next most productive month, recording 23.72% of all mosquitoes at an average of 632 per trap (Table 3). February caught slightly fewer mosquitoes than June, recording 21.37% of all mosquitoes. However, only 9 traps were successfully set in February compared to 10 in June. Therefore, the average of 633 per trap in February was marginally higher than the June average per trap of 632. May was the least productive month for mosquitoes, recording 7% of all mosquitoes with an average of 187 per trap.

January was by far the most productive month for *Cx. annulirostris,* with 11,742 adult females collected in the 10 traps (Tables 3 & 4). February was the next most productive month, with 5,297 adult females collected in the 9 traps (Tables 3 & 5), followed by June (1547 adult females from 10 traps, Tables 3 & 7) and lastly May (1195 adult females from 10 traps, Tables 3 & 6).

June was by far the most productive month for *Cq. xanthogaster,* with 4267 adult females collected from the 10 traps (Tables 3 & 7). This was followed by May, with 527 adult females collected from 10 traps (Tables 3 & 6). Low numbers of this mosquito were recorded in January and February (Tables 3 to 5).

Mansonia uniformis and *An. bancroftii* were most common in June (Tables 3 & 7), with minimal numbers recorded during the other months. *Anopheles farauti s.l.* was most common in June (Tables 3 & 7), followed by May (Tables 3 & 6).

4.1.4 Darwin Rural 2 Baseline Mosquito Trapping 1986 to 1987

The results of the Darwin Rural 2 baseline trapping for the 3 nearest traps to Noonamah Ridge Estate are shown in Tables 8 to 10, with trap locations shown in Figure 1.

The Darwin Rural 2 Trap Site 1 was located at the Elizabeth Valley Rd culvert, about 2.7km to the west of Noonamah Ridge Estate. The trap site was located too far away for the results to be applicable to Noonamah Ridge Estate. However, the results provide an indication of the mosquito breeding habitat along this part of the Elizabeth River. The results indicated a peak in mosquito abundance in May and June (Table 8). The peak month for *Cx. annulirostris* abundance was June, with a total of 334 adult females collected. *Culex annulirostris* numbers in the mid wet season (January/February) were very low. Overall, peak *Cx. annulirostris* numbers during the Darwin Rural 2 baseline study did not reach levels anywhere near what was recorded in Noonamah Ridge Estate. The *Anopheles* mosquitoes reached peak numbers from March to May, while *Cq. xanthogaster* reached peak numbers in June, with elevated numbers in May and September.

The Darwin Rural 2 Trap Site 2 was located on Lot 54 Horsnell Rd adjacent to the creek, about 830m west of Noonamah Ridge Estate, and about 770m west of trap site NR6a. The trap results are applicable to the proposed development. Overall, mosquito numbers were generally low throughout the year, except for a peak in *Cq. xanthogaster* numbers during May (Table 9). May was the peak month for mosquito abundance at the Rural 2 Trap Site 2. The low *Cx. annulirostris* numbers at this historic baseline trap site is in contrast to the very high *Cx. annulirostris* numbers collected at trap site NR6a in January 2015.

The Darwin Rural 2 Trap Site 3 was located at the creek at the end of Hughes Rd, about 1.9km west of Noonamah Ridge Estate. Mosquito numbers were highest in May and June, with *Cq. xanthogaster* and *Cx. annulirostris* the predominant mosquitoes, followed by *Mansonia uniformis* (Table 10). Overall, *Cq. xanthogaster* numbers were moderate, while *Cx. annulirostris* numbers were relatively low. Again, *Cx. annulirostris* numbers did not reach the numbers recorded during the Noonamah Ridge Estate trapping.

4.1.5 Potential breeding sites

4.1.5.1 Larval mosquito surveys

Brief larval mosquito sampling was carried out on 28th January 2015, with survey locations shown in Figure 1. Seasonally flooded grassy creekline areas were surveyed adjacent to traps NR7 and NR8 (Sites L1 & L2), with no mosquito breeding located. Water was flowing quite rapidly down the wheel ruts which were present

along almost the entire length of the grassy creekline. It is likely that the grassy creekline was an important mosquito breeding site before water began to flow, with late wet season and early dry season breeding also likely to occur in residual grassy pools. The main mosquito species expected to breed in the grassy creekline are *Cx. annulirostris, Cq. xanthogaster* and *Anopheles* species mosquitoes. It is likely that this highly disturbed creekline is one of the more important mosquito breeding sites affecting the proposed village centre.

Areas of Noonamah Ridge Estate nearby to the proposed village centre were also investigated on 27th April 2015. Survey locations are shown in Figure 1. All seasonally flooded/waterlogged areas were dry, most likely due to well below average wet season rainfall. The Sandsheet Heath habitat in the northern portion of the site was dry (Site L3), and in general, appeared to be a low nutrient environment and thus unlikely to provide productive mosquito breeding habitat. The downstream reaches of this habitat (Site L5) also appeared to be a low nutrient environment which is unlikely to allow productive mosquito breeding. The small weed infested borrow pits in the northwest portion of the site (Site L4) appeared to be potentially productive breeding habitat for *Cx. annulirostris* and *Anopheles* species.

The seepage area to the southeast of NR4 (Site L8) also appeared to be a relatively low nutrient environment, although the presence of numerous small depressions and greater ground cover compared to the Sandsheet Heath habitat indicated the potential for mosquito breeding in this area after initial flooding in the early/mid wet season, and during the late wet season. Other similar areas are also likely to be mosquito breeding sites of moderate importance in the proposed estate. The small creekline downstream of this area (Site L7) was flowing clear water and contained fish, but could be a localised mosquito breeding site when water flows cease and isolated pools form.

The small swamp on the west side of Redcliffe Rd (Site L9) near the northwest corner of the estate was dry. The roadside drain on the east side of the road was flowing, and probably minimised wet season surface ponding in the adjacent seasonally waterlogged area. The swamp on the west side of the road appeared to contain suitable habitat for productive early/mid wet season *Cx. annulirostris* breeding. Depending on how long the swamp ponds water, it may also be a productive and late wet season/early dry season breeding site for *Cx. annulirostris* and *Anopheles* species mosquitoes. As the area was dry during the survey, the extent of seasonal ponding and potential mosquito breeding remains unknown. If widespread flooding occurs during the wet season, then it is likely that this is one of the more important mosquito breeding sites affecting the proposed village centre.

The seasonally waterlogged areas either side of Horsnell Road were dry at the time of the survey. There is a possibility that productive *Cx. annulirostris* breeding occurs in the seasonally waterlogged area after initial flooding in the early/mid wet season, particularly where it has been cleared for horticulture. The downstream side appears to be drained to some extent by a small drain through Lot 15. If widespread ponding occurs throughout this area, then it is likely to be one of the most important mosquito breeding areas affecting the proposed village centre.

4.1.5.2 Desktop analysis

Potential mosquito breeding sites likely to affect Noonamah Ridge Estate were assessed using high resolution aerial photography. Potential breeding sites are indicated in Figures 1 and 2.

The January adult mosquito trap results suggested that many of the seasonally flooded swamps and grasslands within and adjacent to Noonamah Ridge Estate are likely to be productive breeding sites, after initial widespread flooding following the first monsoon rains. The northern edge of the proposed estate appeared to be affected by very high *Cx. annulirostris* dispersal from the three large swamps just to the north of Goode Rd. The areas of Noonamah Ridge Estate within about 1.6-2km of these swamps would be most affected. The results from the February trapping, about three weeks after the January trapping, still revealed moderate to high levels of *Cx. annulirostris* but about half the January numbers, suggesting bio control started to provide natural control of *Cx. annulirostris* populations. Most mid wet season *Cx. annulirostris* peaks in other areas of Darwin usually last about two weeks to one month, therefore it is likely that *Cx. annulirostris* numbers at Noonamah Ridge Estate continued to decline due to predation. Numbers were likely to have been low to moderate from late February to April.

The January trap results from the southwest corner of Noonamah Ridge Estate suggested the open seasonally flooded area to the north of trap site NR9, and the small paperbark swamp on both sides of Townend Rd are productive mid wet season breeding sites for *Cx. annulirostris.* It is likely that the open seasonally flooded area was more productive than the relatively shaded paperbark swamp, as open sunlit swamps are usually more productive mosquito breeding sites. It is also possible that some of the *Cx. annulirostris* at NR9 were originating from the cleared seasonally waterlogged areas of the creekline to the west of Redcliffe Rd.

The January trap results from the western edge of the centre of the proposed estate (NR6a) suggested high *Cx. annulirostris* dispersal from breeding sites either in the headwaters of the nearby small creek where no incised channel is evident, or dispersal from disturbed seasonally flooded areas to the west of Redcliffe Rd.

The January trap results from the centre of the proposed estate suggested high productivity breeding in the seasonally grassy/vehicle disturbed creekline that runs southeast to northwest in this part of the estate. Potential *Cx. annulirostris* breeding areas along this creekline were likely to have been grassy areas that were inundated with early wet season rainfall, including the wheel ruts before they started to flow water.

The January trap results from the proposed village centre, in the northwest portion of Noonamah Ridge Estate, suggested that the area is significantly impacted by mosquito breeding. Trap catches could have been influenced by dispersal from the seasonally flooded areas west of Redcliffe Rd, with the large wetlands north of Goode Rd also likely to have contributed to the *Cx. annulirostris* abundance in the proposed village centre. Dispersal probably also occurred from the low lying grassy areas associated with the vehicle disturbed creeklines to the south of the proposed

village centre. The low lying areas to the north of the proposed village centre do not appear to be significant mosquito breeding areas, except where several weed infested borrow pits are present.

The trap results also indicated a low to moderate *Cx. annulirostris* peak occurred in the early dry season, with breeding likely to have occurred in residual pools in the grassy creeklines and various small swamps in the estate, and also in the swamps north of Goode Rd. Highest dry season numbers were encountered around the vehicle disturbed grassy creekline where traps NR5 and NR7 were set, and in the northern portion of the site closest to the Goode Rd swamps (Traps sites NR2 & NR10). The much lower peak compared to the January and February peak indicates breeding sites were much smaller compared to the mid wet season breeding sites. The larval sampling indicated that many low lying areas in and adjacent to the estate rapidly dry out once consistent heavy rains cease. In other areas of Darwin, such as Micket Creek, the early-mid dry season *Cx. annulirostris* peak is usually larger than the mid wet season peak, as the swamps pond water well into the dry season.

The golden mosquito *Coquillettidia xanthogaster* reached a peak in June, with highest numbers at trap site NR7 adjacent to the vehicle disturbed grassy creekline, and near the small paperbark swamp at the southwest corner of the estate, indicating these sites are likely to be important breeding sites for *Cq. xanthogaster.* Elevated numbers were also recorded in other areas of the estate nearby to creeklines with dry season flows/ponding.

Anopheles species mosquitoes also reached a peak in June, with numbers of *An. bancroftii* highest at the trap site NR7 vehicle disturbed creekline, while highest *An. farauti s.l.* numbers were recorded at the creekline and associated swamp at the southeast portion of the estate. The breeding sites for this mosquito at the estate therefore appear to be residual dry season ponding in swamps and creeklines.

5.0 Discussion

5.1 Mosquitoes

5.1.1 Species present

The common banded mosquito *Culex annulirostris* was the most important disease vector mosquito collected during the baseline trapping, and also the most common mosquito collected. *Culex annulirostris* is considered the most important disease vector mosquito in the NT, due to the fact that it has the potential to transmit all known endemic mosquito borne diseases of humans in the NT, including the potentially fatal disease caused by Murray Valley encephalitis virus. It is also considered a potential vector of serious exotic diseases such as Japanese encephalitis. *Culex annulirostris* is usually the most common mosquito in the Top End from January to August.

The golden mosquito *Coquillettidia xanthogaster* was the second mosquito common mosquito recorded during trapping, and is important in terms of being a potential pest mosquito, and due to this species being known to reach very high levels in some areas of the Top End.

The northern salt marsh mosquito *Aedes vigilax* was collected in minor numbers during the January trapping. Noonamah Ridge Estate is about 11km from the large tidal swamps and floodplains of the Adelaide River, which is in flight range of this species when major breeding events occur during the late dry season and early wet season. Therefore it is possible that *Ae. vigilax* would seasonally be an important mosquito affecting Noonamah Ridge Estate, as a pest mosquito, and a potential vector of mosquito borne diseases.

Anopheles mosquitoes such as *An. bancroftii, An. annulipes s.l.* and *An. farauti s.l.* were collected in low numbers at some trap sites, and are important in terms of their potential to transmit malaria. The significant pest mosquito *Mansonia uniformis* was recorded in low numbers at some sites, and the urban receptacle breeding mosquito *Aedes notoscriptus* was also recorded in low numbers at some sites during the January trapping.

5.1.1.1 *Culex annulirostris* (common banded mosquito)

Breeding sites

Typical breeding sites for this mosquito are semi-aquatic reed swamps and creeklines, shallow grassy floodplains, shallow billabongs and temporary ground pools with emergent vegetation. This species also breeds in sewage ponds with un-maintained margins and sewage overflow areas, stormwater drains with polluted dry season flows, and artificial wetlands with semi-aquatic vegetation.

Culex annulirostris larvae were not located during sampling in the grassy flooded areas around trap site NR7, although the grassy flooded areas appeared to be suitable breeding habitat for this mosquito. Potential breeding sites affecting Noonamah Ridge Estate were discussed in Section 4.1.5 of this report.

Seasonal abundance

Culex annulirostris is most abundant from January to August in the Top End of the Northern Territory (Whelan 1997), with two peaks usually occurring in this period, a short early/mid wet season peak and an extended late wet-mid dry season peak, depending on the characteristics of nearby breeding sites. The short wet season peak arises when low lying areas become inundated, with *Cx. annulirostris* mosquitoes one of the first insects to colonise the newly flooded area. Once fish and other aquatic predators of mosquitoes colonise the flooded areas, natural mosquito larvae control occurs. The late wet to mid dry season peak occurs when swamps and creeklines begin to dry, leaving behind shallow heavily vegetated pools where mosquito larvae predation is minimal due to physical inaccessibility for fish and other aquatic predators.

The late January trapping revealed that much of Noonamah Ridge Estate experienced high to very high numbers of this mosquito, with moderate to high numbers throughout much of the estate in mid February. Post wet season trapping in May and June revealed low to moderate *Cx. annulirostris* numbers. It is likely that *Cx. annulirostris* would be present in low to moderate numbers during the months of March and April, and July, in areas of the estate nearby to creeklines and seasonally flooded low lying areas.

When the January results are compared to trap results from other areas of the Darwin Region, the *Cx. annulirostris* numbers collected at all sites in Noonamah Ridge Estate were much higher than what was recorded a day earlier from 15 sites around the urban fringes of Darwin. When the June results are compared to the trap results from the Darwin urban fringes, *Cx. annulirostris* numbers were similar to bushland across the road from Karama, but higher than in other fringe areas of Darwin urban.

Spatial abundance

Culex annulirostris can disperse up to 10km from extensive breeding sites, although they are most common within 4km of breeding sites (Whelan 1997a), and there is usually a significant drop in *Cx. annulirostris* numbers 2km away from appreciable breeding sites (Whelan 2004a). Mosquito dispersal investigations have indicated that *Cx. annulirostris* experiences a relatively steep decline in numbers from 1.5km to the 2km mark from their breeding sites in the Darwin Northern Suburbs (Medical Entomology unpublished data).

The January trapping results revealed high to very high numbers throughout much of Noonamah Ridge Estate. The fringes of the northern, middle and southwest portions were the most productive, with high numbers in the centre of the estate adjacent to

the large grassy creekline, and high numbers also at the proposed village centre, although at lower levels than most of the other areas of the estate. Dry season abundance was lower than wet season abundance, with highest numbers collected adjacent to creeklines with dry season ponding, and in the northern edge of the estate closest to the Goode Rd swamps.

Pest numbers

Culex annulirostris only bites at night, is less aggressive compared to other common pest mosquitoes such as *Ae. vigilax, An. bancroftii,* and *Cq. xanthogaster,* and is more timid in the presence of lights and personal protection measures. Generally a much higher EVS trap count is required to indicate a potential appreciable pest problem compared to the other species. In the Darwin Northern Suburbs, a trap catch of 600 per trap in a trap set between residential areas and the breeding sites generally indicates a potentially appreciable pest problem for the adjacent residential area, while a trap catch of 50 per trap in a trap set within a residential area indicates a potential pest problem (Whelan 1997a).

At Noonamah Ridge Estate, the bushland pest threshold was greatly exceeded at six of the trap sites in January, with three trap sites recording levels around the pest threshold, with site NR8 in the southeast corner recording levels below the pest threshold. Trap results from February recorded levels either above the threshold, or slightly below the threshold, at most sites. This indicates the potential for pest problems to occur throughout much of the estate during the mid wet season. The pest threshold was not exceeded during dry season trapping, although low to moderate numbers were recorded close to areas of dry season ponding, and therefore nuisance problems can be expected in those areas.

5.1.1.2 *Coquillettidia xanthogaster* (the golden mosquito)

This mosquito breeds in association with semi-aquatic reeds and other aquatic or semi-aquatic vegetation such as water lilies and grasses, from which they obtain air direct from under water sections of the live plant by a specialised penetration siphon. This larval adaptation prevents the successful surveillance of the breeding sites of this mosquito. The roots of semi-aquatic plants, such as pandanus or paperbark trees may also provide suitable breeding habitat. The most productive breeding sites at Noonamah Ridge Estate appeared to be the vehicle disturbed grassy creekline where traps NR7 and NR5 were set, and the small paperbark swamp at the southwest edge of the estate. It is likely that other grassy creeklines and paperbark/pandanus lined creeklines would also be seasonal sources of *Cq. xanthogaster.* Dispersal is also likely to occur to the estate from the swamps north of Goode Rd.

Peak numbers of this mosquito generally occur in the late wet to mid dry season when semi-aquatic vegetation presence is greatest in shallow flooded areas. *Coquillettidia xanthogaster* is usually most abundant within 2-3km of their breeding sites, although this mosquito can fly further from very large breeding sites. Although *Cq. xanthogaster* is not known to be a vector of human disease in Australia, it can be

a serious pest mosquito. The baseline trapping located greatest numbers during June, with minor numbers during the other months.

Highest *Cq. xanthogaster* numbers were recorded at trap site NR7, followed by trap site NR9, with relatively high numbers at trap site NR2, indicating at least these areas of the estate would experience high seasonal pest problems. The baseline trapping suggested all other areas of the estate would experience nuisance to moderate seasonal pest problems.

5.1.1.3 *Anopheles* mosquitoes

Anopheles mosquitoes usually breed in greatest numbers in freshwater or brackish water reed swamps and paperbark swamps, and also in drains and creeklines with semi-aquatic vegetation. The January results indicated that the mosquito was most likely breeding in grassy creeklines and seasonally flooded localised swamps, similar to *Cx. annulirostris.* The May and June results suggested the early dry season was the peak season for *Anopheles* species mosquitoes at Noonamah Ridge Estate. The most productive breeding habitat appeared to be the open grassy creekline where trap site NR7 was set, along with the creekline and small swamp where trap site NR8 was set. Other creeklines with dry season ponding also appeared to be breeding sites for this mosquito, although produced only minor numbers. The swamps north of Goode Rd were expected to be sources of *Anopheles* mosquitoes to the northern portion of the estate, although trapping suggested these swamps have little impact on the proposed estate for these mosquitoes. Overall, the numbers recorded during baseline trapping were not indicative of an appreciable pest problem, and therefore it is likely that *Anopheles* species mosquito would not be a major pest mosquito at the estate.

5.1.1.4 *Aedes vigilax* (northern salt marsh mosquito)

Typical breeding sites for *Ae. vigilax* include salt marshes, brackish water reed swamps, coastal interdune depressions, poorly draining upper tidal mangrove areas, tidally affected stormwater drains and disturbed upper tidal areas (Whelan 1997a). Eggs are laid in damp depressions in suitable upper tidal areas. Extensive breeding occurs after high tides of about 7.4m and higher in Darwin Harbour and rainfall events over 25mm in the upper tidal zone, from around 7.4m ACD to just above the 8m ACD (maximum high tide) level.

There would be no breeding sites for this species in Noonamah Ridge Estate. However, due to the very long flight range of *Ae. vigilax* (over 60km in pest numbers from large breeding sites), it is expected that some seasonal pest problems may occur in Noonamah Ridge Estate when very large breeding events occur in the Adelaide River tidal swamps. Pest problems are most likely to occur 9-10 days after heavy rains and/or high tides in November and December. The actual pest problems would need to be verified during trapping in November or December. However, occasional complaints to Medical Entomology from Humpty Doo residents suggest that seasonal pest problems might also occur at Noonamah Ridge Estate.

5.1.1.5 Other mosquito species

The water lily mosquito *Mansonia uniformis,* which can be a serious pest mosquito, was recorded in highest numbers at the grassy vehicle disturbed creekline (NR7) in June. The numbers recorded were indicative of a potentially high pest problem. Limited numbers elsewhere suggest this mosquito would not cause widespread pest problems, with areas of the estate closest to creeklines with grassy pools likely to be most affected.

Aedes notoscriptus, the receptacle breeding mosquito, was recorded in very low numbers during trapping. Natural breeding sites are generally tree holes, although this species is highly adaptable to the urban environment and will breed in any artificial receptacle, such as pot plant drip trays, buckets, small containers, rubbish items, stormwater pits, blocked roof gutters and rain water tanks. This species generally increases in numbers after urban development, due to the increased availability of artificial breeding sites. *Aedes notoscriptus* is occasionally implicated in pest complaints, usually from people living next door to houses containing lots of pot plants (with drip trays) and water storage containers.

5.1.2 Mosquito borne disease

5.1.2.1 Ross River virus disease

Ross River virus (RRV) is responsible for the most common arboviral disease in Australia (Russell & Kay 2004), and is the most common mosquito borne disease transmitted by mosquitoes in the Northern Territory (Whelan et al 2008). Symptoms can be debilitating and include joint pain, fever, lethargy, rash, headache and swollen glands, and can last for up to 12 months in some cases, although generally most people will have a severe illness from two weeks to three months (CDC Factsheet 2013).

The main risk months for RRV transmission are December to June, with a January to February peak, although transmission can occur in all months (Whelan 1997b). The humid months of December to March increases the life span of vector mosquitoes, thus increasing the chance of vector mosquitoes living long enough to obtain a virus from a vertebrate host (presumed to be wallabies in the Top End of the NT) and pass it on to a human.

It is thought that about 100 *Cx. annulirostris* in an overnight trap is enough to sustain RRV transmission (Whelan 1987). The very high *Cx. annulirostris* numbers in January, one of the peak months for RRV transmission, indicate that there is a high risk of RRV transmission throughout much of Noonamah Ridge Estate during the mid wet season months of January and February. The early dry season trapping suggested there is a low to moderate RRV risk during this period of the year. During November to January, the northern salt marsh mosquito *Ae. vigilax* is expected to periodically pose a potential RRV risk throughout the estate.

Aedes notoscriptus is another potential vector of RRV, and is likely to pose a low risk during the wet season months, although the RRV risk from *Ae. notoscriptus* will increase when new breeding sites are created by urban development. The storage of water in domestic water containers has the potential to increase the virus risk associated with this species, particularly water storage in unscreened drums/tubs and non-compliant or un-maintained rainwater tanks. Typically, this mosquito is generally only encountered in low numbers around urban Darwin, with high numbers occasionally encountered in poorly maintained yards.

5.1.2.2 Barmah Forest virus disease

Barmah Forest virus (BFV) causes similar symptoms to RRV, but symptoms are generally milder and BFV is not as common as RRV (CDC Factsheet 2013). The principal potential vectors of BFV recorded in Palmerston North were *Ae. vigilax, Cx. annulirostris* and *Ae. notoscriptus.* Main risk months for BFV transmission are the months of October to July, with a peak in January to March, although transmission can occur during all months (Whelan 1997b). The risk of BFV transmission is likely to be similar to the RRV transmission risk in Noonamah Ridge Estate, although BFV is a less common disease.

5.1.2.3 Murray Valley encephalitis virus disease

Murray Valley encephalitis virus (MVEV) can cause a potentially fatal inflammation of the brain tissue (CDC Factsheet 2013). Symptoms include high fever, severe headache, seizures or fits (especially in young children), neck stiffness, drowsiness, confusion and progression to delirium and coma in severe cases (CDC Factsheet 2013). The principal potential vector of MVEV recorded in Noonamah Ridge Estate was *Cx. annulirostris.* The main risk months for MVEV transmission are January to July, with a peak in March to May (Whelan 1997b).

Sentinel chicken data has indicated MVEV activity occurs in Howard Springs adjacent to Dutchies Lagoon and the edge of Leanyer Swamp during some years (ME Annual Report 2013/14). It is therefore likely that *Cx. annulirostris* mosquitoes carrying the virus are also seasonally present in Noonamah Ridge Estate.

When considering the likely seasonal abundance of *Cx. annulirostris* in Noonamah Ridge Estate, the risk of MVEV transmission for an unprotected person could be high in January and February, although these months are not typically regarded as the peak risk months. The early dry season trapping results suggested there is a low to moderate risk of MVEV transmission during this period of the year.

However, only 1 in around 1000 people bitten by an infected mosquito is likely to develop disease symptoms (CDC Factsheet 2013). Therefore the risk of contracting this disease is much lower compared to RRV and BFV.

5.1.2.4 Kunjin virus disease

Kunjin virus (KUNV) can potentially cause a fatal inflammation of the brain, but this severe symptom is much rarer than with MVE disease (Russell & Kay 2004), and KUNV has so far not been associated with fatalities (Gray et al 2011). KUNV typically causes a milder syndrome of severe headaches and fever (Russell & Kay 2004). As the main vector in the NT is *Cx. annulirostris,* the KUNV risk at Noonamah Ridge Estate is expected to be similar to the MVEV risk.

5.1.2.5 Malaria

Endemic malaria is no longer present in the Northern Territory, but there is always a risk of limited local transmission from people returning from overseas countries with malaria, if the infected person is bitten by *Anopheles* mosquitoes.

There are three sibling species of *Anopheles farauti s.l.* in the Northern Territory, which are morphologically identical. The brackish water species *An. farauti s.s.* (*An. farauti* sp. 1) is a known vector of malaria in Vanuatu, Solomon Islands and PNG (Russell & Kay 2004), and is regarded as a potential vector of malaria in tropical Australia. It is also regarded as the principal potential vector in the Top End of the NT (Whelan 1983). The malaria potential of the other sibling species is unknown, although they should still be regarded as potential vectors.

Russell (1987) showed that one of the *An. annulipes* species in south-east Australia was relatively long lived, and *An. annulipes s.l.* in the NT must be considered a potential vector of malaria where sufficient numbers occur. *Anopheles annulipes* was the probable vector of malaria epidemics in at least areas below Katherine prior to 1962, when malaria was eradicated (Whelan 1995). *Anopheles hilli, An. bancroftii* and *An. amictus* must also be regarded as potential vectors, although *An. bancroftii* may not pose an appreciable risk as it is not as long lived as the other species (Russell 1987). Malaria was isolated from *An. farauti s.l.* (probably *An. farauti s.s.*) and *An. hilli* during the 1942 epidemic in Cairns (Russell et al 2007), and both can be seasonally present in relatively high numbers in the Darwin area. Therefore, these species probably pose the greatest risk in the Darwin area, including Noonamah Ridge Estate.

The risk threshold for potential malaria transmission is about 10 or more adult female *Anopheles* species in a nightly EVS trap set within 1km of the nearest breeding or harbouring area. Malaria vector mosquitoes have to bite an infected person and survive the minimum 10 days before it can transmit malaria to another person. Therefore, the greater the number of mosquitoes that bite an infected person, the greater the risk. The risk threshold was moderately exceeded for *Anopheles farauti s.l.* and *Anopheles bancroftii* in June, although only at one trap site for *An. farauti s.l.* (NR8), and at three trap sites for *An. bancroftii* (NR7, NR8 and NR5). The risk threshold was slightly exceeded for *Anopheles farauti s.l.* in January and May at trap site NR8.

In the Northern Territory, similar to the rest of Australia, malaria is a notifiable disease. Each imported case in the Northern Territory is assessed and treated by a health professional, and assessed by Medical Entomology for the potential to cause local malaria transmission. Any risk of local malaria transmission results in Medical Entomology conducting adult mosquito control (fogging) at the edges of adjacent swamps and mosquito harbourage areas to minimise the risk of local malaria transmission. Appropriate urban planning in Darwin has also been largely responsible for the lack of any malaria transmission in the NT since the early 1960's. Living standards have also increased, with insects screens being standard for most houses. Providing the current malaria prevention programs remain in place, and potential breeding sites within about 1.6km of the village centre are remediated, the risk of local malaria transmission in Noonamah Ridge Estate is considered to be low.

5.1.3 Larval mosquito control

There are currently no aerial or ground insecticide larval mosquito control programs established in Litchfield Shire. It should be expected that some form of routine mosquito monitoring and control would need to be implemented to protect the high density urban residents, and to provide a similar quality of life compared to urban residents in Darwin and Palmerston. The exact requirements of a mosquito monitoring and control program would depend on the rectification of existing mosquito breeding sites, and if suitable urban stormwater drainage and drain discharge is implemented. Any mosquito programs would be the responsibility of the local council/authority.

5.1.4 Mosquito breeding and development aspects – Rectification of mosquito breeding sites

Where possible, the rectification of mosquito breeding sites would be the most effective long term option for mosquito control, as it removes the requirement for a routine mosquito control program and the regular use of insecticides. The potential mosquito breeding areas likely to impact on the proposed urban of Noonamah Ridge Estate that should be considered for rectification are discussed below, and are indicated in Figure 2.

Mosquito breeding site rectification is not required in rural residential areas, due to low density living. However, all rural residential lots should have a note on titles warning of the seasonal mosquito problems that exist in the area, and that the NT Department of Health would not be responsible for managing mosquito issues in the estate. Preferably, the large rural residential lots should be placed closest to the seasonally flooded areas (See Section 5.1.8 for suggested zoning).

5.1.4.1 Seasonally flooded grassy drainage lines

Seasonally flooded grassy drainage lines within 1.6km of the proposed village centre should be rectified by improving the drainage of these areas. The main drainage areas of interest are indicated in Figure 2. Most of these grassy drainage lines have been disturbed by vehicles, which is likely to have exacerbated mosquito breeding by creating depressions where water can pond in the early wet season and dry season.

Formalising the wheels ruts into an incised creekline channel is likely to reduce mosquito breeding by improving drainage and fish movement. Any adjacent low lying grassy depressions should be drained into the main channel.

The Sandsheet Heath drainage area to the north of the proposed village centre is not suspected of being a major mosquito breeding habitat. Therefore, this area does not require drainage improvement. However, there should be a separation between this area and urban development, due to the potential for some mosquitoes to arise from this habitat during wet season flooding, and the likely impact of urban drainage spreading weeds and providing increased nutrients. Weed growth and increased nutrients is likely to lead to increased mosquito breeding. A distance of around 500m from any urban development should be sufficient.

5.1.4.2 Disturbed seasonally waterlogged areas west of Redcliffe Rd

It is possible that disturbed seasonally waterlogged areas in rural lots to the west of Redcliffe Rd have created productive mosquito breeding sites for *Cx. annulirostris,* which could impact on the village centre. The main areas of interest are indicated in Figure 2. It is recommended that these areas be inspected after the first monsoon rains during the wet season, to identify areas of residual water ponding that should then be targeted for rectification by draining, filling or a combination of both.

5.1.4.3 Borrow pits and scrapes

The borrow pits and scrapes near the proposed village centre would need to be rectified to be completely free draining. These areas are indicated in Figure 2.

5.1.5 Mosquito breeding and development aspects - Stormwater drainage

Stormwater drains and their discharge sites have the potential to create or exacerbate mosquito breeding in downstream areas. Mosquito breeding can occur in open drains that pond water, with open unlined drains subject to dry season flow the most at risk, due to the continual flows promoting vegetation growth that can then prevent the free drainage of water. Dry season flows are often high in nutrients which can promote high density mosquito breeding. If the dry season water flows are discharged to a low lying area, then a major dry season swamp could be created at the discharge point. Continuous wet season low flows (from seepage entering stormwater pipe systems) could also create a wet season swamp in poorly draining low lying areas that do not have a natural incised drainage channel. Mosquito species that are known to breed in stormwater drains and in artificially created swamps at drain end points include potential disease vector mosquitoes such as *Cx. annulirostris, Ae. vigilax* (in and adjacent to tidal areas), *Anopheles* species mosquitoes, as well as the brown house mosquito *Culex quinquefasciatus*. Historically, the inappropriate storage and disposal of stormwater was responsible for many of the mosquito problems affecting Darwin prior to the mid 1980s, when a

combined NT Government and City of Darwin program rectified many of the past stormwater drainage issues.

Stormwater sumps can also be mosquito breeding sites. Side entry pits with sumps were proven to be dry season mosquito breeding sites in older suburbs of Darwin such as Nightcliff, as well as in Tennant Creek, while Grate inlet pits with sumps have also been found breeding mosquitoes during the dry season on Groote Eylandt and Tennant Creek. This indicates that any type of stormwater pit with a wet sump is likely to be a dry season mosquito breeding site, and therefore should be avoided. Aside from being potential breeding sites for vector mosquito species such as *Aedes notoscriptus,* and pest mosquitoes such as *Cx. quinquefasciatus,* stormwater sumps could also be potential breeding sites for exotic dengue mosquitoes such as *Aedes aegypti* and *Aedes albopictus,* should an introduction of these species occur in the NT.

In regards to the Noonamah Ridge Estate village centre, the proposed lake would be a good end point for the urban stormwater drainage system. Water should be piped or conveyed via open concrete lined low flow drains directly to the lake. The lake should be appropriately designed to minimise the potential for mosquito breeding. Usually, this entails providing steep sides (minimum 1V:3H) to deep water (1.8m). Where shallow margins are required for child safety, the margins should be designed to prevent semi-aquatic vegetation growth, which could be either by providing a short vegetation impervious bench, or a completely shaded shallow zone. Other methods to improve child safety could be appropriate fencing, or planting impenetrable shrub vegetation adjacent to steep edges. The final lake discharge/s should be directed to the adjacent incised creekline, either by a concrete lined low flow channel, or an unlined channel dug back from the creek and planted with trees along the banks to resemble a completely shaded creekline.

In rural residential areas, open stormwater drains can be unlined and discharge to the natural surface downstream of the development, as rural residential drains are usually not subject to dry season low flows. Therefore, appreciable mosquito breeding in rural stormwater drains and at rural drain end points is not expected.

All stormwater infrastructure and drain end points in the urban and rural areas should be placed on an appropriately funded routine inspection and maintenance program. Regular maintenance should also maintain public perception of the infrastructure being a drain, and over the long run, regular maintenance to remove sediment and small trees from within a drain may be more cost effective and less problematic than occasional large scale works.

5.1.6 Mosquito breeding and development aspects – effluent

Effluent storage and dispersal should be in accordance with the relevant Environmental Health regulations and guidelines. The Noonamah Ridge Estate Notice of Intent mentions there are two options, a KEWT system, or a combination of septic and KEWT treatment systems, with effluent from the KEWT system disposed of by irrigation.

The irrigation of effluent can pose potential mosquito breeding issues, and therefore appropriate design and management of the irrigation areas would be required. It is recommended that the irrigation plots be located as far away from the village centre as possible. The irrigation plots would need to be managed to be free from ponding, and there should be no wet season runoff into downstream low lying areas. Aspects to consider would be to utilise more than one irrigation plot, to allow a week on week off rotation, or a roving irrigator. Utilising clean water diversion drains on the upstream side of the irrigation plot should minimise overland flows from entering the irrigation plot, whilst catch drains on the downstream side of the irrigation area should be constructed to catch any wet season runoff and discharge it to a free draining creekline.

If septic tanks are to be utilised in some areas of the estate, they should not be utilised on any lot less than 4000m2 in size. Any lot under 4000m2 (therefore not classed as standard rural residential) should be on reticulated sewage. The future risk of having high densities of old septic tanks with limited maintenance poses a potential mosquito issue in terms of septic tank systems becoming mosquito breeding sites. Whilst owners are required to maintain septic tanks, Medical Entomology commonly finds mosquito problems associated with old/unmaintained septic tanks. In addition, there is a potential long term risk of wet season overflow from large numbers of old unmaintained tanks affecting downstream water quality. The Environmental Health section of the Department of Health is the authority on wastewater. Therefore any proposed effluent treatment systems should be discussed with Environmental Health.

5.1.7 Artificial receptacles

Recent water conserving trends in other states have included an increase in rainwater tank use and use of other containers to capture and store water. This trend towards increased water storage in containers could occur in the Darwin Region, thus increasing the potential for *Ae. notoscriptus* breeding, and providing potential breeding sites for exotic dengue mosquitoes such as *Aedes aegypti. Aedes aegypti* is not present in the NT, but the Darwin Region is at particular risk of importation from overseas vessels or vessels and road transport from Qld. Russell et al. 2009 mentions factors that could increase the distribution of dengue vectors and the disease include a rise in the rate of domestic collection and storage of water. Unscreened water collection tubs, and rainwater tanks with broken screens would provide major potential habitat for receptacle breeding mosquitoes. Urban development should aim to limit the creation of large numbers of potential breeding sites for this mosquito, such as not imposing the requirement for rainwater tanks in covenants and ensuring all stormwater pits are designed and constructed as free draining structures.

5.1.8 Urban residential buffer zone

The standard recommended urban residential buffer from major areas of mosquito breeding is 1.6km, unless the breeding sites are targeted for rectification. This

distance is usually sufficient to protect residents from large areas of uncontrolled mosquito breeding for most of the year.

The proposed urban area is about 1.6km from the large dam in Section 4572. Therefore, the proposed urban area is a sufficient distance away from the dam. Combined with the dam being a mostly open water body, any mosquito breeding that occurs in the dam is not likely to significantly impact on the urban area, as long as the dam does not eventually turn into a large, vegetated shallow swamp.

The proposed village centre is also located further than 1.6km from the large swamps north of Goode Rd. Therefore, the proposed village centre is a sufficient distance away from these swamps.

The main potential breeding sites affecting the proposed village centre appear to be the seasonal swamps on the western side of Redcliffe Rd, within about 1.6km of the village centre. The grassy drainage lines to the south of the proposed village centre also appear to be significant mosquito breeding areas that would impact on the village centre. The borrow pits and scrapes are also likely to impact on the proposed village centre. Therefore, these areas would need to be targeted for rectification.

5.1.9 Rural residential lot layout

The trap results indicated that most areas of Noonamah Ridge Estate adjacent to potential mosquito breeding habitat, such as seasonally flooded swamps or creeklines lacking a continuous incised channel, experienced high to very high mid wet season *Cx. annulirostris* abundance. Therefore, to minimise the density of people within close proximity to mosquito breeding sites, it is recommended that larger rural residential lots (2ha) be provided within 500m of seasonally flooded areas such as creeklines that lack a continuous incised channel (for those not remediated as part of the urban development), seasonally flooded swamps and low lying grassy areas. Smaller rural lots should be located further than 500m from seasonally flooded areas.

Due to some rural residential lots likely to be impacted by seasonal mosquito problems, there should be a note on titles warning residents of the likelihood of seasonal mosquito problems, and that the NT Department of Health would not be responsible for alleviating the mosquito problems.

5.2 Limitations

The baseline study did not include intensive larval mosquito sampling. Therefore, whilst the adult mosquito trap results and brief site visits give a good indication of where the mosquitoes are originating from, the actual breeding sites within and adjacent to Noonamah Ridge Estate are not known.

6.0 Findings

- High to very high levels of the common banded mosquito *Culex annulirostris* were recorded throughout much of the proposed Noonamah Ridge Estate during the late January trapping, with moderate to high levels recorded throughout much of the estate during the mid February trapping (See Figure 1 for trap locations). Low to moderate levels were recorded in the early dry season. *Culex annulirostris* is the principal vector of mosquito borne disease in the Northern Territory, capable of transmitting Ross River virus, Barmah Forest virus, Murray Valley encephalitis and Kunjin virus.

- The widespread high *Cx. annulirostris* numbers in late January 2015 and widespread moderate to high numbers in mid February 2015 suggests there are numerous productive breeding sites affecting the proposed estate. The major breeding sites appear to be the large seasonal swamps to the north of Goode Rd, seasonally flooded areas to the west of Redcliffe Rd, borrow pits north of the proposed village centre, several vehicle disturbed grassy drainage lines, and localised swamps near the southwest corner of the estate. Potential breeding sites affecting the proposed estate are indicated in Figures 1 & 2.

  Moderate *Cx. annulirostris* numbers recorded during the early dry season were focussed around the grassy vehicle disturbed drainage line where Trap Sites NR5 and NR7 were set, and in the northern portion of the estate. Therefore, the main dry season *Cx. annulirostris* breeding sites in the estate appear to be grassy creeklines with dry season ponding. Dry season dispersal probably also occurs from the large swamps to the north of Goode Rd, particularly to the northern reaches of the estate within about 2km of these swamps.

- The Sandsheet Heath drainage area in the northern portion of the estate does not have the characteristics of an important mosquito breeding area. However, this habitat may be a localised source of mosquitoes during the wet season.

- Several *Anopheles* mosquito species were recorded during trapping, with elevated numbers recorded in the early dry season at trap sites NR7 and NR8. *Anopheles* species mosquitoes are regarded as potential vectors of Malaria.

- The important pest mosquito *Coquillettidia xanthogaster* was also recorded during trapping, with peak numbers occurring in June, and highest numbers occurring at trap site NR7.

- There is a potential that during exceptional tidal mosquito breeding events associated with the distant Adelaide River, most likely during November and December each year, the northern salt marsh mosquito *Aedes vigilax* would disperse to Noonamah Ridge Estate from the tidal

swamps. This mosquito is a potential vector of Ross River virus and Barmah Forest virus.

- Currently, there is a high potential for mosquito borne disease transmission in Noonamah Ridge Estate during the mid wet season, due to the widespread high levels of *Cx. annulirostris* recorded during the late January and mid February trapping. *Culex annulirostris* levels during the early dry season suggests there is also a low to moderate mosquito borne disease risk at the estate during the early dry season, with areas closest to grassy creeklines with dry season ponding at greatest risk. *Aedes vigilax* is likely to pose a periodic virus risk during the late dry and early wet season, although the level of risk would need to be determined by further trapping.

- Once residential development occurs, the receptacle mosquito *Aedes notoscriptus* may pose a RRV and BFV risk to residents when it breeds in receptacles in urban backyards.

- *Anopheles* species mosquitoes would pose a potential malaria risk, when numbers are elevated during their peak season (late wet and early dry season), and when a person infected with malaria is present and bitten by *Anopheles* mosquitoes in the estate. However, due to the current health programs in place, the risk of local malaria transmission is considered to be very low.

- The impact of mosquitoes on future residents in Noonamah Ridge Estate could be reduced by a number of ways. The modification of mosquito breeding sites within 1.6km of the proposed village centre, combined with the buffering effect of rural residential areas, would greatly reduce mosquito problems affecting the denser populated village centre, and therefore reduce the threat of pest and disease problems.

- The collection and discharge of stormwater from the village centre could create new mosquito breeding sites, if stormwater structures are not designed to minimise mosquito breeding, and if the discharge site is not free draining. The routine maintenance of stormwater infrastructure would also be important in preventing mosquito breeding from occurring in the stormwater infrastructure.

- The discharge of effluent could create new mosquito breeding sites, if ponding occurs in the irrigation area, and if high nutrient runoff occurs into low lying areas.

7.0 Recommendations

- The vehicle disturbed grassy drainage lines within 1.6km of the proposed village centre should be provided with a suitable central drainage line, with dense canopy creekline trees planted along the central drainage line, to prevent emergent vegetation from growing. Currently the wheel ruts act as an informal channel subject to erosion and ponding. Low lying areas associated with the vehicle disturbed creeklines should be drained into the central channel where required.

- The seasonally waterlogged area on the west side of Redcliffe Rd, in Section 4548, should be investigated during the wet season to determine if draining is required to remove residual wet season ponding.

- The seasonally flooded disturbed low lying areas in the rural lots to the west of Redcliffe Rd, within about 1.6km of the proposed village centre, should be investigated during the wet season to determine if rectification is required to remove residual wet season ponding.

- The broad low lying area (including the Sandsheet Heath habitat) to the north of the proposed village centre is unlikely to be a productive breeding area for mosquitoes. However, as some wet season mosquito breeding is likely to occur, and the area could be negatively impacted by urban stormwater discharge, a 500m urban buffer should be established from this area.

- The urban stormwater drainage network should be designed to minimise mosquito breeding. The proposed lake should be designed with minimal mosquito breeding potential (i.e. steep sides and deep water), with urban stormwater discharging directly into the lake via an impervious drain. An annual routine inspection and maintenance program should be implemented for the urban stormwater system.

- Where possible, rural stormwater drains should discharge into incised shaded creeklines, and not to the nearest low lying area where potential nutrients and weed conveyance could alter the habitat to suit mosquito breeding.

- The effluent irrigation areas would need to comply with relevant Environmental Health Regulations and Medical Entomology Guidelines, with formal approvals sought from the Environmental Health Section. This would include ensuring the irrigation area/s is appropriately designed and managed to prevent mosquito breeding. Design aspects to consider would be to utilise more than one irrigation plot, to allow a week on week off rotation, or a roving irrigator. A clean water diversion drain is

recommended on the upstream side of any irrigation plot, while a catch drain on the downstream side of the irrigation area is recommended to catch any wet season runoff and discharge it to a free draining area.

- Larger rural residential blocks should be established closest to grassy creeklines, swamps and seasonally flooded areas, to reduce the density of people living adjacent to mosquito breeding areas, and to provide a diversion to mosquito dispersal. In general, lots within 500m of creeklines that lack a defined incised channel, swamps and large seasonally flooded areas are recommended to be a minimum of 2ha. Rural residential lots should have a mosquito note on titles, notifying potential buyers of the seasonal mosquito problem.

8.0 Acknowledgements

The authors would like to thank EcOz Environmental Services for commissioning Medical Entomology to carry out the study.

Mosquitoes were identified by Medical Entomology officers Jane Carter, Jaana Wenham and Nadine Copley. Baseline trapping was carried out by Jane Carter, Nadine Copley and Storm Barrett.

9.0 References (cited and uncited)

Communicable Disease Centre (CDC), Department of Health and Community Services NT Factsheet (2013) 'Ross River virus'.

Communicable Disease Centre (CDC), Department of Health and Community Services NT Factsheet (2013) 'Murray Valley encephalitis virus'.

Communicable Disease Centre (CDC), Department of Health and Community Services NT Factsheet (2014) 'Mosquitoes'.

'Guidelines for preventing biting insect problems for urban residential developments or subdivisions in the Top End of the Northern Territory' Medical Entomology, NT Department of Health and Families 2009.

Gray, T.J, Burrow, J.N, Markey, P.G, Whelan, P.I, Jackson, J, Smith, D.W, and Currie, B.J. (2011), 'Case report:West Nile virus (Kunjin subtype) disease in the Northern Territory of Australia – A case of encephalitis and review of all reported cases'. *American Journal of Tropical Medicine and Hygiene* Vol 85(5), 2011, pp. 952-956.

Jacups, S.P, Kurucz, N, Whelan, P.I, and Carter J.M. 'A comparison of *Aedes vigilax* larval population densities and associated vegetation categories in a coastal wetland, Northern Territory, Australia', *Journal of Vector Ecology* Vol. 34, no. 2, pp.311-316.

Jacups, S.P., Warchot, A. & Whelan, P.I. (2012), 'Anthropogenic ecological changes and impacts on mosquito breeding and control strategies in salt-marshes, Northern Territory, Australia'. EcoHealth April 2012.

Kurucz, N., Jacups, S., Whelan, P.I., Carter, J. and McDonnell, J. (2010), 'Salt marsh mosquito control larval control in a coastal wetland, Northern Territory', The Northern Territory Disease Control Bulletin, Vol. 17, No. 1 March 2010'.

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., Griffiths, M., Debenham, M. L., Bryan, J. H., Russell, R. C., Geary, M., & Marks, E. N. (1988), 'The Culicidae of the Australasian Region Vol. 6', 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., 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. (1988a), '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. (1988b), '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.

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.

'Medical Entomology Annual Report 2013/14', Medical Entomology, NT Department of Health.

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.

Mosquito breeding and sewage pond treatment in the NT. Medical Entomology, NT Department of Health and Families 2009.

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* 12 (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.

Russell, R. C., Currie, B.J., Lindsay, M.D.A., Mackenzie, J.S., Ritchie, and Whelan, P.I. (2009), 'Dengue and climate change:predictions for the future should incorporate knowledge from the past', Medical Journal of Australia, Vol. 190; No.5; 2 March 2009.

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. (1987), 'Biting insects and the rural area strategy plan'. Medical Entomology Branch, Northern Territory Department of Health April 1986. Revised 1987.

Whelan, P.I. (1990), 'Urban stormwater drainage and its effect on mosquito breeding habitats in an intertidal creek at Casuarina, Darwin, NT'. In HK Larson, MG Michie and JR Hanley (eds.) (1988), *Darwin Harbour.* Australian National University North Australia Research Unit Mangrove Monograph No. 4 pp. 181-197.

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), 'Problem 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. (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., 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., 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.

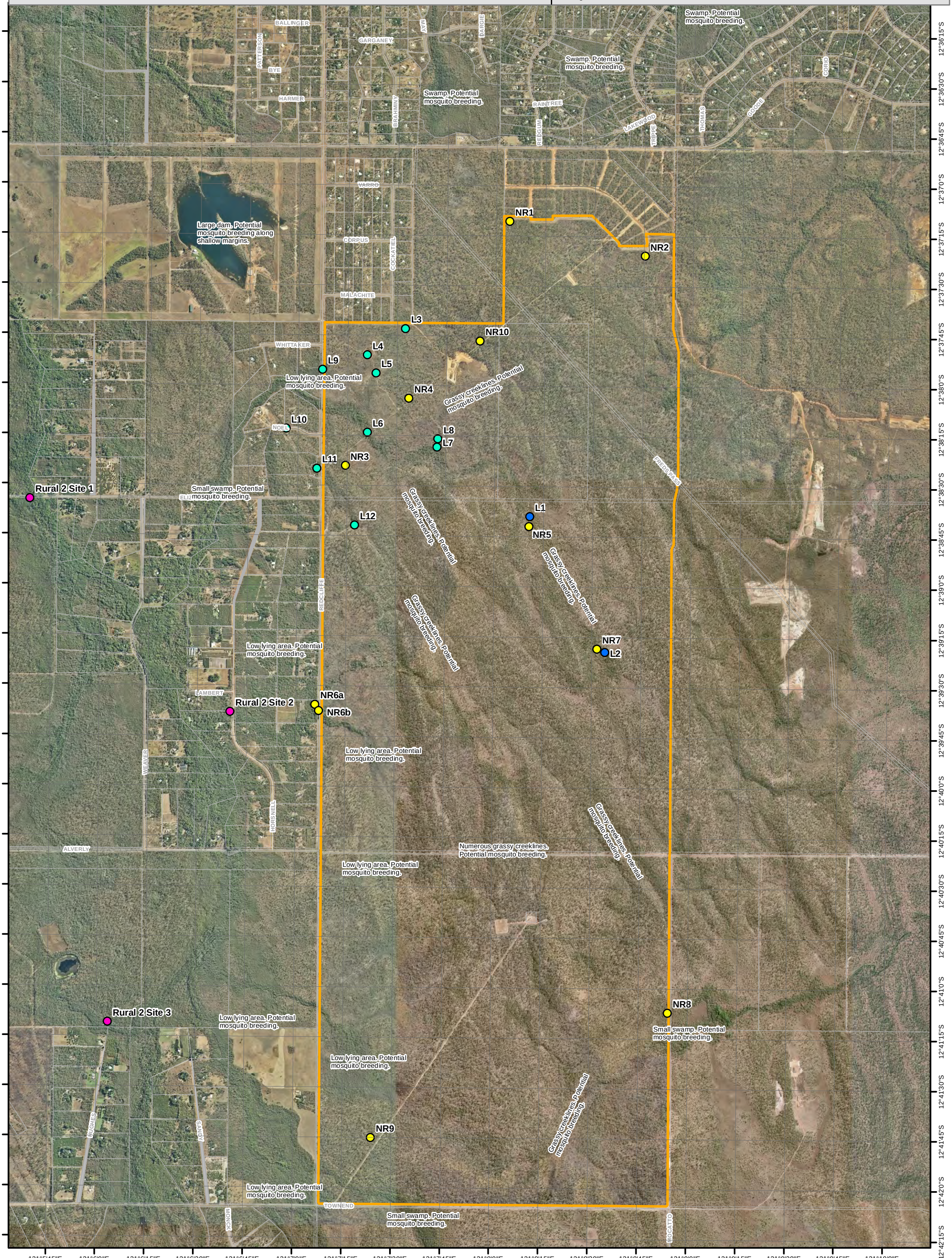
Figures

Figure 1 - Noonamah Ridge Baseline Biting Insect Investigation. Location of adult mosquito monitoring trap sites, larval survey sites and areas of potential mosquito breeding.

N W E S

Datum: GCS GDA 94 Absolute scale 1:30,000

0 500 1,000 1,500 2,000 Meters



Legend

- Noonamah Ridge Estate baseline adult mosquito trap sites (CO2 baited EVS type traps)
- Darwin Rural 2 1986-87 baseline adult mosquito trap sites (CO2 baited EVS type traps)
- Larval mosquito survey points 28 January 2015
- Larval mosquito survey points 27 April 2015
- Noonamah Ridge Estate boundary

Prepared and produced by Medical Entomology, Department of Health, Darwin, Northern Territory of Australia June 2015

F:\ENT\Cents_files\gis\gis_data\Noonamah Ridge\Fig 1 Noonamah Ridge.mxd

Figure 2 - Noonamah Ridge Baseline Biting Insect Investigation. Potential mosquito breeding areas nearby to the urban centre. Rectification required.

N
W E
S

Datum: GCS GDA 94 Absolute scale 1:15,000

0 200 400 600 800 1,000 Meters

NR1

Rectify borrow pits to be free from ponding

NR10

Rectify extractive area to be free from ponding

NR4

NR3

NR5

NR7

NR6a

NR6b

12°36'45"S
12°37'0"S
12°37'15"S
12°37'30"S
12°37'45"S
12°38'0"S
12°38'15"S
12°38'30"S
12°38'45"S
12°39'0"S
12°39'15"S
12°39'30"S

131°6'30"E
131°6'45"E
131°7'0"E
131°7'15"E
131°7'30"E
131°7'45"E
131°8'0"E
131°8'15"E
131°8'30"E

Legend

Adult biting insect trap locations (CO2 baited EVS traps)

Proposed urban centre

Low lying areas within 1.6km of urban centre likely to require rectification by improving drainage.

Vehicle disturbed grassy drainage lines within 1.6km of urban centre that require a formal constructed drainage channel.

Prepared and produced by Medical Entomology, Department of Health, Darwin, Northern Territory of Australia May 2015

F:\ENT\Clients_files\gis\gis_data\Noonamah Ridge\Fig 2 Noonamah Ridge residential layout.mxd

Tables

Table 1: Noonamah Ridge Estate biting insect assessment. Total number of all female mosquito species collected in CO2 baited traps at all sites .

Trap location	*Ae. (Adm) alboscutellatus*	*Ae. (Cha) elchoensis*	*Ae. (Fin) britteni*	*Ae. (Fin) kochi*	*Ae. (Fin) notoscriptus*	*Ae. (Mac) tremulus*	*Ae. (Mol) pecuniosus*	*Ae. (Och) vigilax*	*An. (Ano) bancroftii*	*An. (Cel) amictus*	*An. (Cel) annulipes s.l.*	*An. (Cel) farauti s.l.*	*An. (Cel) meraukensis*	*An. (Cel) novaguinensis*	*Cq. (Coq) xanthogaster*	*Cx. (Cui) pullus*	*Cx. (Cux) annulirostris*	*Cx. (Cux) gelidus*	*Cx. (Cux) palpalis*	*Cx. (Cux) quinquefasciatus*	*Cx. (Cux) sitiens*	*Cx. (Cux) Vishnui group*	*Cx. (Ocu) bitaeniorhynchus*	*Cx. (Ocu) squamosus*	*Ma. (Mnd) uniformis*	Trap failure mosquitoes	*Ur. (Ura) albescens*	*Ur. (Ura) nivipes*	*Ve. (Ver) reesi*	**Totals**	**%**	**No. of traps set**	**Avg. per trap**
NR1_Noonamah Ridge site 1, 1.36km from fork in access track from Redcliffe Rd (travelling north down boundary of Sec. 4584, 570 GOODE RD, LLOYD CREEK, 50m east of track in bush adjacent to cleared area near cul de sac.	0	22	0	0	1	0	5	0	4	0	0	1	2	1	158	19	2535	0	18	0	0	23	0	0	7	0	0	1	0	2797	10.49	4	699.25
NR2_Noonamah Ridge site 2, 1.44 km from trap site 1, travelling east along boundary line of proposed development site	0	26	4	3	5	0	1	0	6	0	4	2	0	0	176	22	3255	3	17	0	0	43	0	0	2	0	0	0	0	3569	13.39	4	892.25
NR3_Noonamah Ridge site 3, 290m down first access track running east, just after the Elizabeth Valley/Redcliffe Rd. intersection (20m behind large granite boulders)	0	2	0	0	4	0	0	0	2	0	3	0	7	2	715	26	1384	0	0	0	0	7	0	0	2	0	0	0	0	2154	8.08	4	538.50
NR4_Noonamah Ridge site 4, 1.05km down first access track running east, just after the Elizabeth Valley/Redcliffe Rd. intersection at fallen tree across track, 20m in bush north of track.	0	8	0	0	3	0	0	2	3	0	3	1	4	1	276	13	1415	0	24	0	0	29	0	0	3	0	0	0	0	1785	6.70	4	446.25
NR5_Noonamah Ridge site 5, 1.9km from site 4, SE along track through seepage areas.	0	2	0	0	0	0	7	0	15	0	0	6	0	3	225	24	1773	0	3	0	0	8	1	0	6	0	0	0	0	2073	7.78	4	518.25
NR_6a_Noonamah Ridge site 6a, 1.34km north from Redcliffe/Townend Rd intersection, approx 50m into bush on west side of road_CLOSED 29/1/2015	0	0	0	6	0	0	0	0	3	1	0	0	0	0	0	96	2064	0	0	0	0	96	0	0	0	0	0	0	0	2266	8.50	1	2266.00
NR6b_Noonamah Ridge site 6b, 4.56km north from Redcliffe Townend Rd intersection, just after creekline culvert on west side of road.	1	0	0	4	0	0	0	0	6	0	1	0	1	0	283	7	211	0	11	2	0	0	0	1	3	0	0	0	0	531	1.99	3	177.00
NR7_Noonamah Ridge site 7, 3.25km from site 4, SE along track through seepage areas, adjacent to site of spring	0	0	0	1	4	0	1	0	97	0	1	14	5	0	1337	33	2455	4	6	0	0	49	1	0	132	0	1	0	3	4144	15.54	4	1036.00
NR8_Noonamah Ridge site 8, 1.8 km down unmaintained road opposite Mocatto Rd/Townend Rd intersection, approx. 30m in bush on west side of road.	0	0	0	10	0	0	0	0	43	0	3	68	4	0	633	62	957	1	0	0	1	94	0	2	35	0	0	0	0	1913	7.18	4	478.25
NR9_Noonamah Ridge site 9, approx. 730m down first access track after Redcliffe Rd/Townend Rd intersection, and 70m in bush on west side of access track (1st powerpole after illegal dump)	0	16	0	28	3	1	3	0	0	0	1	3	1	6	956	124	2618	6	19	0	0	141	1	0	0	0	0	0	0	3927	14.73	4	981.75
NR10_Noonamah Ridge site 10, 160m down track NE of large cleared topsoil mined area, approx 20m in bush, north of track.	0	13	0	0	1	0	3	0	4	0	6	0	0	2	320	3	1114	0	27	0	0	6	0	0	3	1	0	0	0	1502	5.63	3	500.67
Totals	1	89	4	52	21	1	20	2	183	1	22	95	24	15	5079	429	19781	14	125	2	1	496	3	3	193		1	1	3	26661	100.00	39	683.62
%	0.00	0.33	0.02	0.20	0.08	0.00	0.08	0.01	0.69	0.00	0.08	0.36	0.09	0.06	19.05	1.61	74.19	0.05	0.47	0.01	0.00	1.86	0.01	0.01	0.72		0.00	0.00	0.01	100.00			
Avg. per trap	0.03	2.28	0.10	1.33	0.54	0.03	0.51	0.05	4.69	0.03	0.56	2.44	0.62	0.38	130.23	11.00	507.21	0.36	3.21	0.05	0.03	12.72	0.08	0.08	4.95		0.03	0.03	0.08	683.62			

*Cx. (Cux) annulirostris grp.** includes *Cx. (Cux) annulirostris, Cx. (Cux) palpalis, Cx. (Cux) annulirostris grp.*

Table 2: Noonamah Ridge Estate biting insect assessment. Total number of all female mosquito species collected in CO2 baited traps on each trap night at all sites.

Trap location	29-Jan-15	18-Feb-15	07-May-15	04-Jun-15	**Totals**	**%**	**No. of traps set**	**Avg. per trap**
NR1_Noonamah Ridge site 1, 1.36km from fork in access track from Redcliffe Rd (travelling north down boundary of Sec. 4584, 570 GOODE RD, LLOYD CREEK, 50m east of track in bush adjacent to cleared area near cul de sac.	1555	864	199	179	2797	10.49	4	699.25
NR2_Noonamah Ridge site 2, 1.44 km from trap site 1, travelling east along boundary line of proposed development site	2178	876	155	360	3569	13.39	4	892.25
NR3_Noonamah Ridge site 3, 290m down first access track running east, just after the Elizabeth Valley/Redcliffe Rd. intersection (20m behind large granite boulders)	696	580	188	690	2154	8.08	4	538.50
NR4_Noonamah Ridge site 4, 1.05km down first access track running east, just after the Elizabeth Valley/Redcliffe Rd. intersection at fallen tree across track, 20m in bush north of track.	639	537	274	335	1785	6.70	4	446.25
NR5_Noonamah Ridge site 5, 1.9km from site 4, SE along track through seepage areas.	998	455	189	431	2073	7.78	4	518.25
NR_6a_Noonamah Ridge site 6a, 1.34km north from Redcliffe/Townend Rd intersection, approx 50m into bush on west side of road_CLOSED 29/1/2015	2266	Not collected			2266	8.50	1	2266.00
NR6b_Noonamah Ridge site 6b, 4.56km north from Redcliffe Townend Rd intersection, just after creekline culvert on west side of road.	Not collected	127	35	369	531	1.99	3	177.00
NR7_Noonamah Ridge site 7, 3.25km from site 4, SE along track through seepage areas, adjacent to site of spring	1064	1151	149	1780	4144	15.54	4	1036.00
NR8_Noonamah Ridge site 8, 1.8 km down unmaintained road opposite Mocatto Rd/Townend Rd intersection, approx. 30m in bush on west side of road.	354	703	116	740	1913	7.18	4	478.25
NR9_Noonamah Ridge site 9, approx. 730m down first access track after Redcliffe Rd/Townend Rd intersection, and 70m in bush on west side of access track (1st powerpole after illegal dump)	2366	405	273	883	3927	14.73	4	981.75
NR10_Noonamah Ridge site 10, 160m down track NE of large cleared topsoil mined area, approx 20m in bush, north of track.	657	1	288	557	1502	5.63	3	500.67
Totals	12773	5698	1866	6324	26661	100.00	39	683.62
%	47.91	21.37	7.00	23.72	100.00			
Avg. per trap	327.51	146.10	47.85	162.15	683.62			

Table 3: Noonamah Ridge Estate biting insect assessment. Total number of all female mosquito species collected in CO2 baited traps on each trap night.

Date collected	*Ae. (Adm) alboscutellatus*	*Ae. (Cha) elchoensis*	*Ae. (Fin) kochi*	*Ae. (Fin) notoscriptus*	*Ae. (Mac) tremulus*	*Ae. (Och) vigilax*	*An. (Ano) bancroftii*	*An. (Cel) amictus*	*An. (Cel) annulipes s.l.*	*An. (Cel) farauti s.l.*	*An. (Cel) meraukensis*	*An. (Cel) novaguinensis*	*Cq. (Coq) xanthogaster*	*Cx. (Cui) pullus*	*Cx. (Cux) annulirostris*	*Cx. (Cux) gelidus*	*Cx. (Cux) palpalis*	*Cx. (Cux) quinquefasciatus*	*Cx. (Cux) sitiens*	*Cx. (Cux) Vishnui group*	*Cx. (Ocu) bitaeniorhynchus*	*Cx. (Ocu) squamosus*	*Ma. (Mnd) uniformis*	*Ur. (Ura) nivipes*	*Ve. (Ver) reesi*	*Ae. (Mol) pecuniosus*	*Ae. (Fin) britteni*	Trap failure mosquitoes	*Ur. (Ura) albescens*	**Totals**	**%**	**No. of traps set**	**Avg. per trap**
29/01/2015	0	22	35	8	0	2	10	1	3	18	1	0	130	343	11742	7	21	0	1	401	0	0	5	0	3	16	4	0	0	12773	47.91	10	1277.30
18/02/2015	0	14	12	10	0	0	6	0	0	7	1	0	155	78	5297	7	0	0	0	95	2	3	11	0	0	0	0	1	0	5698	21.37	9	633.11
7/05/2015	1	39	2	3	0	0	13	0	10	29	13	7	527	8	1195	0	2	0	0	0	1	0	12	0	0	4	0	0	0	1866	7.00	10	186.60
4/06/2015	0	14	3	0	1	0	154	0	9	41	9	8	4267	0	1547	0	102	2	0	0	0	0	165	1	0	0	0	0	1	6324	23.72	10	632.40
Totals	1	89	52	21	1	2	183	1	22	95	24	15	5079	429	19781	14	125	2	1	496	3	3	193	1	3	20	4		1	26661	100.00	39	683.62
%	0.00	0.33	0.20	0.08	0.00	0.01	0.69	0.00	0.08	0.36	0.09	0.06	19.05	1.61	74.19	0.05	0.47	0.01	0.00	1.86	0.01	0.01	0.72	0.00	0.01	0.08	0.02		0.00	100.00			
Avg. per trap	0.03	2.28	1.33	0.54	0.03	0.05	4.69	0.03	0.56	2.44	0.62	0.38	130.23	11.00	507.21	0.36	3.21	0.05	0.03	12.72	0.08	0.08	4.95	0.03	0.08	0.51	0.10		0.03	683.62			

*Cx. (Cux) annulirostris grp.** includes *Cx. (Cux) annulirostris, Cx. (Cux) palpalis, Cx. (Cux) annulirostris grp.*

TABLE 4: NOONAMAH RIDGE ADULT MOSQUITO BASELINE MONITORING RESULTS

		Ae. (Cha) elchoensis		*Ae. (Fin) britteni*		*Ae. (Fin) kochi*		*Ae. (Fin) notoscriptus*		*Ae. (Mac) species*		*Ae. (Mol) pecuniosus*		*Ae. (Och) vigilax*		*An. (Ano) bancroftii*		*An. (Cel) amictus*		*An. (Cel) annulipes s.l.*		*An. (Cel) farauti s.l.*		*An. (Cel) meraukensis*		*Cq. (Coq) xanthogaster*		*Cx. (Cui) pullus*		*Cx. (Cux) annulirostris*		*Cx. (Cux) gelidus*		*Cx. (Cux) palpalis*		*Cx. (Cux) sitiens*		*Cx. (Cux) Vishnui group*		*Ma. (Mnd) uniformis*		*Ve. (Ver) reesi*		**TOTALS**	
Trap location	Date collected	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	**Total No. of females**	**Total No. of males**
NR1_Noonamah Ridge site 1, 1.36km from fork in access track from Redcliffe Rd (travelling north down boundary of Sec. 4584, 570 GOODE RD, LLOYD CREEK, 50m east of track in bush adjacent to cleared area near cul de sac.	29-Jan-2015	5	10	0	0	0	0	1	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	1	0	5	0	16	0	1506	0	0	0	0	0	0	0	16	0	0	0	0	0	**1555**	**10**
NR2_Noonamah Ridge site 2, 1.44 km from trap site 1, travelling east along boundary line of proposed development site	29-Jan-2015	13	0	4	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	35	0	17	0	2061	0	0	0	9	0	0	0	35	0	1	0	0	0	**2178**	**0**
NR3_Noonamah Ridge site 3, 290m down first access track running east, just after the Elizabeth Valley/Redcliffe Rd. intersection (20m behind large granite boulders)	29-Jan-2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	20	0	656	0	0	0	0	0	0	0	7	0	0	0	0	0	**696**	**0**
NR4_Noonamah Ridge site 4, 1.05km down first access track running east, just after the Elizabeth Valley/Redcliffe Rd. intersection at fallen tree across track, 20m in bush north of track.	29-Jan-2015	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	11	0	4	0	594	0	0	0	0	0	0	0	27	0	0	0	0	0	**639**	**0**
NR5_Noonamah Ridge site 5, 1.9km from site 4, SE along track through seepage areas.	29-Jan-2015	0	0	0	0	0	0	0	0	0	0	7	0	0	0	3	0	0	0	0	0	0	0	0	0	17	0	10	0	951	0	0	0	0	0	0	0	7	0	3	0	0	0	**998**	**0**
NR_6a_Noonamah Ridge site 6a, 1.34km north from Redcliffe/Townend Rd intersection, approx 50m into bush on west side of road_CLOSED 29/1/2015	29-Jan-2015	0	0	0	0	6	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	0	0	0	96	0	2064	0	0	0	0	0	0	0	96	0	0	0	0	0	**2266**	**0**
NR7_Noonamah Ridge site 7, 3.25km from site 4, SE along track through seepage areas, adjacent to site of spring	29-Jan-2015	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3	0	0	0	0	0	3	0	0	0	0	0	16	0	995	0	0	0	0	0	0	0	41	0	0	0	3	0	**1064**	**0**
NR8_Noonamah Ridge site 8, 1.8 km down unmaintained road opposite Mocatto Rd/Townend Rd intersection, approx. 30m in bush on west side of road.	29-Jan-2015	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	6	1	40	0	256	0	1	0	0	0	1	0	28	0	1	0	0	0	**354**	**1**
NR9_Noonamah Ridge site 9, approx. 730m down first access track after Redcliffe Rd/Townend Rd intersection, and 70m in bush on west side of access track (1st powerpole after illegal dump)	29-Jan-2015	2	6	0	0	23	0	0	0	0	6	3	0	0	0	0	0	0	0	1	0	0	0	0	0	40	0	121	0	2020	0	6	0	12	0	0	0	138	0	0	0	0	0	**2366**	**12**
NR10_Noonamah Ridge site 10, 160m down track NE of large cleared topsoil mined area, approx 20m in bush, north of track.	29-Jan-2015	2	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	3	0	639	0	0	0	0	0	0	0	6	0	0	0	0	0	**657**	**0**
TOTALS		**22**	**16**	**4**	**0**	**35**	**0**	**8**	**0**	**0**	**6**	**16**	**0**	**2**	**0**	**10**	**0**	**1**	**0**	**3**	**0**	**18**	**0**	**1**	**0**	**130**	**1**	**343**	**0**	**11742**	**0**	**7**	**0**	**21**	**0**	**1**	**0**	**401**	**0**	**5**	**0**	**3**	**0**	**12773**	**23**

Note: CO2 Trap (EVS CO2 baited) - overnight collection.

Please note: When "Trap failure mosquitoes" and "Not collected" = "1" in the insect species columns, this means that the corresponding trap site was a trap failure or the trap was not set/collected.

TABLE 5: NOONAMAH RIDGE ADULT MOSQUITO BASELINE MONITORING RESULTS

				Ae. (Cha) elchoensis		*Ae. (Fin) kochi*		*Ae. (Fin) notoscriptus*		*An. (Ano) bancroftii*		*An. (Cel) farauti s.l.*		*An. (Cel) meraukensis*		*Cq. (Coq) xanthogaster*		*Cx. (Cui) pullus*		*Cx. (Cux) annulirostris*		*Cx. (Cux) gelidus*		*Cx. (Cux) Vishnui group*		*Cx. (Ocu) bitaeniorhynchus*		*Cx. (Ocu) squamosus*		*Ma. (Mnd) uniformis*		Trap failure mosquitoes		**TOTALS**	
Trap location	Trap type	Date set	Date collected	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	**Total No. of females**	**Total No. of males**
NR1_Noonamah Ridge site 1, 1.36km from fork in access track from Redcliffe Rd (travelling north down boundary of Sec. 4584, 570 GOODE RD, LLOYD CREEK, 50m east of track in bush adjacent to cleared area near cul de sac.	CO2 Trap	17-Feb-15	18-Feb-2015	7	3	0	0	0	0	0	0	0	0	0	0	10	0	3	0	834	0	0	0	7	0	0	0	0	0	3	0	0	0	**864**	**3**
NR2_Noonamah Ridge site 2, 1.44 km from trap site 1, travelling east along boundary line of proposed development site	CO2 Trap	17-Feb-15	18-Feb-2015	3	3	3	0	3	0	0	0	0	0	0	0	32	0	5	0	819	0	3	0	8	0	0	0	0	0	0	0	0	0	**876**	**3**
NR3_Noonamah Ridge site 3, 290m down first access track running east, just after the Elizabeth Valley/Redcliffe Rd. intersection (20m behind large granite boulders)	CO2 Trap	17-Feb-15	18-Feb-2015	2	0	0	0	4	0	0	0	0	0	0	0	39	0	6	0	527	0	0	0	0	0	0	0	0	0	2	0	0	0	**580**	**0**
NR4_Noonamah Ridge site 4, 1.05km down first access track running east, just after the Elizabeth Valley/Redcliffe Rd. intersection at fallen tree across track, 20m in bush north of track.	CO2 Trap	17-Feb-15	18-Feb-2015	2	0	0	0	2	0	0	0	0	0	0	0	17	0	9	0	503	0	0	0	2	0	0	0	0	0	2	0	0	0	**537**	**0**
NR5_Noonamah Ridge site 5, 1.9km from site 4, SE along track through seepage areas.	CO2 Trap	17-Feb-15	18-Feb-2015	0	0	0	0	0	0	0	0	0	0	0	0	4	0	11	0	438	0	0	0	1	0	1	0	0	0	0	0	0	0	**455**	**0**
NR6b_Noonamah Ridge site 6b, 4.56km north from Redcliffe Townend Rd intersection, just after creekline culvert on west side of road.	CO2 Trap	17-Feb-15	18-Feb-2015	0	0	2	0	0	0	0	0	0	0	0	0	6	0	7	0	111	0	0	0	0	0	0	0	1	0	0	0	0	0	**127**	**0**
NR7_Noonamah Ridge site 7, 3.25km from site 4, SE along track through seepage areas, adjacent to site of spring	CO2 Trap	17-Feb-15	18-Feb-2015	0	0	0	0	0	0	4	0	4	0	1	0	13	0	17	0	1095	0	4	0	8	0	1	0	0	0	4	0	0	0	**1151**	**0**
NR8_Noonamah Ridge site 8, 1.8 km down unmaintained road opposite Mocatto Rd/Townend Rd intersection, approx. 30m in bush on west side of road.	CO2 Trap	17-Feb-15	18-Feb-2015	0	0	2	0	0	0	2	0	2	0	0	0	5	0	17	0	607	0	0	0	66	0	0	0	2	0	0	0	0	0	**703**	**0**
NR9_Noonamah Ridge site 9, approx. 730m down first access track after Redcliffe Rd/Townend Rd intersection, and 70m in bush on west side of access track (1st powerpole after illegal dump)	CO2 Trap	17-Feb-15	18-Feb-2015	0	1	5	0	1	0	0	0	1	0	0	0	29	0	3	0	363	0	0	0	3	0	0	0	0	0	0	0	0	0	**405**	**1**
NR10_Noonamah Ridge site 10, 160m down track NE of large cleared topsoil mined area, approx 20m in bush, north of track.	CO2 Trap	17-Feb-15	18-Feb-2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1		
TOTALS				**14**	**7**	**12**	**0**	**10**	**0**	**6**	**0**	**7**	**0**	**1**	**0**	**155**	**0**	**78**	**0**	**5297**	**0**	**7**	**0**	**95**	**0**	**2**	**0**	**3**	**0**	**11**	**0**			**5698**	**7**

Note: CO2 Trap (EVS CO2 baited) - overnight collection.

Please note: When "Trap failure mosquitoes" and "Not collected" = "1" in the insect species columns, this means that the corresponding trap site was a trap failure or the trap was not set/collected.

TABLE 6: NOONAMAH RIDGE ADULT MOSQUITO BASELINE MONITORING RESULTS

				Ae. (Adm) alboscutellatus		*Ae. (Cha) elchoensis*		*Ae. (Fin) kochi*		*Ae. (Fin) notoscriptus*		*Ae. (Mol) pecuniosus*		*An. (Ano) bancroftii*		*An. (Cel) annulipes s.l.*		*An. (Cel) farauti s.l.*		*An. (Cel) meraukensis*		*An. (Cel) novaguinensis*		*Cq. (Coq) xanthogaster*		*Cx. (Cui) pullus*		*Cx. (Cux) annulirostris*		*Cx. (Cux) palpalis*		*Cx. (Ocu) bitaeniorhynchus*		*Ma. (Mnd) uniformis*		**TOTALS**	
Trap location	Trap type	Date set	Date collected	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	**Total No. of females**	**Total No. of males**
NR1_Noonamah Ridge site 1, 1.36km from fork in access track from Redcliffe Rd (travelling north down boundary of Sec. 4584, 570 GOODE RD, LLOYD CREEK, 50m east of track in bush adjacent to cleared area near cul de sac.	CO2 Trap	6-May-15	7-May-2015	0	0	9	0	0	0	0	0	0	0	4	0	0	0	1	0	1	0	1	0	58	0	0	0	124	0	0	0	0	0	1	0	**199**	**0**
NR2_Noonamah Ridge site 2, 1.44 km from trap site 1, travelling east along boundary line of proposed development site	CO2 Trap	6-May-15	7-May-2015	0	0	5	1	0	0	0	0	1	0	4	0	3	0	1	0	0	0	0	0	50	0	0	0	91	0	0	0	0	0	0	0	**155**	**1**
NR3_Noonamah Ridge site 3, 290m down first access track running east, just after the Elizabeth Valley/Redcliffe Rd. intersection (20m behind large granite boulders)	CO2 Trap	6-May-15	7-May-2015	0	0	0	0	0	0	0	0	0	0	1	0	3	0	0	0	5	0	2	0	48	0	0	0	129	0	0	0	0	0	0	0	**188**	**0**
NR4_Noonamah Ridge site 4, 1.05km down first access track running east, just after the Elizabeth Valley/Redcliffe Rd. intersection at fallen tree across track, 20m in bush north of track.	CO2 Trap	6-May-15	7-May-2015	0	0	5	3	0	0	0	0	0	0	1	0	3	0	1	0	4	0	1	0	41	0	0	0	216	0	2	0	0	0	0	0	**274**	**3**
NR5_Noonamah Ridge site 5, 1.9km from site 4, SE along track through seepage areas.	CO2 Trap	6-May-15	7-May-2015	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0	0	0	0	0	64	0	3	0	118	0	0	0	0	0	0	0	**189**	**0**
NR6b_Noonamah Ridge site 6b, 4.56km north from Redcliffe Townend Rd intersection, just after creekline culvert on west side of road.	CO2 Trap	6-May-15	7-May-2015	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	21	0	0	0	0	0	0	0	**35**	**0**
NR7_Noonamah Ridge site 7, 3.25km from site 4, SE along track through seepage areas, adjacent to site of spring	CO2 Trap	6-May-15	7-May-2015	0	0	0	0	1	0	1	0	1	0	1	0	0	0	5	0	1	0	0	0	54	0	0	0	78	0	0	0	0	0	7	0	**149**	**0**
NR8_Noonamah Ridge site 8, 1.8 km down unmaintained road opposite Mocatto Rd/Townend Rd intersection, approx. 30m in bush on west side of road.	CO2 Trap	6-May-15	7-May-2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	1	0	0	0	75	0	5	0	15	0	0	0	0	0	4	0	**116**	**0**
NR9_Noonamah Ridge site 9, approx. 730m down first access track after Redcliffe Rd/Townend Rd intersection, and 70m in bush on west side of access track (1st powerpole after illegal dump)	CO2 Trap	6-May-15	7-May-2015	0	0	12	11	0	0	2	0	0	0	0	0	0	0	2	0	1	0	2	0	99	0	0	0	154	0	0	0	1	0	0	0	**273**	**11**
NR10_Noonamah Ridge site 10, 160m down track NE of large cleared topsoil mined area, approx 20m in bush, north of track.	CO2 Trap	6-May-15	7-May-2015	0	0	8	2	0	0	0	0	2	0	1	0	1	0	0	0	0	0	1	0	26	0	0	0	249	0	0	0	0	0	0	0	**288**	**2**
TOTALS				**1**	**0**	**39**	**17**	**2**	**0**	**3**	**0**	**4**	**0**	**13**	**0**	**10**	**0**	**29**	**0**	**13**	**0**	**7**	**0**	**527**	**0**	**8**	**0**	**1195**	**0**	**2**	**0**	**1**	**0**	**12**	**0**	**1866**	**17**

Note: CO2 Trap (EVS CO2 baited) - overnight collection.

Please note: When "Trap failure mosquitoes" and "Not collected" = "1" in the insect species columns, this means that the corresponding trap site was a trap failure or the trap was not set/collected.

TABLE 7: NOONAMAH RIDGE ADULT MOSQUITO BASELINE MONITORING RESULTS

				Ae. (Cha) elchoensis		*Ae. (Fin) kochi*		*Ae. (Mac) tremulus*		*An. (Ano) bancroftii*		*An. (Cel) annulipes s.l.*		*An. (Cel) farauti s.l.*		*An. (Cel) meraukensis*		*An. (Cel) novaguinensis*		*Cq. (Coq) xanthogaster*		*Cx. (Cux) annulirostris*		*Cx. (Cux) palpalis*		*Cx. (Cux) quinquefasciatus*		*Ma. (Mnd) uniformis*		*Ur. (Ura) albescens*		*Ur. (Ura) nivipes*		**TOTALS**	
Trap location	Trap type	Date set	Date collected	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	No. of females	No. of males	**Total No. of females**	**Total No. of males**
NR1_Noonamah Ridge site 1, 1.36km from fork in access track from Redcliffe Rd (travelling north down boundary of Sec. 4584, 570 GOODE RD, LLOYD CREEK, 50m east of track in bush adjacent to cleared area near cul de sac.	CO2 Trap	3-Jun-15	4-Jun-2015	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	85	12	71	0	18	0	0	0	3	0	0	0	1	0	**179**	**12**
NR2_Noonamah Ridge site 2, 1.44 km from trap site 1, travelling east along boundary line of proposed development site	CO2 Trap	3-Jun-15	4-Jun-2015	5	2	0	0	0	0	1	0	1	0	1	0	0	0	0	0	59	7	284	0	8	0	0	0	1	0	0	0	0	0	**360**	**9**
NR3_Noonamah Ridge site 3, 290m down first access track running east, just after the Elizabeth Valley/Redcliffe Rd. intersection (20m behind large granite boulders)	CO2 Trap	3-Jun-15	4-Jun-2015	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	615	52	72	0	0	0	0	0	0	0	0	0	0	0	**690**	**52**
NR4_Noonamah Ridge site 4, 1.05km down first access track running east, just after the Elizabeth Valley/Redcliffe Rd. intersection at fallen tree across track, 20m in bush north of track.	CO2 Trap	3-Jun-15	4-Jun-2015	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	207	16	102	0	22	0	0	0	1	0	0	0	0	0	**335**	**16**
NR5_Noonamah Ridge site 5, 1.9km from site 4, SE along track through seepage areas.	CO2 Trap	3-Jun-15	4-Jun-2015	2	0	0	0	0	0	11	0	0	0	3	0	0	0	3	0	140	8	266	0	3	0	0	0	3	0	0	0	0	0	**431**	**8**
NR6b_Noonamah Ridge site 6b, 4.56km north from Redcliffe Townend Rd intersection, just after creekline culvert on west side of road.	CO2 Trap	3-Jun-15	4-Jun-2015	0	0	1	0	0	0	6	0	1	0	0	0	1	0	0	0	265	30	79	0	11	0	2	0	3	0	0	0	0	1	**369**	**31**
NR7_Noonamah Ridge site 7, 3.25km from site 4, SE along track through seepage areas, adjacent to site of spring	CO2 Trap	3-Jun-15	4-Jun-2015	0	0	0	0	0	0	89	0	1	0	2	0	3	0	0	0	1270	0	287	0	6	0	0	0	121	0	1	0	0	0	**1780**	**0**
NR8_Noonamah Ridge site 8, 1.8 km down unmaintained road opposite Mocatto Rd/Townend Rd intersection, approx. 30m in bush on west side of road.	CO2 Trap	3-Jun-15	4-Jun-2015	0	0	2	0	0	0	41	0	3	0	35	0	3	0	0	0	547	1	79	0	0	0	0	0	30	0	0	1	0	1	**740**	**3**
NR9_Noonamah Ridge site 9, approx. 730m down first access track after Redcliffe Rd/Townend Rd intersection, and 70m in bush on west side of access track (1st powerpole after illegal dump)	CO2 Trap	3-Jun-15	4-Jun-2015	2	0	0	0	1	0	0	0	0	0	0	0	0	0	4	0	788	4	81	0	7	0	0	0	0	0	0	0	0	0	**883**	**4**
NR10_Noonamah Ridge site 10, 160m down track NE of large cleared topsoil mined area, approx 20m in bush, north of track.	CO2 Trap	3-Jun-15	4-Jun-2015	3	0	0	0	0	0	3	0	3	0	0	0	0	0	1	0	291	183	226	0	27	0	0	0	3	0	0	0	0	0	**557**	**183**
TOTALS				**14**	**2**	**3**	**0**	**1**	**0**	**154**	**0**	**9**	**0**	**41**	**0**	**9**	**0**	**8**	**0**	**4267**	**313**	**1547**	**0**	**102**	**0**	**2**	**0**	**165**	**0**	**1**	**1**	**1**	**2**	**6324**	**318**

Note: CO2 Trap (EVS CO2 baited) - overnight collection.

Please note: When "Trap failure mosquitoes" and "Not collected" = "1" in the insect species columns, this means that the corresponding trap site was a trap failure or the trap was not set/collected.

Table 8. Darwin Rural 2 Baseline Biting Insect Trapping. Site 1, Elizabeth River, 5 m S of Elizabeth Valley Rd, W side of crossing. Total number of all adult female mosquitoes collected in CO2 baited EVS traps.

Species	15-May-86	13-Jun-86	9-Jul-86	8-Aug-86	5-Sep-86	3-Oct-86	31-Oct-86	26-Nov-86	24-Dec-86	23-Jan-87	19-Feb-87	26-Mar-87	24-Apr-87	Totals	%
Ae. (Adm) alboscutellatus	0	0	0	0	0	0	0	1	0	0	0	1	0	2	0.09
Ae. (Fin) kochi	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0.05
Ae. (Fin) notoscriptus	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0.09
Ae. (Mac) tremulus	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0.05
Ae. (Muc) alternans	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0.09
Ae. (Neo) lineatopennis	5	0	0	0	0	0	2	0	0	0	0	12	0	19	0.90
Ae. (Och) normanensis	0	0	0	0	0	0	0	1	1	9	36	5	0	52	2.47
Ae. (Och) vigilax	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0.09
An. (Ano) bancroftii	97	25	3	0	0	0	0	0	0	0	0	7	64	196	9.30
An. (Cel) annulipes s.l.	17	3	2	2	0	0	1	1	0	0	23	0	0	49	2.33
An. (Cel) farauti s.l.	80	0	0	0	0	0	0	0	0	0	4	50	4	138	6.55
An. (Cel) meraukensis	86	5	3	0	0	0	0	0	1	0	4	8	1	108	5.13
An. (Cel) novaguinensis	42	0	0	0	0	0	0	0	0	0	0	10	0	52	2.47
Cq. (Coq) xanthogaster	67	303	9	0	50	0	1	0	0	0	0	2	7	439	20.84
Cx. (Cui) pullus	1	1	0	0	0	0	2	0	1	0	6	8	6	25	1.19
Cx. (Cux) annulirostris grp	130	334	4	7	6	0	1	0	1	0	16	32	38	569	27.01
Cx. (Cux) bitaeniorhynchus	1	2	0	0	0	0	0	0	0	0	7	5	0	15	0.71
Cx. (Cux) species 32	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.05
Cx. (Cux) squamosus	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.05
Ma. (Mnd) uniformis	27	8	4	0	0	0	0	0	0	0	0	0	81	120	5.70
mosquitoes unidentifiable (damaged)	12	0	0	0	0	0	0	0	0	0	0	0	0	12	0.57
Nil mosquitoes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Ur. (Ura) nivipes	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0.05
Ve. (Ver) reesi	53	0	0	0	0	0	0	0	0	58	172	15	2	300	14.24
Totals	620	682	26	9	58	0	7	4	4	69	269	156	203	2107	100.00
%	29.43	32.37	1.23	0.43	2.75	0.00	0.33	0.19	0.19	3.27	12.77	7.40	9.63	100.00	

Table 9. Darwin Rural 2 Baseline Biting Insect Trapping. Site 2, approximately 20 m S of Horsnell Rd, W of creek line on Lot 54

Species	16-May-86	13-Jun-86	5-Jul-86	9-Jul-86	8-Aug-86	3-Oct-86	31-Oct-86	26-Nov-86	24-Dec-86	22-Jan-87	19-Feb-87	26-Mar-87	24-Apr-87	Totals	%
Ae. (Fin) notoscriptus	0	0	0	0	0	0	0	0	0	0	1	1	0	2	0.21
Ae. (Neo) lineatopennis	1	0	0	0	0	0	0	1	0	2	1	6	0	11	1.14
Ae. (Och) normanensis	0	0	0	0	0	0	2	0	0	1	32	2	1	38	3.93
Ae. (Och) vigilax	1	0	1	0	0	0	0	0	0	0	0	0	0	2	0.21
An. (Ano) bancroftii	10	7	0	4	0	0	0	0	0	0	0	0	9	30	3.10
An. (Cel) amictus	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.10
An. (Cel) annulipes s.l.	11	0	0	1	0	0	0	1	0	1	13	3	0	30	3.10
An. (Cel) farauti s.l.	8	0	0	0	0	0	0	0	0	0	0	1	7	16	1.65
An. (Cel) hilli	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.10
An. (Cel) meraukensis	8	0	0	1	0	0	0	0	0	0	4	3	0	16	1.65
An. (Cel) novaguinensis	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0.10
Cq. (Coq) xanthogaster	323	17	14	51	0	7	5	1	0	0	0	1	23	442	45.71
Cx. (Cui) pullus	1	0	0	0	0	0	2	0	0	0	5	1	8	17	1.76
Cx. (Cux) annulirostris grp	77	31	4	39	1	14	0	1	0	0	9	30	9	215	22.23
Cx. (Cux) bitaeniorhynchus	7	0	0	0	0	0	0	0	0	0	2	11	10	30	3.10
Cx. (Cux) species 32	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.10
Cx. (Lop) species 167	0	0	0	0	0	0	0	0	0	0	3	0	0	3	0.31
Ma. (Mnd) uniformis	9	6	0	3	0	0	0	0	0	0	0	0	35	53	5.48
Trap failure mosquitoes	0	0	0	0	0	0	0	0	1	0	0	0	0		
Ur. (Ura) albescens	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0.10
Ve. (Ver) reesi	12	0	0	0	0	0	0	0	0	2	38	5	0	57	5.89
Totals	469	61	20	100	1	21	10	4		6	108	65	102	967	100.00
%	48.50	6.31	2.07	10.34	0.10	2.17	1.03	0.41		0.62	11.17	6.72	10.55	100.00	

Table 10. Darwin Rural 2 Baseline Biting Insect Trapping. Site 3, 50 m N of end of service Rd off Townend Rd on Section 1717

Species	15-May-86	13-Jun-86	9-Jul-86	8-Aug-86	5-Sep-86	3-Oct-86	31-Oct-86	26-Nov-86	24-Dec-86	23-Jan-87	19-Feb-87	26-Mar-87	24-Apr-87	Totals	%
Ae. (Cha) elchoensis	0	0	1	0	0	0	0	0	0	0	1	0	1	3	0.20
Ae. (Fin) kochi	1	0	1	0	0	0	0	0	0	0	2	0	0	4	0.26
Ae. (Fin) notoscriptus	0	0	0	0	0	0	0	3	1	2	2	0	0	8	0.52
Ae. (Mol) pecuniosus	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0.07
Ae. (Och) normanensis	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0.13
Ae. (Och) vigilax	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0.07
An. (Ano) bancroftii	8	1	2	1	0	0	0	0	0	1	0	1	25	39	2.55
An. (Cel) annulipes s.l.	0	0	0	1	0	0	0	0	0	0	0	1	0	2	0.13
An. (Cel) farauti s.l.	19	1	0	0	0	0	0	0	0	0	0	1	2	23	1.50
An. (Cel) meraukensis	2	1	0	0	0	0	0	0	0	0	1	0	2	6	0.39
An. (Cel) novaguinensis	6	0	0	0	0	0	0	0	0	0	1	10	0	17	1.11
Cq. (Coq) xanthogaster	249	293	119	16	0	5	1	0	1	0	1	1	68	754	49.25
Cx. (Cui) pullus	0	0	1	0	0	0	1	0	0	0	4	0	9	15	0.98
Cx. (Cux) annulirostris grp	116	135	48	6	0	14	12	3	1	1	85	29	56	506	33.05
Cx. (Cux) quinquefasciatus	0	0	1	0	0	0	0	0	0	1	0	0	0	2	0.13
Cx. (Cux) sitiens	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0.07
Cx. (Cux) species 32	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.07
Cx. (Cux) vicinus	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.07
Ma. (Mnd) uniformis	28	20	57	3	0	3	0	0	0	0	0	0	31	142	9.27
Mi. (Eto) elegans	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.07
Not collected mosquitoes	0	0	0	0	1	0	0	0	0	0	0	0	0		
Ve. (Ver) reesi	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0.13
Totals	429	451	232	27		22	14	7	3	6	102	44	194	1531	100.00
%	28.02	29.46	15.15	1.76		1.44	0.91	0.46	0.20	0.39	6.66	2.87	12.67	100.00	