

BITING INSECT MANAGEMENT PLAN Holtze Development Area



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ACRONYMS

BFV	Barmah Forest virus
BIMP	Biting Insect Management Plan
CEMP	Construction environment management plan
DIPL	Department of Infrastructure, Planning and Logistics
ha	hectares
KUNV	Kunjin virus
m	metres
MREV	Murray Valley encephalitis virus
NT EPA	Northern Territory Environment Protection Authority
RRV	Ross River virus

1 INTRODUCTION

The Greater Holtze area has been identified as a beneficial land development area. The Greater Holtze area is comprised of four potential development areas – referred to as Holtze, Kowandi, Holtze North and Howard Springs North.

This biting insect management plan (BIMP) currently only relates to the Holtze development only and enabling infrastructure required to support this development (the Proposal). It is acknowledged that biting insect habitat in the Greater Holtze area will require management in future, however this is not included in the current development. Aerial mosquito control in the tidal and brackish water swamps to the north and northeast of the Holtze area will also reduce mosquito problems affecting Holtze, and should be investigated as part of a regional mosquito strategy for the Greater Holtze area.

1.1 Purpose

This BIMP aims to:

- Support the NT EPA Referral Report by demonstrating available management and mitigation measures to reduce the risk posed by biting insects to human health.
- Minimise the impact of mosquitoes at the Proposal site during construction and operation.
- Provide a framework for control practices to be implemented to deter adult biting insects on site and prevent the establishment of new of breeding sites.
- Indicate the health and safety legislation and guidelines regarding biting insects.

This BIMP has been informed by a study undertaken by NT Department of Health (Medical Entomology) – see Appendix A - to support the Proposal, as well as other examples of acceptable management recommendations provided by similar projects.

1.2 Scope

There are two key potential impacts to human health to consider regarding mosquitoes, these being:

- Proximity of the Proposal (during construction and operation) to existing mosquito breeding habitat.
- Creation of new mosquito breeding habitat (during construction and operation).

This BIMP outlines management actions available to the Proposal, to be implemented in both the short- and long-term, to mitigate the risk of mosquito impact on human health.

1.3 Statutory requirements

This BIMP considers the requirements of the following legislation and guidance:

- *NT Public and Environmental Health Act 2011*
- *NT Public and Environmental Health Regulations 2014*
- *Work Health and Safety (National Uniform Legislation) Act 2011*
- *Guidelines for Preventing Biting Insect Problems for Urban Residential Developments or Subdivisions in the Top End of the NT* (Whelan, 2009)
- *Northern Territory Subdivision Development Guidelines* (2020)

The BIMP will be subject to ongoing review and change to ensure it remains relevant to the above legislation and guidance documents throughout the life of the Proposal.

2 PROPOSAL DESCRIPTION

The Proposal involves the clearing of approximately 116 ha for the purpose of urban development of the Holtze Development Area – see Figure 2-1 – including:

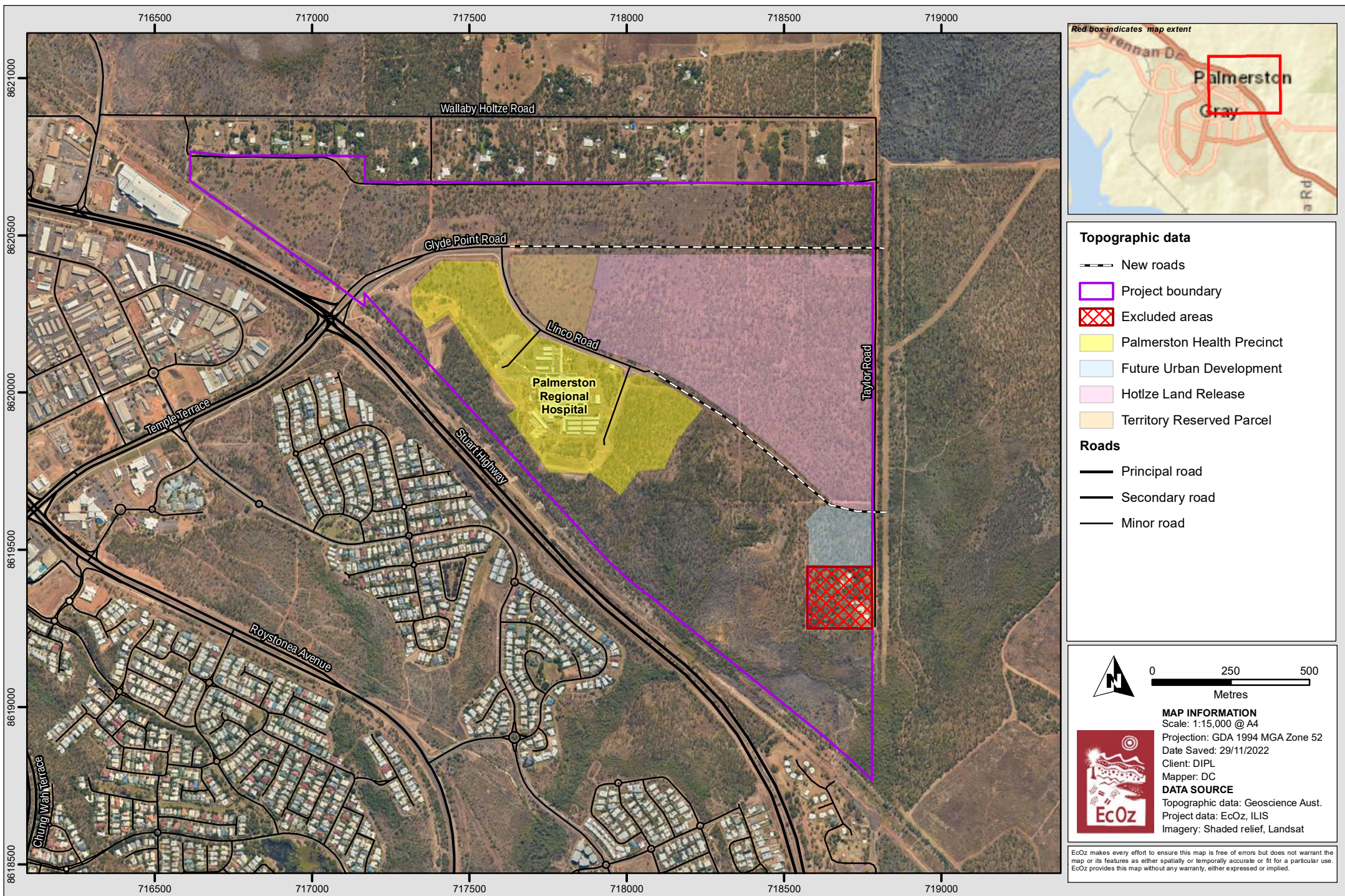
- Holtze Land Release
- Territory Reserve Parcel
- The Palmerston Health Precinct
- Other residential future urban development areas west of Taylor Road.

Works include construction of enabling and subdivision infrastructure, comprising sewerage, water supply, power, communications, roads, drainage and social infrastructure.

Following initial enabling infrastructure works, the land will be subdivided and released for development of residential, commercial, public space and community purposes.

The implementation of the BIMP is likely to be the responsibility of multiple entities, including:

- Department of Health for the active management of natural breeding areas outside of the Proposal area.
- Litchfield Council with respect to maintaining drainage infrastructure to minimise biting insect breeding.
- DIPL with regards to design and delivery of engineering solutions to trunk infrastructure and through the release of land to developers.
- Developers through the design of neighborhood infrastructure to reduce biting insect breeding.
- Contractors through the Construction and Environmental Management Plans to reduce insect breeding during construction.



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Figure 3-1. Development within the Holtze development area

3 ENVIRONMENTAL VALUES

The Proposal is proximate to coastal mangroves, estuarine creeks and swamps that provide suitable habitat for a variety of biting insects such as midges and mosquitoes – see Figure 3-1. Mosquitoes can pose potential health risks, both as pest insects and as vectors of diseases such as Ross River virus (RRV), Barmah Forest virus (BFV), Murray Valley encephalitis virus (MVEV), Kunjin virus (KUNV) and Japanese encephalitis virus (JEV). Previous biting insect investigations undertaken by NT Department of Health across 2019 and 2020 at and near the site provide an indication of biting insects that occur within the Proposal area, with mosquitoes identified as the most important biting insects in the area. The main mosquitoes recorded during this investigation include:

- *Aedes vigilax* - vector of RRV and BFV.
- *Culex annulirostris* - vector of RRV, BFV, MVEV, and KUNV.
- *Coquillettidia xanthogaster*.
- *Anopheles sp.* – vector of malaria.

There are multiple mosquito breeding sites in and around the Proposal area, including seasonally flooded wetlands and large freshwater wetlands, both natural and man-made. Additionally, the site is within flight range of important mosquito species that are breeding in the Shoal Bay coastal swamps to the north and northeast.

Holtze and Kowandi experience seasonally high to very high salt marsh mosquito (*Aedes vigilax*) problems during the build-up and early wet season months. This species is an aggressive biter, and bites day and night. Holtze and Kowandi North experiences seasonally high to very high *Coquillettidia xanthogaster* abundance during the early dry season, with parts of Holtze and Kowandi North experiencing moderate to high *Culex annulirostris* abundance during the early dry season. *Coquillettidia xanthogaster* predominantly bites at night, although can bite during the day in shaded areas near their breeding sites, while *Cx. annulirostris* only bites after sundown.

3.1 Potential sources of biting insects

There are sources of biting insects in the form of suitable habitat both within the Proposal area and adjacent. These are described below.

3.1.1 Within the Proposal area

Two areas of borrow pits were identified adjacent to Mitchell Creek, north of the Stuart Highway within the section of the Proposal area identified for open space, forming potential mosquito breeding sites particularly during the wet season. Mitchell Creek upstream of the Stuart Highway appears unlikely to produce appreciable mosquito numbers, due to the limited potential area of residual ponding compared to the large swamps. However, the creek might occasionally produce localised dry season populations of *Cx. annulirostris* and *Anopheles sp.* There is the potential that future urban stormwater low flows could result in changed dry season flow conditions and increased nutrient levels, which could increase mosquito breeding productivity. Moderate density *Cx. annulirostris* breeding has been found in a small arm of Mitchell Creek in Zuccoli during the late dry season, suggesting urban discharge in Holtze could also increase mosquito breeding in upper Mitchell Creek. The potential future colonisation of this part of Mitchell Creek with semi-aquatic weeds, such as olive hymenachne and paragrass, could further exacerbate any current mosquito breeding.

3.1.2 Outside the Proposal area

There are suitable breeding habitats for biting insects outside the Proposal area, but near enough to be considered a potential source of biting insects for the Proposal area. These are discussed below.

Kowandi large paperbark swamp

A large paperbark swamp (approximately 21 ha) on the Kowandi is 900 m east of the planned residential boundary along Taylor Road. This site is a very large paperbark swamp with shallow ponding and thick coverage of aquatic and emergent vegetation; however, it dries out by end of June. The site has been identified to provide habitat for mosquito species *Anopheles* sp., potential *Cx. annulirostris*, *Cq. xanthogaster* and *Ma. Uniformis*. Traps near the Kowandi North paperbark swamp traps near the Kowandi North paperbark swamp exceeded the nominal virus threshold level of *Culex annulirostris*, capable of transmitting RRV, BFV, MVEV and KUNV.

Culex annulirostris, *An. annulipes* s.l. and *An. farauti* s.l. larvae were collected in the swamp in low numbers, with mosquito larvae more prevalent within about 5 -10 m of the water's edge. Adult *Ma. uniformis* and *Cq. xanthogaster* were observed biting during both surveys of this swamp, which was suggestive of the swamp being a breeding site for these species. The larvae of both *Ma. uniformis* and *Cq. xanthogaster* attach to the roots of aquatic plants, and although aquatic plants were shaken and swept with nets to try and dislodge any larvae, none were recovered. It is possible that deeper water areas or wider areas of the swamp needed to be surveyed.

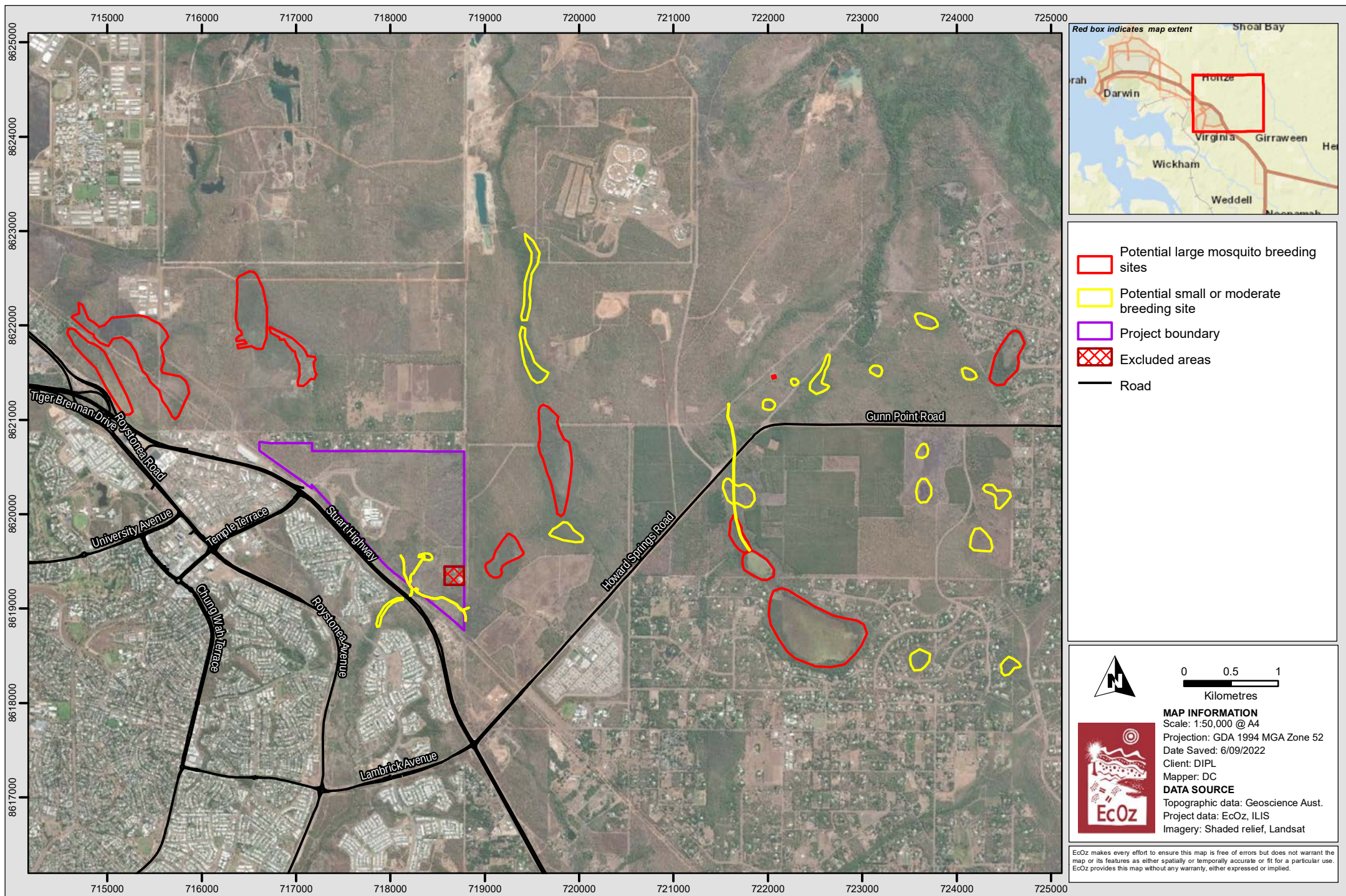
Kowandi small paperbark swamp

A smaller paperbark swamp (approximately 9 ha) on the Kowandi is 250 m east of the planned residential boundary along Taylor Road. This site is a smaller paperbark swamp, south-west of Kowandi large paperbark swamp, and has been identified to provide potential habitat for mosquito species *Cq. xanthogaster*, *Cx. annulirostris* and *Anopheles* sp. Adult mosquito trapping recorded minor to low *Cx. annulirostris*, *Anopheles* sp. and *Ma. uniformis* abundance, suggesting the swamp is either less productive than the larger northern swamp in Kowandi North, or the swamp is of similar productivity, but produces less than half the mosquitoes of the larger swamp. Additionally, aerial photography assessed by Department of Health indicated the swamp was dried up by June 2020, so activity/trapping at the swamp after this time could be mosquitoes from a nearby site.

Other

There are multiple other mosquito breeding sites in the broader area surrounding the Proposal area. *Ae. vigilax* commonly breeds in mangrove, swamp, and salt marsh habitats, and is a carrier of RRV and BFV. Milners Swamp and associated upper tidal channel of Kings Creek, and the southern half of the Howard River coastal swamplands and associated upper mangrove channel of the Howard River, are most likely the main sources of *Ae. vigilax* impacting the Proposal area.

Based on the current urban development plans, an acceptable urban buffer can be maintained between these other sites outside the Proposal area (i.e. they are greater than the normal recommended urban buffer), however these would need to be addressed/managed during future stages of the Greater Holtze development. Notably, Section 65 paperbark swamp and adjacent large sandmining area, and the Yarrawonga swamplands are all to the north-west of the Proposal area. These sites are identified as providing breeding habitat for *Anopheles* sp., *Cx. annulirostris* and *Cq. xanthogaster*, however as described above, the Proposal area is outside the normal recommended urban buffer recommended for these sites.



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Figure 3-1. Biting insect habitat within and proximal to the Proposal

4 ASSESSMENT

An assessment against the NT EPA's factor for Human Health has been undertaken in the Proposal NT EPA Referral Report. Refer to Section 7.7 of the Referral Report document for information relevant to the assessment of Human Health.

5 MANAGEMENT PROVISIONS

This section of the BIMP provides a consolidated plan for environmental management to manage the environmental risks identified. Presented are the potential impacts associated with the Proposal, and the measures proposed to avoid, mitigate, or manage those impacts.

It is recognised that key biting insect habitat identified in close proximity (i.e. within 500 – 1,600 m) to the Proposal area site may pose a potential risk to human health of future residents without appropriate mitigation and management, as well as Milners Swamp and associated upper tidal channel of Kings Creek, and the southern half of the Howard River coastal swamplands and associated upper mangrove channel of the Howard River. Department of Health recommend a minimum 1 km (Kowandi North small paperbark swamp) and 1.6 km urban residential exclusion buffer (Kowandi North large paperbark swamp) - Figure 3-1 - around these key biting insect habitats, however a buffer has not been recommended for the sources of salt marsh mosquito species. It should be noted buffers recommended by Department of Health are based on uncontrolled and untreated mosquito breeding habitat. For the sites where an urban buffer has been recommended, implementing an exclusion buffer as the primary management measure is not feasible, as this would significantly reduce the land available for residential development, ultimately impacting on the objectives and overall benefits of the Proposal.

Eventually, these habitats will be modified as part of the future development of the Greater Holtze area, however habitat modification involves further consideration through stormwater and hydrological design of these areas that are not yet completed. Habitat modification may involve either filling/draining swamp areas, converting them to deeper water bodies, and/or modifying/removing semi-aquatic vegetation that provides breeding habitat for certain species. Habitat modification is not available or feasible for sites providing habitat for salt marsh mosquito species, therefore insecticide and aerial treatments will be explored. Additionally, it is unlikely aerial and insecticide treatments would be effective on species where larvae attach to stems and roots of aquatic plants, however these species - *Ma. uniformis* and *Coquillettidia xanthogaster* – are not disease carrying and would therefore pose a nuisance risk as opposed to a public health risk. Ultimately, habitat modification/engineering solutions that are effective against these species will be part of the future development of Holtze North and Kowandi.

Until such a time that high risk habitats proximal to the Proposal area can be modified, the Proposal will manage the risk to public health from biting insects in a manner consistent with existing mosquito management programs, including:

- 1) Aerial treatment and barrier (residual surface insecticide) treatments as required, as an interim measure before habitat modification can occur. This should include treatment of:
 - o Noogoo and Milners Swamp and associated upper tidal channel of Kings Creek
 - o The southern half of the Howard River coastal swamplands and associated upper mangrove channel of the Howard River
 - o Section 65 paperbark swamp and adjacent large sandmining area
 - o The Yarrowonga swamplands to the north-west of the Proposal area.
- 2) Continued consideration of engineering controls to guide future management of biting insect habitat through development of the broader Greater Holtze area. While further investigation is required, successful engineering controls are the preferred treatment of this habitat.

- 3) Work with Department of Health to determine appropriate ongoing management actions to manage the potential risk to human health.

In addition to these key commitments, there are a range of mitigation and management actions available to the Proposal through the design and planning, construction, and occupation/operation phases. These are presented in the following sections.

This BIMP should be reviewed and updated throughout the Proposal lifecycle, as required. This document provides a strategy and mitigation actions available to the Proposal, however it is recognised further work is required to determine funding and ongoing ownership of various actions. Ultimately, DIPL is responsible for ensuring there is a clear management plan in place for the Proposal area, and DIPL is committed to working with relevant stakeholders to achieve this. Some mitigations in the following sections assigned to DIPL may ultimately be the responsibility of an alternative authority, however DIPL is responsible for ensuring any ownership is transferred effectively, and management plans are prepared in consultation with relevant stakeholders, especially where alternative authorities are responsible for meeting objectives of such plans.

5.1 Timeline

As discussed above, key mosquito breeding habitat adjacent to the Proposal area at both Kowandi North large and small paperbark swamps must be modified to manage the impacts of mosquitoes on human health. It is anticipated these solutions will be available, concurrently to the first residents occupying property in the Proposal area. At these two paperbark swamps, aerial and insecticide mitigations would be relied upon in the short term - i.e. until engineering solutions are available – prior to large numbers of residents occupying the Proposal area. Ultimately, when large numbers of residents occupy the urban area, it is anticipated nearby habitats that can be modified, will be modified, while other sites – i.e. habitat for salt marsh species – will continue to be managed via insecticides and aerial programs.

5.2 Design and planning

The Proposal will be designed to manage the impacts of biting insects. Aspects of design and planning that have been/will be undertaken to manage risks are provided in Table 5-1.

Table 5-1. Mitigation actions during design and planning

Potential impact	Design component	Owner
Proximity of the Proposal to existing biting insect habitat	Incorporate designs and plans for the three small creek lines of Mitchell Creek to have a continuous shaded incised channel from the edge of urban development to the Stuart Highway, with the creek lines revegetated to create a fully shaded canopy to prevent weed growth in the channel, and a footpath provided along one edge of each of the upgraded channels to assist with mosquito surveys and future machinery access for channel maintenance.	DIPL
	Incorporate designs and plans for the borrow pits identified to provide biting insect habitat near Mitchell Creek to be filled so they flow into Mitchell Creek to avoid future pooling of water.	DIPL
	Determine appropriate ongoing management actions and any associated trapping/monitoring programs deemed necessary.	DIPL/DoH
	Undertake further ecological and hydrological studies on problem areas that require habitat modification to inform the Greater Holtze planning already underway.	DIPL
	Planning for aerial mosquito control programs of habitats that are unable to be modified as part of the current Proposal.	DIPL/DoH
	Investigation planting shrub vegetation alongside any acoustic road barrier fencing (e.g. similar to Lyons alongside Lee Point Road), which could be treated with bifenthrin and act as a physical	DIPL

Potential impact	Design component	Owner
	mosquito dispersal barrier. However, as adult mosquito control insecticides are harmful to beneficial insects, any long-term program to regularly treat planted barrier vegetation zones would require careful consideration and management.	
Creation of new mosquito breeding habitat	Drainage infrastructure will be designed in consultation with Department of Health, and in accordance with the <i>Guidelines for Preventing Biting Insect Problems for Urban Residential Developments or Subdivisions in the Top End of the NT</i> . Ultimately, the final drainage infrastructure will need to be designed and constructed in accordance with the handover authority requirements.	DIPL
	Preparation of a Stormwater Management Plan including controls and drainage considerations appropriate to mitigating potential mosquito breeding sites.	DIPL

5.3 Construction

Table 5-2 outlines available mitigation measures to minimise impacts of biting insects during construction. This includes protective measures to mitigate against being in proximity to existing mosquito breeding habitat, and measures to minimise the likelihood of creating new mosquito breeding habitat. These actions, and others as deemed appropriate by the successful Developer and Department of Health, should be incorporated into the Proposal's construction environment management plan (CEMP).

Table 5-2. Mitigation actions during construction

Potential impact	Management action	Owner
Proximity of the Proposal to existing mosquito breeding habitat	Conduct inductions and training regarding personal protection.	DIPL/Developer
	Minimise work at dusk and night when mosquitoes will be most prevalent.	DIPL/Developer
	Make available personal protective clothing and insect repellent adequate to protect against bites to all site personnel.	DIPL/Developer
	Undertaking ongoing monitoring to inform timing of spraying.	DIPL/DoH
	Entry of biting insects into indoor spaces, such as site offices, will be prevented or at least minimised by sealing off and air-conditioning buildings (where possible).	DIPL/Developer
	Any personnel suspected of suffering from mosquito borne diseases must remain off site until medically declared clear, to prevent the spread of the disease.	DIPL/Developer
	Managing mosquito numbers locally through the use of residual surface insecticides during peak times.	Developer (Department of Health can provide advice)
Creation of new mosquito breeding habitat	Design stockpile / laydown / site compound area to reduce likelihood of pooling / creation of temporary habitat.	Developer
	Vegetation growth within structures that pool water should be removed to reduce breeding site potential.	Developer
	Assess construction sites for pooled water after rain, removing any pooled water if identified.	Developer

Potential impact	Management action	Owner
	Residence time for standing water should be less than 5 days.	Developer
	Treat unavoidable shallow ponding with a residual mosquito larvicide (e.g. methoprene 30 day pellets) until the shallow ponding has been rectified/developed.	Developer
	Vehicle ruts, man-made or natural depressions occurring through construction activities will be rectified to avoid pooling of water following heavy rainfall.	Developer
	Sediment basins should be maintained, with sediment periodically removed, to ensure capacity is retained in the structures.	Developer

5.4 Occupancy

As noted in Section 5, it is recognised that key biting insect habitat identified in close proximity (i.e. within minimum 500 – 1,600 m) to the Proposal area site may pose a risk to human health of future residents. Ultimately, these habitats will be modified as part of the future development of Holtze North and Kowandi, however this involves further studies associated with stormwater and hydrological design of these areas that are not yet completed.

Table 5-3 outlines mitigation measures available to the Proposal for the occupancy/operation phase of the Proposal. Details of drainage infrastructure can be found within the Proposal's NT EPA Referral Report.

Table 5-3. Mitigation actions during occupancy

Potential impact	Management action	Owner
Proximity of the Proposal to existing mosquito breeding habitat	Encourage residents to avoid potential mosquito nuisance by using personal protective measures and techniques common across the Top End.	DIPL
	Until a time that nearby breeding habitat can be modified, undertake aerial spraying and larval surveys.	DIPL
	Include advice to future residents on building design, for example installation of veranda fans, installation of insect screens, use of outdoor mosquito repellents.	DIPL
Creation of new mosquito breeding habitat	Implement stormwater management plan, and maintain stormwater drainage.	DIPL/Litchfield Council
	Uphold sufficient maintenance of drainage infrastructure to ensure drainage paths are clear and pooling is minimised.	DIPL/Litchfield Council
	Educate residents about ways to minimise creation of habitat at their residences, such as not allowing water to pool for extended periods of time.	DIPL
	If required, any rainwater tanks must be of an approved design and be completely screened to prevent mosquito entry. All approvals for rainwater tanks should be entered on a registry so that periodic inspection can be made.	DIPL

6 REVIEW AND IMPLEMENTATION

This BIMP has been prepared to:

- Support the NT EPA Referral Report by demonstrating available management and mitigation measures to reduce the potential risk posed by biting insects to human health.
- Manage the impact of mosquitoes at the Proposal site during construction and operation.
- Provide a framework for control practices to be implemented to deter adult mosquitoes on site and prevent the establishment of new or breeding sites.

This document will be reviewed throughout detailed design and updated accordingly, to reflect specific design measures and required actions as further information is available. As noted, key habitat proximal to the Proposal will be modified through future development of Holtze North and Kowandi. DIPL will prepare separate management plans for those sites in consultation with Department of Health, including details of habitat modification that will ultimately mitigate the potential impacts for future Holtze residents.

7 SUMMARY

The Proposal area is proximal to coastal mangroves, estuarine creeks and swamps that provide suitable habitat for mosquitoes. Previous biting insect investigations undertaken by Department of Health across 2019 and 2020 at and near the site indicate biting insects occur within the Proposal area, with mosquitoes the primary biting insect in the area. There is potential the Proposal will also inadvertently create new mosquito breeding habitat within and near the Proposal area.

Areas to be developed for residential use as part of the Proposal occur within the recommended buffer area around key mosquito breeding habitat identified by Department of Health. Ultimately, these key habitats will be modified as part of future development of the Greater Holtze area, however further consideration is required for this to occur that will not be part of the current Proposal.

Until such a time that high risk habitats proximal to the Proposal area can be modified, the Proposal will take the following approach to controlling the risk of biting insects:

- 1) Aerial treatment and barrier (residual surface insecticide) treatments as required, as an interim measure before habitat modification can occur. This may include treatment of:
 - o Noogoo and Milners Swamp and associated upper tidal channel of Kings Creek.
 - o The southern half of the Howard River coastal swamplands and associated upper mangrove channel of the Howard River.
 - o Section 65 paperbark swamp and adjacent large sandmining area.
 - o The Yarrowonga swamplands to the north-west of the Proposal area.
- 2) Continued consideration of engineering controls to guide future management of biting insect habitat through development of the broader Greater Holtze area. While further investigation is required, successful engineering controls are the preferred treatment of this habitat.
- 3) Work with Department of Health to determine appropriate ongoing management actions to manage the risk to human health.

In addition to these key commitments, there are multiple mitigation and management actions available to the Proposal through the design and planning, construction, and occupation/operation phases.

The Proposal will work closely with relevant stakeholders and authorities to ensure mitigations are effective.

8 REFERENCES

Department of Health and Families; Whelan, P (2009). *Guidelines for Preventing Mosquito Problems for Urban Residential Developments and Subdivisions in the Top End of the NT* [unpublished].

Department of Infrastructure, Planning and Logistics (2020). *Northern Territory Subdivision Development Guidelines* [unpublished].

APPENDIX A DEPARTMENT OF HEALTH ASSESSMENT REPORT

Holtze-Kowandi North-Howard Springs
Forestry Reserve
Biting Insect Assessment
November 2019 to October 2020

Final Report November 2020

Medical Entomology
Centre for Disease Control
Public Health Unit
Top End Health Service
NT Health

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1 Introduction

The Holtze baseline trapping between November 2019 and October 2020 was a continuation of the baseline trapping program carried out from March 2014 to February 2015. Trapping recommenced in November 2019 at most of the original sites that were still considered relevant, with additional traps set in the Howard Springs Forestry Reserve in December 2019. The expanded project site is shown in Figure 1.

Based on the original study that encompassed Sections 4229, 4231 and 5623, it was determined that Holtze is subject to widespread high seasonal salt marsh mosquito (*Aedes vigilax*) problems, with elevated localised populations of common banded mosquitoes (*Culex annulirostris*) also present. Both species are considered the main vectors of endemic mosquito borne diseases in the Darwin Region. Much of Holtze was also found to be affected by high seasonal numbers of the golden mosquito *Coquillettidia xanthogaster*. *Anopheles* mosquitoes, which are potential vectors of malaria, were also seasonally present in Holtze.

This report outlines the baseline trapping results from November 2019 to October 2020, with some comparisons to the previous baseline study, and conclusions and recommendations provided based on both baseline mosquito investigations. The recommendations suggest measures that could be carried out to allow urban residential living across large portions of the project site, with reduced mosquito populations at a level at least similar to the lesser mosquito prone suburbs of Darwin and Palmerston. If land use objectives change, the recommendations can be updated to respond to the desired land use. The recommendations from this report replace the recommendations provided in the previous baseline mosquito investigation report.

2 Methods

Adult mosquito trapping carried out for this baseline mosquito assessment was a continuation of the Holtze Baseline Biting Insect Assessment 2015. Ten trap sites from the previous baseline study were used, starting in November 2019, with four additional new trap sites selected in the Howard Springs Forestry Reserve (Portion 2821) in December 2019, and one new trap site at Milners Creek adjacent to Thorngate Road in December 2019. The previous trap site PN10 was only set once in November 2019, and was shifted to Portion 2821 in December when the study area was expanded into forestry lot. Trap sites, and the study area, are shown in Figure 1.

All adult mosquito monitoring traps were set in the afternoon and collected the following morning after sunrise. Traps were mostly set during the week of the full moon, similar to the previous study, as some important mosquito species are thought to appear in greatest numbers during the full moon period. Trap collections were processed at the Medical Entomology Laboratory, with all mosquitoes identified to species levels using taxonomic keys.

Larval mosquito surveys were carried out on the 5th February, 7th of May, 13th May, 1st July, 18th August and 8th September 2020 at select potential mosquito breeding habitats within or nearby to the project site, with a standard 300ml/volume mosquito dipper and/or 10L white bucket used to search for larvae at the vegetated edges of the various water bodies.

3 Baseline mosquito investigation results

3.1 Holtze and Howard Springs Forestry trapping November 2019 to October 2020

3.1.1 Overall mosquito numbers

The overall combined results are displayed in Tables 1 and 2, with select important species results shown in Figures 2 to 5. Individual tables for each monthly trapping event are provided in Appendix 1. Trap locations are also displayed in the various figures. The overall mosquito numbers are displayed as total numbers and an average number of mosquitoes per night in Tables 1 & 2, to highlight the most productive trap sites. As mosquito species are seasonal in nature and not present in the same numbers month after month, please see Section 3.1.2 and Figures 2 to 5 for the seasonal and spatial abundance of important mosquitoes in and nearby to the project site.

The most productive trap was PN03a, which was set just inside the Yarrawonga swamplands near Thorngate Rd. This trap collected 15.37% of all mosquitoes, at a very high average of 880 adult female mosquitoes per trap night (Table 1). Trap PN03a was located about 1.3km NW of the western most edge of the project site. The next most productive trap was PN02a, set just outside the project site alongside Wallaby Holtze Road, with this trap collecting 14% of all mosquitoes, at a very high average of 753 adult female mosquitoes per trap night (Table 1).

Trap Site PN06, set near Taylor Rd near the southern half of Holtze and Kowandi North, was the third most productive trap, recording 9% of all mosquitoes at a high average of 494 adult female mosquitoes per trap night (Table 1). Trap site PN06 was set about 230m from the smaller paperbark swamp in Kowandi North. This was closely followed by PN14, set outside of the project area near the Milner Creek culvert on Thorngate Rd (high average of 443 adult female mosquitoes per trap night), and trap site PN09, set along the northern edge of Kowandi North about 500m from the very large paperbark swamp (high average of 423 adult female mosquitoes per trap night). Most other trap sites recorded moderate to relatively high average mosquito numbers, with the exception of trap sites set near the Stuart Highway, which recorded relatively low average mosquito numbers per trap night (Table 1).

3.1.2 Seasonal and spatial abundance

The seasonal abundance of mosquitoes at the project site so far appears to be relatively distinct and divided into two periods, the early wet season, when salt marsh mosquitoes (*Aedes vigilax*) were the main species, along with the common banded mosquito (*Culex annulirostris*) in January, and the early to mid-dry season when the golden mosquito (*Coquillettidia xanthogaster*) and *Cx. annulirostris* were the main species recorded (Table 2). Other important freshwater mosquito species, such as *Anopheles bancroftii* and *Mansonia uniformis*, also reached their peak levels during the early to mid-dry season (Table 2).

Aedes vigilax is an important mosquito species, and was the second most abundant mosquito species collected in the study area (Table 1). This species was relatively widespread across the site during November 2019, with highest numbers recorded in the northern Holtze to Yarrawonga Swamp-Milner Creek area, although no traps were set in the Forestry Reserve during November (as the forestry was not part of the project site in November), which was the peak month for this species (Figures 2a-2c). Trapping commenced in the Forestry Reserve in December, and the comparatively high numbers of *Ae. vigilax* in the Forestry Reserve in December, when compared to the Holtze and Kowandi North December results, suggest high to very high *Ae. vigilax* numbers would also have been present in the Forestry Reserve in November. The seasonal abundance of *Ae. vigilax* appreciably decreased in

January, with this species generally absent from the study area from February onwards, before reappearing in appreciable numbers during early October 2020.

Aedes vigilax levels recorded in November were considered high to very high at all sites, except for PN10, whilst December abundance ranged from low to very high across the project site, with the very high levels recorded at the northern edge of the Forestry Reserve (Portion 2821). *Aedes vigilax* is a tidal-brackish water mosquito, with the trap results suggesting long distance dispersal from the extensive Shoal Bay tidal swamps to the north of the project site. When compared to the worst affected areas of Darwin at the same time, *Ae. vigilax* numbers were generally similar to the urban fringes of Leanyer, but lower compared to bushland opposite Karama.

Culex annulirostris is considered the most important mosquito species in the NT, and was the third most abundant mosquito collected in the study area. *Culex annulirostris* was recorded at all sites, with highest numbers recorded in the traps located nearest to shallow swamps (Figures 3a-3c). Overall, the highest abundance was recorded in the Forestry Reserve traps near the paperbark swamps downstream of Dutchies Lagoon, and Forestry Reserve trap closest to the Bronzwewing Ave reed lagoon, as well as adjacent to the large Kowandi North paperbark swamp, and in the trap located alongside Milner Creek near the Thorngate Road culvert, and alongside Wallaby Holtze Road (Table 1, Figure 3a). July was the peak abundance month, followed by June, May, January and February (Figure 3a). When compared to Darwin, the peak levels recorded in the more productive parts of the project site during the dry season were higher than trap catches at the urban edge of Leanyer and Marrara, and similar to the urban edge of Karama. Conversely, mid wet season (January and February) *Cx. annulirostris* numbers in the worst affected areas of the project site were lower compared to the fringes of Leanyer and Karama, and similar to the fringes of Marrara.

Coquillettidia xanthogaster was the most abundant mosquito collected in the study area (Table 1, Figure 4a). This species was recorded in high to very high numbers at most sites during the May to July period, with the seasonal peak at most sites occurring in July (Figure 4a). The presence of male mosquitoes can provide some indication of potential nearby breeding grounds. Almost all traps recorded *Cq. xanthogaster* males in July (Appendix 1), with the highest number of males collected at Wallaby Holtze Rd, followed by the trap located about 500m from the Kowandi North large paperbark swamp, and the trap set near the southern Mitchell Creek culvert at the Stuart Highway. In comparison with the most productive mosquito areas in Darwin for this mosquito, *Cq. xanthogaster* levels were generally much higher throughout most of the project site.

Several *Anopheles* species were recorded during the trapping period, with *Anopheles bancroftii* the most abundant *Anopheles* mosquito in the study area, and was also the fourth most abundant mosquito species collected during the trapping (Table 1). *Anopheles meraukensis* was the second most abundant *Anopheles* mosquito, followed by *Anopheles annulipes* s.l. (Table 1). Overall, trap site PN14, located outside the project area, was the most productive trap for *Anopheles* mosquitoes (Table 1), with this site located outside of the project site. Although the abundance of *Anopheles* species within the project site was low from a potential pest perspective, levels recorded near the large Kowandi North paperbark swamp and in the Forestry Reserve exceeded potential malaria thresholds (see Section 4.1.5). The peak season for *An. bancroftii* and *An. meraukensis* was April to July (Figures 5a & 5b).

Mansonia uniformis was another potentially important species recorded at trap locations nearby to shallow vegetated swamps, although overall numbers were considered low (Table 1).

3.2 Larval mosquito surveys

Results from all larval mosquito surveys carried out as part of this study are shown in Tables 3 and 4, with survey locations and species detection locations shown in Figures 6 and 7. Potential mosquito breeding sites important to the project site are shown in Figure 8.

3.2.1 Larval mosquito survey 5 February 2020

A larval mosquito survey was carried out on the 5th of February at numerous seasonally flooded areas in and adjacent to the project site. Despite most sites containing wet season flooding, no mosquito larvae were found. This suggested very low productivity breeding in the different swamp systems, which was reflected in the February adult mosquito trapping results.

3.2.2 Larval mosquito survey 7 and 13 May 2020

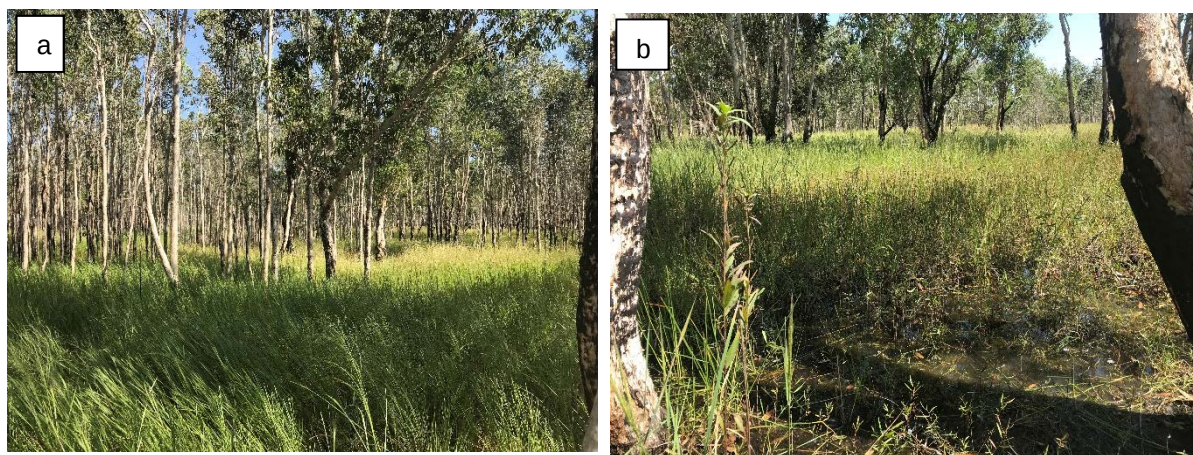
Larval mosquito surveys were again carried out on the 7th May at various swamps, and also on the 13th May at the large Kowandi North paperbark swamp. Results are shown in Table 3.

Yarrawonga (Holtze) eastern paperbark swamp and associated swamplands

Anopheles annulipes s.l. and *Anopheles farauti* s.l. larvae were collected along the eastern edges of the Yarrawonga swamplands, however, in low densities only (Table 3). The middle and western side of the swamplands were not inspected. Areas surveyed are shown in Photos a to d. The grassy areas to the east and south of Thorngate Road were dry at the time of the survey, except at the bike track cross junction culvert. The paperbark area of the swamplands contained the main water body in early May. The various photos indicate heavy grass and semi-aquatic vegetation coverage across the floor of the swamp, which is a precursor for seasonally productive mosquito breeding. It was noted however that despite the heavy vegetation coverage, numerous small fish were present in the swamp, indicating natural mosquito control was still occurring, albeit probably at a much reduced efficiency.

Mosquito species that could potentially breed in deeper water, such as *Cq. xanthogaster*, were not targeted. *Coquillettidia xanthogaster* larvae are very difficult to find, as they attach themselves to the roots of aquatic vegetation.

Overall, the Yarrawonga swamplands in the area surveyed was relatively shallow, with numerous shallow depressions across the floor of the swamp.



Photos. a) Yarrawonga swampland near Thorngate Rd, NE edge. Heavy grass coverage. b) Yarrawonga swampland at trap site PN03a. Heavy grass coverage. Some Eleocharis reeds under paperbarks at top of picture.



Photos. c) Yarrowonga swampland, near SW corner of eastern paperbark swamp, at footpath culvert. Heavy grass coverage. d) Yarrowonga swampland, eastern paperbark swamp, at southwest edge of paperbarks. Heavy aquatic plant coverage across water surface. All four sites contained shallow flooding.

Kowandi North large paperbark swamp

Larval mosquito inspections were carried out at the western edge of the road easement, extending to about 100m north of the road easement. The swamp, despite a relatively dense coverage of paperbarks, was mostly sunlit and therefore contained large amounts of aquatic vegetation. The aquatic vegetation extended well into the swamp from the water's edge (in that area of the swamp), which, as with the Yarrowonga swamplands, was suggestive of a productive larval mosquito habitat (Photos e and f).

Culex annulirostris, *An. annulipes* s.l. and *An. farauti* s.l. larvae were collected in the swamp in low numbers (Table 3), with mosquito larvae more prevalent within about 5 -10m of the water's edge. Adult *Ma. uniformis* and *Cq. xanthogaster* were observed biting during both surveys of this swamp, which was suggestive of the swamp being a breeding site for these species. The larvae of both *Ma. uniformis* and *Cq. xanthogaster* attach to the roots of aquatic plants, and although aquatic plants were shaken and swept with nets to try and dislodge any larvae, none were recovered. It is possible that deeper water areas or wider areas of the swamp needed to be surveyed.



Photos. e & f) Kowandi North large paperbark swamp 7th May 2020. Shallow water, large expanse of dense semi-aquatic and aquatic plants, extending well into the water from the water margin. Groundwater was observed flowing into the swamp from a wheel rut about 10m from the water's edge.

Howard Springs Forestry Reserve. Swamps downstream of Dutchies Lagoon.

The paperbark swamp downstream of Dutchies Lagoon, closest to Howard Springs Road, was surveyed at the northeast and southern margins (Photos g and h). No mosquito larvae were located in the relatively clear water, with minimal semi-aquatic and aquatic vegetation present compared to

Yarrawonga eastern paperbark swamp and the Kowandi North paperbark swamp. Numerous small fish were present. The swamp had the appearance of a low productivity early dry season mosquito breeding site, with water levels still high at the time of the survey, indicating the swamp was in a natural stage of lowest mosquito productivity.

The Tall sedge lagoon, to the northwest of Dutchies Lagoon, was also inspected at the northeast edge (Photo i). Water levels were still high, and extended into the paperbark fringe, about 20 from the start of the dense tall grassy area of the swamp. *Culex species* 32 larvae were collected in very low densities at the water margin, amongst dying grass. The swamp's dense standing grass area was not surveyed due to the relatively deep water. Several *Ma. uniformis* adults were observed biting, suggesting the swamp could be a potential breeding site for this species. The complete coverage of the lagoon with dense tall sedges (*Scleria poaeformis*) was also indicative of a potentially major *Cq. xanthogaster* breeding site, and potentially productive *Cx. annulirostris* breeding site.



Photos. g) Large paperbark swamp northwest of Dutchies Lagoon, south of Howard Springs Rd - NE edge. Relatively clear water. Dead thin grass species, possibly speargrass, in the flooded section. Moderate to deep water. h) Large paperbark swamp north of Dutchies Lagoon, south of Howard Springs Rd - southern edge. Clear water, mostly dead thin grass species. i) Tall sedge lagoon NW of Dutchies Lagoon. Very large area of dense tall semi-aquatic sedge (*Scleria poaeformis*) in main area of lagoon, with an open grassy paperbark fringe.

Localised freshwater wetlands - eastern portion of Howard Springs Forestry Reserve

These areas were not surveyed for mosquito larvae, due to very dense and tall gamba/mission grass, which made access impossible on foot.

Bronzewing Avenue reed lagoon

Water levels were high at the time of the survey, extending past the semi-aquatic reed edge and into the paperbark fringe. Low mosquito breeding was found in the road drain leading into the swamp, although no important human health species were collected (Table 3). The dense areas of semi-aquatic reeds could not be accessed for sampling due to the high water level, with further surveys required at a later stage. The reeds appeared to be *Eleocharis* species, suggesting suitable habitat for numerous important mosquito species, including *Cx. annulirostris*, *Anopheles* species, *Cq. xanthogaster* and *Ma. uniformis*. The almost complete coverage of semi-aquatic reeds and grasses across the waterbody suggested this lagoon is likely to be a very important mosquito breeding site (Photos j and k).



Photos. j) Bronzewing Avenue reed lagoon - very large area of semi-aquatic reeds and grasses across the lagoon. k) Lower reaches of drain leading into lagoon from Bronzewing Avenue.

3.2.3 Larval mosquito survey 1 July 2020

Kowandi North large paperbark swamp

This large paperbark swamp was dry in July. The overflow channel from the swamp was also dry, and the start of the downstream pandanus forest was also dry at the upstream limits of the pandanus forest (Photos l to n).



Photos. l) Kowandi North large paperbark swamp, western portion along road reserve. Dry with dense groundcover. m) Kowandi North large paperbark swamp outlet channel. Sandy, well defined channel from edge of swamp to paperbark area 220m downstream.



Photo. n) End point of Kowandi North paperbark swamp overflow channel.

Yarrawonga swamplands

The swamp appeared dry from Thorngate Rd in July 2020. Due to very dense groundcover the swamp was not traversed by foot. However, an examination of [Sentinel Hub](#) aerial photography with select colour bands suggested the swamp area near Thorngate Road and southeast of Pinelands was dry by late June.

Howard Springs Forestry Reserve – Areas downstream of Dutchies Lagoon

The large paperbark swamp closer to Howard Springs Road was dry, except for minor ponding in the swamp drainage line (Photos o and p). The tall sedge lagoon to the northwest of Dutchies Lagoon was still mostly flooded, when viewed from the NE corner, with water sitting in the tall sedge main body of the lagoon and adjacent grassy margin (Photo q). Water was also ponding in the paperbark swamp that immediately adjoins the tall sedge lagoon. Low level *Anopheles bancroftii*, *An. annulipes* s.l. and *Cx. annulirostris* breeding was detected amongst the dense short grass, along with other less important mosquito species (Table 4). Relatively high densities of *Cx. annulirostris* larvae were located in wheel ruts associated with the firebreak along the east margin of the lagoon.



Photos. o) Large paperbark swamp downstream of Dutchies Lagoon, close to Howard Springs Road. Dry, limited ground cover. p) Shallow drainage line through swamp, minor ponding. q) NE edge of the tall sedge lagoon NE of Dutchies Lagoon. Ponding in the grass and sedge, and in the downstream paperbark swamp.

Bronzewing Ave reed lagoon

This lagoon was holding water in the reed/open shallow water area (Photo r), with water having retreated from the paperbark fringes. *Anopheles bancroftii* and *Cx. annulirostris* breeding was detected at the grassy northern edge of the lagoon, along with other less important mosquito species (Table 4).



Photo. r). Bronzewing Ave reed lagoon, looking south from northern edge. Very large expanse of semi-aquatic and aquatic vegetation.

3.2.4 Larval mosquito survey 18 August 2020

In August, two areas in and nearby to the project site where water was still likely to be present were surveyed, the Tall sedge lagoon in the Howard Springs Forestry, and the Bronzewing Ave reed lagoon. Survey results are shown in Table 4. There were no important mosquito species collected in the Tall sedge lagoon, although the dense tall sedges restricted the surveyable area to the outer edge of the lagoon. *Culex annulirostris* larvae were detected in very low densities along the northern edge of the Bronzewing Ave reed lagoon, with no larvae located along the eastern edge of the lagoon.

3.2.5 Larval mosquito survey 8 September 2020

The Tall sedge lagoon was dry at the northern margin, but could not be inspected for more than 10-15m inside the sedge vegetation. The mud was still damp, suggesting the swamp had only recently dried out (Photo s).



Photo. s) Tall sedge lagoon, northern edge. Damp mud.

The paperbark swamp downstream of the Tall sedge lagoon was briefly traversed to inspect the groundcover. The floor of the swamp was noted to contain patches of dense short grass and other grasses in the more sunlit areas, and areas of aquatic plants similar to that in the large Kowandi North paperbark swamp, but somewhat less dense (Photos t and u). The paperbark swamp in the section immediately downstream of the Tall sedge lagoon contained numerous obvious depressions. All of these factors suggest likely dry season and early wet season mosquito breeding in this swamp.



Photos. t) Start of paperbark swamp immediately downstream of the tall sedge lagoon. Open grassy area, and shallow depressions were present in the floor of the swamp. u) Paperbark swamp downstream of the Tall sedge lagoon, patches of semi-aquatic plants.

The Bronzewing Ave reed lagoon was still ponding water, with an abundance of water birds present in the lagoon (Photo v). Water was still ponding in the mixed *Eleocharis* reeds/lodged grass margin at the northern edge of the lagoon, with low level *Cx. annulirostris* and *An. bancroftii* breeding detected (Table 4).



Photo. v) Northern edge of Bronzewing Ave reed lagoon, with water ponding in the mixed grass and *Eleocharis* reed margin of the open pool. Numerous water birds. Low level mosquito breeding at the water margin.

At the northwest corner of the lagoon, water had mostly retreated below the large *Eleocharis* reed patch (Photo w). However, relatively high level *Cx. annulirostris* breeding was detected in the relatively open water below the reeds. *Culex annulirostris* larvae were found amongst floating debris, under lily leaves and amongst dying aquatic vegetation (Photo x). This high productivity site in the lagoon was located

only 50m from the low productivity northern edge, highlighting the variability of productive mosquito breeding areas within a large larval habitat.



Photos. w) North east margin of lagoon, very thick coverage of *Eleocharis* reeds. Water had retreated below the large reed area. x) Western edge of late dry season open pool in northern portion of lagoon. Mosquito larvae were found amongst floating debris and lilies.

The lower portion of Mitchell Creek near the footpath and Stuart Highway was inspected, with one small muddy pool located near the road culvert, with numerous small fish that would likely have soon perished. The creekline to the north of the footpath/old railway was dry. The creek channel near the footpath contained numerous depressions and high spots caused by vegetation growth, but semi-aquatic vegetation was absent. The creek channel (south arm) appeared to be very shallow in the overgrown section that runs parallel with the footpath. The north arm was not inspected, nor the middle to upper reaches of the three arms. Based on aerial photography, it appears that a continuous incised channel does not exist in either of the three arms.

4 Discussion

4.1 Mosquitoes

4.1.1 The northern salt marsh mosquito *Aedes vigilax*

The results from the current baseline trapping were similar to the previous baseline trapping program, with high to very high seasonal *Ae. vigilax* abundance recorded in Holtze and Kowandi North, and also in the Howard Springs Forestry Reserve. The current and past trapping results most likely collected peak levels of this species across Holtze and Kowandi North. The Forestry Reserve data is likely to have represented the second highest peak during the 2019 *Ae. vigilax* season, due to the absence of November 2019 results.

Aedes vigilax lays eggs in damp saline depressions, which subsequently hatch after being inundated following high tides or rainfall. This species utilises a wide range of saline habitats, ranging from poorly draining mangrove forests, saltmarshes, coastal reed swamps, interdunal depressions, tidal stormwater drains, coastal parkland depressions and tidal rock pools. *Aedes vigilax* has a very long flight range from major larval habitats, capable of flying at least 60km in pest numbers (Whelan 1997a). Shoal Bay contains very productive and extensive *Ae. vigilax* larval habitats, which results in the Darwin area, within about 10-20km of the Shoal Bay coastal swamps, experiencing annual pest problems during the build-up and early wet season. Highest *Ae. vigilax* abundance can be expected within about 3-5km of the Shoal Bay coastal swamplands.

When considering the project site, the Milners Swamp and associated upper tidal channel of Kings Creek, and the southern half of the Howard River coastal swamplands and associated upper mangrove channel of the Howard River, are most likely the main sources of *Ae. vigilax* impacting the project site. While these sites have not been examined in detail during the baseline study, previous ad-hoc helicopter surveys by Medical Entomology have shown high *Ae. vigilax* breeding in these areas.

Aedes vigilax is an aggressive day and night biting species, capable of transmitting Ross River virus (RRV) and Barmah Forest virus (BFV). The trap results indicate *Ae. vigilax* is likely to be the most abundant species in Holtze and the Howard Springs Forestry Reserve during the build-up months and early wet season. The levels recorded in November and December were high to very high. In comparison to Darwin at the same time, *Ae. vigilax* numbers were lower compared to the urban edge of Karama, and similar to the urban edge of Leanyer.

4.1.2 The common banded mosquito *Culex annulirostris*

Culex annulirostris is generally considered to be the most important mosquito species in the NT, due to its potential to transmit numerous mosquito borne diseases. *Culex annulirostris* larvae can be found in a variety of freshwater and brackish water habitats, with open grassy/semi-aquatic reed habitat considered the most productive natural larval habitats in the Darwin region. This species is also commonly associated with man-made structures such as wastewater ponds (when semi-aquatic vegetation is present) and blocked stormwater drains. Lee et al (1989) notes that *Cx. annulirostris* will disperse up to 7km from their larval site, and possibly further, while Whelan (1997a) suggests that this species will fly up to 10km from their breeding site.

The abundance of this mosquito, from a potential pest aspect, was generally low to moderate within the study area during the current baseline trapping, with the exception of relatively high numbers nearby to the Kowandi North large paperbark swamp, and close to the Forestry Reserve paperbark swamps downstream of Dutchies Lagoon. Both baseline studies revealed *Cx. annulirostris* is most abundant from May to August, with peak numbers in either June or July. In other areas in the Darwin Region, *Cx. annulirostris* can also reach peak numbers in January or February, after widespread flooding following monsoonal rains. This mid wet season peak was not detected during the baseline trapping, either due to a lack of productive mid wet season larval habitat, or in the case of 2020, due to poor rainfall. It is also possible that the less sensitive monthly trapping missed the mid wet season peak.

Overall, the dry season abundance recorded in the more productive areas of the project site were higher compared to trap catches at the urban edge of Leanyer and Marrara, and similar to the urban edge of Karama. Conversely, mid wet season (January and February) *Cx. annulirostris* numbers in the worst affected areas of the project site were lower compared to the urban edge Leanyer and Karama, and similar to the urban edge of Marrara.

The potential larval habitats within and nearby to the project site are numerous and extensive, including the two large paperbark swamps in Kowandi North, the Tall sedge lagoon and downstream paperbark swamps (particularly the paperbark swamp immediately downstream of the Tall sedge lagoon), Dutchies Lagoon, the Yarrowonga swamplands, the Section 65 paperbark swamp and nearby sandmining area, and the large grassy lagoon south of Bronzewing Avenue in Section 3418 (Howard River Park). On a smaller scale, Mitchell Creek, as well as seasonally waterlogged areas across the study area, may produce local populations of this species, particularly if these sites receive future urban stormwater discharge. The small swamps/depressions between the Forestry Reserve and Howard Springs, including the small wastewater ponds, could also impact the nearby areas of the project site. Two distant, but potentially very large breeding sites, are the extensive reed/grassy swamp in the Howard Springs Hunting Reserve (Howard Springs Hunting Reserve swamp) and Milners Swamp, located 2.2km and 4.6km from the project site respectively. The Howard Springs Hunting Reserve swamp in particular

is likely to have produced at least some *Cx. annulirostris* that subsequently dispersed into the Forestry Reserve.

While low *Culex annulirostris* larval densities were recovered from the large Kowandi North paperbark swamp, the very large size of the swamp indicates it could produce appreciable adult *Cx. annulirostris* populations. This was confirmed by adult mosquito trapping adjacent to and 500m from the swamp, which revealed the second and third highest *Cx. annulirostris* trap catches in the project site. *Culex annulirostris* larvae were also recovered in low to relatively high densities from the grassy edges of the Tall Sedge lagoon, which might explain why the nearest trap, albeit 800m from the lagoon, was the most productive for this species, although Dutchies Lagoon would have also provided mosquitoes to most traps in the Forestry Reserve. *Culex annulirostris* larvae were also recovered in low to relatively high densities from the Bronzewing Ave reed lagoon, which combined with the high water bird populations, makes the lagoon very important in terms of the potential for mosquito borne disease transmission.

Culex annulirostris is considered the most important mosquito in the NT from a disease aspect, capable of transmitting RRV, BFV, Murray Valley encephalitis virus (MVEV) and Kunjin virus (KUNV). In some parts of the project site, adult *Cx. annulirostris* exceeded the potential MVEV/KUNV virus threshold of 70-100 per trap that can lead to seroconversions in sentinel chickens (Kurucz et al 2005), subsequently potentially leading to human transmission. The traps near the Kowandi North paperbark swamp, and east and west edges of the Forestry Reserve, were the main traps within the project site that exceeded the nominal virus threshold level. The nominal virus threshold was also met at the trap near the Palmerston hospital in June 2020.

4.1.3 The golden mosquito *Coquillettidia xanthogaster*

This mosquito was recorded in seasonally high to very high early to mid-dry season numbers throughout much of the Holtze and Howard Springs Forestry area, with the previous baseline trapping also identifying high to very high numbers. The potential pest problem near the large Kowandi North paperbark swamp appeared to be higher compared to any other urban area in the Darwin Region, whilst abundance in the Forestry Reserve appeared similar to bushland opposite Karama, which is the worst area for this species near urban Darwin. The peak season was May to July across the project site, which is the usual peak season for this species in the Darwin Region.

Coquillettidia xanthogaster can be an appreciable pest species, biting mainly after sundown but also in densely shaded areas during the daytime. It is not considered a vector of mosquito borne disease in the NT. The larvae of this species cannot be easily found, as they attach themselves to the stems and roots of aquatic plants, and therefore the larvae of this species could not be located during limited larval mosquito surveys. However, the trap results suggest the various paperbark swamps, and possibly Dutchies Lagoon, the Tall sedge lagoon, and the Bronzewing Ave reed lagoon are likely to be appreciable sources of this species. The pandanus lined pools within Mitchell Creek could also offer localised habitat for *Cq. xanthogaster* larvae. Due to the long flight range of this species, Milners Swamp and the Howards Springs Hunting Reserve swamp could be additional sources of this mosquito during very large breeding events, as this species is known to fly up to 5km from very large breeding sites (Whelan 1997a).

4.1.4 *Anopheles* species mosquitoes

During the current and previous trapping, *Anopheles* species mosquitoes were recorded in low numbers from a pest perspective in the project site. *Anopheles* species larvae, however, were recovered from the Kowandi North large paperbark swamp, Tall sedge lagoon, Dutchies Lagoon, Yarrowonga swamplands eastern paperbark swamp, and Bronzewing Ave reed lagoon. This suggests extensive habitat exists within and adjacent to the project site. Other potential breeding sites affecting the project site would include the Section 65 paperbark swamp and the adjacent sandmining swamp, the smaller paperbark swamp in Kowandi North, and at least the first paperbark swamp immediately downstream of the Tall

sedge lagoon, but possibly also the second paperbark swamp closer to Howard Springs Road. Small drainage lines/creeklines, such as Mitchell Creek and the Dutchies Lagoon overflow drain, could also provide localised larval habitat during the mid-dry season. Despite the low *Anopheles* species numbers in the adult monitoring traps, the main season was clearly observed to be the late wet to mid-dry season.

Anopheles species mosquitoes are highly important, as mosquitoes from this genus are the vectors of malaria. Please see Section 4.1.5 below for further discussion. Some species, particularly *Anopheles bancroftii*, can also be appreciable pest mosquitoes in the Darwin region.

4.1.5 Mosquito borne diseases

Ross River and Barmah Forest viruses

The main vectors of Ross River virus (RRV) and Barmah Forest virus (BFV) in the study area are the northern salt marsh mosquito *Ae. vigilax*, and the common banded mosquito *Cx. annulirostris*. The *Ae. vigilax* trap results suggest the risk of mosquito borne disease transmission throughout the project site could be higher than in existing Palmerston and much of Darwin, but similar to somewhat lower compared to the northern fringes of Darwin adjacent to the Leanyer and Holmes Jungle swamps. *Culex annulirostris* trap results so far suggest the risk posed by this species could be somewhat similar to Durack and Marrara, but probably lower than the edge of Leanyer. Wallabies are considered to be the main host animal of RRV, with populations likely to be present within and adjacent to the study area, whilst the host animal for BFV is unknown, however is likely to be present in the study area as BFV infections have been recorded throughout the NT. The main RRV and BFV season in the Darwin region is usually December to June, with a January to March peak.

After urban, rural and industrial/commercial development occurs, a third potential vector species is likely to become locally abundant, the container breeding mosquito *Aedes notoscriptus*.

Murray Valley encephalitis virus and Kunjin virus

Murray Valley encephalitis virus and Kunjin virus are the two most serious endemic mosquito borne diseases in the NT, although human disease cases are rare. Usually, only about one in 500-1000 people who are bitten by an infected mosquito develop symptoms ([CDC factsheet](#)). MVEV can be fatal or cause permanent neurological symptoms in up to half of all cases. *Culex annulirostris* would be the principal vector mosquito in the study area.

Sentinel chicken flocks are used to monitor for the seasonal prevalence of these two viruses in the NT, with a flock at Howard River Park located close to the project site detecting KUNV during most years. MVEV detections in the Howard River Park sentinel chickens have been less common, with only one detection in the past 10 years, although it was recorded during most years from 1999 to 2009. Migratory water birds, particularly herons and egrets, are thought to be the main host animal for both viruses, with the Bronzewing Ave reed lagoon, Howard Springs Hunting Reserve swamp, and probably Milners Swamp, representing favourable habitat for migratory water birds nearby to the project site. In general, based on sentinel chicken data, the peak MVEV season is considered to be March to May, with the main risk season being January to July.

In terms of the risk throughout much of the project site, based on vector mosquito numbers, it appears to be similar to the fringes of Marrara, but possibly lower than the edge of Leanyer. However, the *Cx. annulirostris* season is extended in the study area, compared to Leanyer Swamp which has a drainage system to reduce dry season ponding. Therefore, it is possible that the virus risk in the study area is greater than at the edge of Leanyer. It should be noted however, that despite KUNV and MVEV being detected in sentinel chickens at the edge of Leanyer during some years, so far no human cases of MVEV and KUNV have been notified in urban Darwin. It is possible that the shorter *Cx. annulirostris* season in Leanyer due to drainage, and helicopter control of Holmes Jungle Swamp, has reduced the

potential for virus transmission along the northern edges of Darwin. Other prevention measures, such as the use of personal insect repellents, protective clothing, houses with insect screens and staying indoors during problem periods, have most likely also played a role in the lack of human cases. It would be expected that the various prevention strategies mentioned above would be implemented in future residential areas of the project site.

Malaria

Malaria was declared eradicated in Australia in 1981, with the last case of local transmission in the NT in 1962 (Whelan 1995). Most *Anopheles* species are considered potential vectors of malaria, with *An. farauti* s.l. generally considered the primary vector (Russell 1987), and *An. bancroftii* and *An. annulipes* s.l. also potential vectors in the NT (Whelan 1997a). All three species were recorded in the project site. In general, about 10 or more *Anopheles* mosquitoes in an overnight CO₂ baited EVS trap could represent a potential malaria risk, if a person returning from overseas with malaria is bitten by local *Anopheles* mosquito. The current and past baseline trap results suggest the most important risk area in the Holtze-Kowandi area would be close to the large paperbark swamp in Kowandi North, where the indicative malaria risk threshold was exceeded for *An. bancroftii*. Traps in the Forestry Reserve nearby to Dutchies Lagoon, the Tall sedge lagoon and associated paperbark swamps, and nearby to the Bronzewing Ave reed lagoon, also recorded *An. bancroftii* levels above the risk threshold.

Provided that larval habitat remediation and mosquito monitoring and control is carried out, in combination with current Top End Health Service protocols to monitor and treat patients, the likelihood of local malaria transmission in future urban areas would be considered very low.

4.1.6 Potential mosquito breeding sites

The project site contains numerous seasonally flooded wetlands that offer breeding habitat for pest and potential disease carrying mosquitoes. The project site is also close to large freshwater wetlands, both natural and man-made/disturbed, and within the flight range of important mosquito species that are breeding in the Shoal Bay coastal swamps to the north and northeast. Overall, trap results suggest a late wet season to mid-dry season mosquito peak in most of the swamps, with the exception of the Bronzewing Ave reed swamp, which appears to offer potential mosquito breeding habitat during almost all months of the year. The short mid wet season *Cx. annulirostris* peak that is common in other areas of Darwin was absent from the study area, despite the availability of potential breeding habitat. This may have been due to poor rainfall, but possibly due to the monthly trapping missing the short peak, which usually occurs not long after the first or second monsoon.

Conversely, the poor wet season may have been a contributor to the very high *Cq. xanthogaster* numbers, which relies on aquatic vegetation. Low rainfall might not have 'drowned out' aquatic and emergent vegetation, allowing an increase in breeding habitat for this mosquito.

Based on the recent adult mosquito trapping season and associated brief larval mosquito habitat investigations, and along with an examination of aerial photography, potentially important breeding sites within and nearby to the project site are discussed below, and indicated in Figure 8.

Kowandi North large paperbark swamp

This large swamp is about 21.5ha in size, with the largest portion of the swamp located within the project area. The trap results suggest this swamp is a very large source of *Cq. xanthogaster*, low to relatively high source of *Cx. annulirostris*, an important source of *Anopheles* mosquitoes, and localised source of *Ma. uniformis*. Of the important mosquito species, larval mosquito surveys have recovered *Cx. annulirostris* and *Anopheles* species larvae from this swamp. The observation of day biting *Cq. xanthogaster* and *Ma. uniformis* at the swamp, combined with dense aquatic and emergent plants and associated soft roots, was indicative of this swamp providing larval habitat for these two species, whose larvae attach to the roots and stems of aquatic plants and are therefore difficult to find. Overall, adult

mosquito trapping results suggest this swamp is one of the largest source of mosquitoes within the project site. Aerial photography indicated the swamp was dry by late June 2020, albeit after two consecutive 'dry' wet seasons, with a survey at the beginning of July confirming the swamp was dry. Current adult mosquito trapping suggested the most important months for mosquito productivity in this swamp is April to end of June.

Several swamps around Darwin, most notably the Leanyer, Casuarina and Coconut Grove swamps, were highly impacted by urban stormwater runoff, which increased or created appreciable dry season mosquito breeding (Jacups et al 2012). The swamps were modified to reduce the anthropogenic caused mosquito breeding in the 1980's (Jacups et al 2012), however can still produce appreciable numbers of mosquitoes, particularly when drains become blocked with vegetation and sediment. It is therefore likely that any future upstream urban development could lead to increased mosquito productivity in Kowandi North large paperbark swamp, particularly for *Cx. annulirostris* and *Anopheles* species.

This paperbark swamp has an incised outflow channel that arises from the NW corner of the swamp, which flows in a northerly direction for about 220m before being cut off by a relatively large and dense pandanus forest. A paperbark swamp appears to be located downstream of the pandanus forest. The Kowandi North large paperbark swamp outflow channel was open and sandy, and therefore is unlikely to be an appreciable source of mosquitoes. This area somewhat resembles Rapid Creek upstream of the airport, which is considered a moderate seasonal source of *Cx. annulirostris*, *Cq. xanthogaster* and *Anopheles* species, therefore it is possible that some mosquitoes from this pandanus and paperbark swamp would impact on Kowandi North and Holtze.

Kowandi North small paperbark swamp

The smaller paperbark swamp located in the central western portion of Kowandi North is about 8.5ha in size. This swamp was not surveyed by Medical Entomology. Aerial photography suggested this swamp had dried out by the first or second week of June 2020. Adult mosquito trapping recorded minor to low *Cx. annulirostris*, *Anopheles* species and *Ma. uniformis* abundance, suggesting the swamp is either less productive than the larger northern swamp in Kowandi North, or the swamp is of similar productivity, but produces less than half the mosquitoes of the larger swamp. Conversely, the adult mosquito trap set nearby to this swamp caught more *Cq. xanthogaster* than the two traps set nearby to the larger paperbark swamp in Kowandi North, despite the much smaller size of this swamp. However, peak *Cq. xanthogaster* numbers in the trap set nearby to this swamp were recorded in early July, about a month after this swamp had dried out. This indicates a high proportion of *Cq. xanthogaster* numbers collected nearby to this swamp may have dispersed to the area from other breeding sites, at least from late June onwards.

Urban stormwater discharge could increase the mosquito productivity of this swamp, as outlined above for the large paperbark swamp in Kowandi North.

Howard Springs Forestry Reserve. Tall sedge lagoon and downstream paperbark swamps

The Tall sedge lagoon to the NW of Dutchies Lagoon, in the southwest portion of the Forestry Reserve, is about 6ha in size, and joins onto a downstream paperbark swamp of about 4.5ha in size. Further downstream, closer to Howard Springs Road, is another paperbark swamp of about 6.5ha in size. Of the three swamps, the Tall sedge lagoon and paperbark swamp immediately downstream of the Tall sedge lagoon are likely to be the most productive for mosquito breeding, due to the abundance of semi-aquatic vegetation. *Culex annulirostris*, *An. annulipes s.l.* and *An. bancroftii* larvae were the important mosquito species found in the grassy NE margin of the Tall sedge lagoon. No mosquito larvae were recovered from the sedge area of the swamp, although the very dense sedge vegetation restricted the extent of surveys. The dominant tall sedge vegetation, Cyperaceae - *Scleria poaeformis*, is considered relatively uncommon in the NT, therefore there has been no association established between this semi-aquatic plant and mosquito breeding as yet.

The paperbark swamp immediately downstream of the Tall sedge lagoon appears to have the characteristics of a high productivity mosquito breeding site, with numerous depressions in the floor of the swamp, dense couch type grass coverage and areas of semi-aquatic/aquatic vegetation. This was somewhat similar to the large Kowandi North paperbark swamp. This suggests *Cx. annulirostris*, *Anopheles* species and *Cq. xanthogaster* are the likely important mosquito species that would breed in this swamp.

Due to the extended dry season ponding, the main mosquito breeding season for this lagoon is likely to be April to July.

Seasonally waterlogged/ponding area eastern portion of Howard Springs Forestry Reserve

An examination of aerial photography suggested this seasonally waterlogged area did not contain any large areas of residual surface ponding in 2020, although this could have been due to the well below average wet season. The relatively dense grass groundcover suggests this swamp could be an important localised source of *Cx. annulirostris* during at least normal to above average wet seasons.

Mitchell Creek

Mitchell Creek, upstream of the Stuart Highway, appears to split into three arms, with all three arms appearing to lack a continuous incised channel when examined via aerial photography. The two traps set near Mitchell Creek recorded the fewest mosquitoes in the project area, indicating these arms of Mitchell Creek are not likely to be appreciable sources of mosquitoes. The seasonally high *Cq. xanthogaster* numbers in the Mitchell Creek area were most likely mosquitoes that had dispersed from nearby paperbark swamps, although it cannot be discounted that this species could be breeding in the paperbark/pandanus lined channels.

An ad-hoc late dry season survey in an arm of Mitchell Creek at Zuccoli identified localised *Anopheles* species and *Cx. annulirostris* breeding, suggesting the same could occur in the areas of Mitchell Creek in Holtze. The greatest potential for Mitchell Creek to cause issues to future residents in Holtze would be when urban stormwater discharge increases dry season ponding and nutrient levels in the creeklines. The potential future colonisation of this part of Mitchell Creek with semi-aquatic weeds, such as olive hymenachne and paragrass, could further exacerbate any current mosquito breeding.

The small borrow pit areas located near Mitchell Creek are potentially localised sources of *Cx. annulirostris* and *Anopheles* species.

Dutchies Lagoon

This lagoon has been recognised as a major source of *Cx. annulirostris*, *Cq. xanthogaster* and *Anopheles* species mosquitoes (Whelan 1987). A larval mosquito survey in June 2017 also revealed relatively high *Cx. annulirostris* and *Anopheles bancroftii* breeding at the southwest grassy edge of the lagoon, indicating productive habitat exists. Overall, it appears that the main mosquito breeding period at Dutchies Lagoon is April to July.

Section 65 paperbark swamp and associated Section 65 & Section 4228 sandmining swamp

Trap results from Wallaby Holtze Rd, 900m from the Section 65 paperbark swamp and 500m from the sandmining swamp, recorded very high to extremely high *Cq. xanthogaster* numbers during the early-mid dry season. Numbers of *Cq. xanthogaster* at Wallaby Holtze Road were similar to the Yarrawonga swamplands, and much higher than at any trap site within the project area. Therefore, the trap results suggest that one, or both of these swamps, contain very productive breeding sites for *Cq. xanthogaster*.

Baseline adult mosquito trapping also suggested that one, or both of these swamps, are sources of low numbers of *Anopheles* species mosquitoes, during the late wet and early dry season. *Culex annulirostris*

numbers at Wallaby Holtze Road were considered low to moderate, and were slightly lower compared to the traps set near the Kowandi North large paperbark swamp, suggesting low to moderate *Cx. annulirostris* breeding in these two swamps.

An examination of aerial photography suggested the paperbark swamp was dry by late June 2020, similar to the Kowandi North large paperbark swamp, while the sandmining swamp was dry by late July 2020. The adult mosquito trap results indicated April to July is the peak period for mosquito abundance from these swamps.

Yarrowonga (Holtze) swamplands

The adult mosquito monitoring trap next to this swampland yielded similar overall mosquito numbers to the mosquito trap set near the Section 65 paperbark swamp and associated sandmining swamp. However, the trap near the Yarrowonga swamplands collected the single largest *Cq. xanthogaster* peak of all the trap sites, with over 6000 collected during the overnight trapping in early July. Larval mosquito surveys revealed the swamp has a thick understory of grass and other semi-aquatic vegetation, with *Anopheles* species larvae recovered in low numbers from the eastern fringes of the main paperbark swamp alongside Thorngate Road. Overall, the dense semi-aquatic vegetation is suggestive of important breeding habitat for *Anopheles* species, *Cx. annulirostris* and *Cq. xanthogaster*. Aerial photography suggested the swamp was dry by late June 2020, with adult mosquito trap results indicating the peak mosquito breeding season for this swampland is likely to be April to late June.

Bronzewing Avenue reed lagoon

This lagoon was confirmed as a breeding site for *Cx. annulirostris* and *Anopheles* species, and is likely to be a significant breeding site for *Cq. xanthogaster* and *Ma. uniformis*, due to the widespread coverage of the water surface with semi-aquatic reeds and grasses. Highest larval mosquito densities were recorded during September, in relatively open shallow water with floating debris, after water had mostly retreated from the *Eleocharis* reed margin at the NW corner of the swamp. Overall, it appears likely that mosquito breeding occurs almost all year in the lagoon, with a dry season peak in mosquito productivity.

Milners Swamp

The upper tidal areas of Milners Swamp, and other tidal swamps associated with Kings Creek, are likely to be the main sources of *Ae. vigilax* to at least Holtze and Kowandi North, and a significant source of *Ae. vigilax* to the Forestry Reserve. The tidal swamps would be most productive during September to January, with October to December the peak productivity months. Adult mosquito trapping results showed high to very high levels throughout much of the study area, suggesting the tidal swamps are large and productive. The project site is within the flight range of *Ae. vigilax* arising from the tidal and brackish water areas of Milners Swamp.

Milners Swamp, when including both the tidal and freshwater/brackish water reed/grass areas, is about 200ha in size. The upstream portion of Milners Swamp is shown in Figure 1. Aerial photography suggests the freshwater section of the swamp is large, possibly about 150ha in size. The large size of the freshwater component of Milners Swamp suggests that during high productivity breeding events, other long dispersing species such as *Cq. xanthogaster* and *Cx. annulirostris* could also disperse to the project area. The closest part of the freshwater swamp to the study area is about 4.6km away, which is within the flight range of both species. The July 2020, and in particular August 2020 trapping results, suggested a proportion of *Cx. annulirostris* and *Cq. xanthogaster* in at least Holtze and Kowandi North may have originated from Milners Swamp.

Howard River swamps (western swamplands)

The tidal swamps associated with the Howard River are anticipated to be sources of *Ae. vigilax* to the project site during September to December/January, whilst the Howard Springs Hunting Reserve freshwater grassy/reed swamp could be a source of *Cx. annulirostris* and *Cq. xanthogaster* to the

Forestry Reserve during major breeding events in the early to mid-dry season. The Howard Springs Hunting Reserve swamp is very large at over 350ha in size. Therefore, any significant mosquito breeding events could affect a very wide area. The Hunting Reserve swamp is indicated in Figure 1.

The Hunting Reserve swamp is located about 2.2km to the north of the project area, which is considered close enough to allow appreciable *Cx. annulirostris* and *Cq. xanthogaster* dispersal to the project site. The tidal mangroves and floodplains 6-7km to the north and northeast of the hunting reserve is probably a seasonal source of high *Ae. vigilax* numbers, due to long flight range of *Ae. vigilax*.

A small paperbark swamp and small pits are also located about 1.2km to the east of the project site, potentially impacting the eastern most edge of the project site, but most likely only to a low to moderate extent. The wide sand plains habitat alongside the freshwater extent of the Howard River are probably only of low productivity, although this large potential mosquito breeding habitat may still occasionally produce elevated mosquito numbers during the wet season.

Small swamps north of Howard Springs Forestry Reserve

The relatively small swamps between Howard Springs and Howard Springs Road could be localised sources of *Anopheles* species, *Cx. annulirostris* and *Cq. xanthogaster*. The productivity of each swamp, if they are similar to the swamps in the study area, might be low to moderate. The closest baseline trap site, located about 550m from the largest 3ha swamp in this area, was generally unproductive for *Cx. annulirostris* and *Anopheles* species, and one of the least productive sites for *Cq. xanthogaster*. This suggests that these northern localised swamps may not have a large impact on the project site, although trapping was carried out during and after a well below average wet season.

Large number of extractive industry swamps around Howard River and Kings Creek

In addition to the Section 65 and Section 4228 sandmining swamp, an examination of aerial photography showed very large areas of extractive industry in the Kings Creek and Howard River catchment, most about 2km or further away from the project area. Historic extractive industry pits in these areas appear to either evolve into paperbark swamps, or remain as deep open water pits. Despite the distance, the cumulative area of the more distant extractive industry pits suggests there is the potential for freshwater mosquitoes with long flight ranges, particularly *Cx. annulirostris* and *Cq. xanthogaster*, to disperse from the pits to the study area during large breeding events. This would be more likely to occur if the current larger active pits cannot be remediated into a free draining or deep water landform. It would be difficult to determine the effect of all the extractive pits on mosquito numbers in the general area, due to the very large natural swamps creating widespread mosquito abundance.

4.1.7 Mosquito breeding and development aspects

Removing or modifying mosquito breeding sites to suit fish control is the most effective form of mosquito control, as it removes the need to create and appropriately fund a mosquito monitoring and insecticide control program. The effectiveness of mosquito control programs is generally determined by funding, staff expertise and site conditions (e.g. can sites be easily accessed). The overuse of insecticides could also increase the risk of insecticide resistance occurring. Therefore, wherever possible, an engineering solution to remove shallow water ponding, either by draining, filling or creating deep water bodies, should be investigated. It should also be considered that urban development has a high potential to create impacts downstream of stormwater drains such as increased nutrients, changed water flows (i.e. dry season flows), and subsequent vegetation change and proliferation of wetland weeds.

Remediation of mosquito breeding sites has a long history in Darwin (Jacups et al 2012) and Palmerston (Kinhill Stearns 1983, Liehne 1985), and also in regional towns such as Katherine (Kurucz et al 2003), and Alice Springs (Jacups et al 2011). Therefore, there are numerous examples to draw information from. Mosquito breeding remediation suggestions for the project site are provided below. A qualified engineer should be engaged to determine the most appropriate remediation measures, and Medical

Entomology can provide input into the design process where necessary. It is also probable that remediation of undisturbed swamps would also require environmental assessment, therefore other relevant studies are likely to be required to accompany the engineering assessment.

4.1.7.1 Remediation of larval habitats – Holtze and Kowandi North area

Kowandi North

The Kowandi North large paperbark swamp appears to be the main source of important freshwater mosquito species in Kowandi North and the eastern half of Holtze. It is therefore recommended that the swamp be investigated for the removal of shallow surface water by either drainage (e.g. similar to paperbark swamps west of Elrundie Ave, Palmerston), or conversion into a deep open water body, similar to Marlows Lagoon or the various urban Palmerston lakes. Any modification should comply with the handover authority requirements, particularly with regards to carrying out ongoing maintenance. The smaller paperbark swamp should also be modified in a similar manner to remove the potential for mosquito breeding.

Whilst the area downstream of Kowandi North, in Section 4225, has a natural incised low flow outlet channel arising from the NW edge of the large paperbark swamp, the low flow channel is blocked by vegetation about 220m downstream of the swamp. The current low flow channel should be extended to the downstream continuous incised creek channel, which appears to start about 900m from the north boundary of Section 5623. Previous examples of long low flow discharge channels include the Mitchell Creek low flow pipe in Palmerston, and main trunk drains from Vanderlin Dve to Buffalo Creek in Darwin, and the main trunk drains from Elrundie Ave in Palmerston to the daily flushed tidal mangroves of the Elizabeth River.

Section 4228 and Section 65 sandmining swamp

The old sandmining swamp should be investigated for draining the large areas of residual surface ponding, or converting the disturbed site into a deeper ponding area, similar to the other nearby quarry areas in the Kings Creek/Milners Creek catchment. It is a general recommendation of Medical Entomology that all borrow pits/extractive mining pits within 1.6km of future urban residential areas are rectified.

Section 65 large paperbark swamp

This swamp is situated about 1km from the northwest boundary of Holtze. It is suspected that this swamp is a very appreciable source of *Cq. xanthogaster* to the wider area, and locally an important source of *Ma. uniformis*, *Cx. annulirostris* and *Anopheles* species.

Initially, it might be advisable to rectify the extractive industry larval mosquito habitats mentioned above first, and the Yarrowonga swamplands, and then re-assess if the Section 65 paperbark swamp is producing appreciable numbers of important mosquito species to (future) urban areas of Holtze. Overall however, the rectification of this swamp should still be investigated during the initial planning of urban development within 1.6km of this swamp, to ensure remediation measures can be quickly implemented when mosquito problems are attributed to this swamp.

Mitchell Creek

Mitchell Creek upstream of the Stuart Highway appears unlikely to produce appreciable mosquito numbers, due to the limited potential area of residual ponding compared to the large swamps. However, the creek might occasionally produce localised dry season populations of *Cx. annulirostris* and *Anopheles* species. The three southern arms would represent the greater risk due to their length and discontinuous inverts, although the two short northern arms opposite the hospital may become important if dry season stormwater discharge occurs.

There is the potential that future urban stormwater low flows could result in changed dry season flow conditions and increased nutrient levels, which could increase mosquito breeding productivity. Moderate density *Cx. annulirostris* breeding has been found in a small arm of Mitchell Creek in Zuccoli during the late dry season, suggesting urban discharge in Holtze could also increase mosquito breeding in upper Mitchell Creek. The main recommendation would be to ensure each of the three small creeklines has a continuous shaded incised channel from the edge of urban development to the Stuart Highway, with the creeklines revegetated to create a fully shaded canopy to prevent weed growth in the channel, and a footpath provided along one edge of each of the upgraded channels to assist with mosquito surveys and future machinery access for channel maintenance. The managed area of Rapid Creek between McMillans Rd and Trower Rd is a potential example to replicate, due to the footpaths and managed landscaped areas allowing easy access to the creekline to carry out mosquito surveys and control. The installation of weirs to create fish ponds in the creeklines, similar to Rapid Creek and Sandy Creek near Royal Darwin Hospital, would also be recommended. The creeklines should also be appropriately zoned to allow future maintenance activities to occur.

Other stormwater drainage designs, such as concrete lining the three southern channels to the Stuart Highway culverts, would also represent a suitable upgrade from a mosquito perspective.

Overall, the management requirements for the three arms of Mitchell Creek, and any stormwater modifications, should suit the requirements of the final management authority. Notwithstanding, at present, large areas of Mitchell Creek opposite Farrar, Johnston and Zuccoli appear to be generally overgrown with weeds or groundcover vegetation, which would greatly hinder any mosquito surveys from occurring should they ever be required. From a Medical Entomology perspective, this situation should be avoided in the study area, and therefore it is recommended that the various arms of Mitchell Creek upstream of the Stuart Highway are not left as vacant bushland.

Yarrawonga swamplands

The swamp was investigated for drainage in the 1980's (Palmerston Development Authority, July 1985), although the works do not appear to have been fully carried out in the southern portion of the swamplands closest to Palmerston. Draining was decided as an option to eliminate or at least inhibit mosquito breeding, by removing residual surface water ponding. This solution should be re-investigated and implemented, or an alternative solution investigated/implemented. A series of urban lakes stocked with fish, such as in nearby Durack, could represent a suitable alternative mosquito mitigation option, and could be beneficial with regards to creating a dry season fish reservoir in the wider Yarrawonga swamplands area.

Any works and mosquito control carried out in this swampland would also benefit the nearby residential areas of Palmerston, and parts of the Pinelands area, as well as the southern areas of Robertson Barracks.

4.1.7.2 Remediation of larval habitats – Howard Springs Forestry Reserve

The main swamp system within the Forestry Reserve appears to be the smaller grassy lagoon northwest of Dutchies Lagoon, followed by the grassy swamp in the eastern portion of the site, and the paperbark swamps downstream of the smaller Dutchies Lagoon. Rectifying these swamps to minimise mosquito breeding would remove the recommendation for urban exclusion buffers from these sites. Urban exclusions buffer zones would only then be recommended from the nearby Dutchies Lagoon and grassy lagoon south of Bronzewing Ave.

From a mosquito perspective, there are several management options to consider for the potential mosquito breeding sites in the Forestry Reserve. These are outlined below.

Tall sedge lagoon

The Tall sedge lagoon appears to hold water/moisture well into the dry season, therefore converting the shallow lagoon into a deeper lake might be a suitable mosquito mitigation option. A permanent open water lagoon with fish, similar to the urban Palmerston lakes, would greatly reduce mosquito breeding potential, with fish providing natural mosquito control.

Paperbark swamps between Howard Springs Road and Small Dutchies

These two swamps should be modified to contain permanent, relatively deep open water, similar to the urban Palmerston lakes, or converted into dry drainage basins, if downstream levels allow. A combination of both measures might also be suitable. It appears that the first swamp downstream of the Tall sedge lagoon might be more amenable for conversion into a lake, due to dry season seepage from the adjacent sedge lagoon.

Shallow grassy depression/lagoon eastern portion of forestry reserve

This area did not appear to flood in the 2019/20 wet season, although historic aerial photography suggests that grassy ponding of over 2ha could occur during a normal-above average wet season. Therefore, this site should be remediated to be free from potential water ponding, such as filling/conversion into a dry drainage basin.

Small swamps and sewage ponds north of Howard Springs Road

Dependant on the final urban site layout, there may not be a requirement to modify any of the small swamps within 1km of Howard Springs Road, except those that appear to be old borrow pits (the two small circular swamps adjacent to Howard Springs Road). The remaining sites could be controlled via peak season aerial operations, unless they can be drained via future trunk discharge drains, similar to Palmerston downstream of Elrundie Ave.

The small sewage ponds north of Howard Springs Road may require modification/increased management if urban development was to occur within 1.6km of the ponds.

Dutchies Lagoon

With regards to Dutchies Lagoon, it is mentioned as a quote by a Larrakia person in the CSIRO Sustainable Ecosystems 2008 Water Resources Report *'Back then, used to see turtles wandering (on the road)...used to go and take them and put them in the lagoon opposite the post office (Wadham Lagoon?). Don't see them any more as fences have gone up around the place...turtles can't travel between lagoons to breed...and pets probably bail them up. Those fences might be right down into the lagoon. People used to hunt for magpie goose there...probably not anymore. People use to fish and get turtles in the lagoon. That's when everything used to run into each other. Used to be lots of lilies, now there's lots of reeds and the lagoon is full of grass; since they put culverts in the lagoon has been dry more often. The fire brigade burns the grass now (Interview, 4/2/08).'*

The present Dutchies Lagoon is a major limiting factor for urban development in the southern portion of the Forestry Reserve, due to its very large size and complete coverage with semi-aquatic grasses. The lagoon is privately owned, which would inhibit mosquito control/prevention strategies being implemented by a local authority. Ideally, the lagoon should be a permanent open water body similar to those in urban Palmerston, before urban development would be deemed suitable within 1km of Dutchies Lagoon. At present, an urban residential exclusion buffer zone from this lagoon appears to be the most feasible mitigation option to consider. The already recognised 1km modified urban exclusion buffer zone combined with a rural buffer to the south of the lagoon, would also apply to areas to the north of the lagoon. This buffer is already considered to be a somewhat relaxed buffer, and therefore Medical Entomology would not support reducing the 1km urban exclusion buffer width without mosquito control or modification of Dutchies Lagoon.

Bronzewing Avenue reed lagoon

It is unlikely that this lagoon could be modified, as it appears to be a dry season refuge for various water bird species. Aerial mosquito control would also be an unlikely option, due to the adjacent rural residential buildings and high dry season bird population. An urban residential exclusion buffer zone from this lagoon appears to be the most feasible mitigation option to consider, with the maximum 1.6km urban residential exclusion buffer recommended due to its high mosquito borne disease potential. Rural residential could be utilised within the buffer zone, however due to the potential major mosquito borne disease risk, lots within the buffer should be low density (about 2ha in size), but perhaps with a transition zone of smaller rural lots towards the outer limit of the buffer. Day use commercial/industrial would also represent a suitable development type within the buffer zone.

Milners Swamp and Howard River swamps

It would be considered unfeasible and environmentally destructive to attempt remediation of these distant and very large swamps. The provision of peak season salt marsh mosquito (*Ae. vigilax*) control, and possibly peak season *Cx. annulirostris* control, might provide sufficient protection considering the distance (>2.2km from edge of Howard Springs Hunting Reserve swamp, >4.6km from edge of Milners Swamp) from the project site. However, due to the very large size of the Howard Springs Hunting Reserve swamp, and thus potential to produce large numbers of freshwater mosquitoes that could be difficult to fully control, it is recommended that a large buffer distance be provided, with 3km a suggested urban exclusion zone.

4.1.7.3 Stormwater drainage

Stormwater discharge from urban areas has the potential to exacerbate mosquito breeding in downstream low lying areas, via changed water flows, particularly if dry season flows occur, and potentially due to increased nutrient input. These conditions may alter semi-aquatic plant species and/or plant densities, and subsequently increase favourable larval habitat, along with the creation of unseasonal ponding. Weeds may also colonise waterways, making effective mosquito surveillance and control difficult to implement.

The general recommendations for the study area would be to discharge the stormwater directly into creek lines with a continuous incised channel, or a deep open water body that has a suitable low flow discharge drain. There are numerous examples in Darwin and Palmerston of what works well, and not so well, from a mosquito perspective. Overall, it appears that regular drain maintenance is crucial to minimise mosquito breeding in stormwater infrastructure, as small blockages caused by weeds or sediment could still be enough to allow productive mosquito breeding. Therefore, the handover authority should have an adequately funded routine maintenance program that includes frequent maintenance to prevent mosquito breeding.

Medical Entomology can provide input into the design phase of stormwater infrastructure where required, with the end point of discharge drains of particular interest. Overall, stormwater drainage requirements can be found in the [Northern Territory Subdivision Development Guidelines](#).

4.1.7.4 Wastewater treatment and discharge

Dependant on the final choice of effluent treatment and dispersal, it is generally advisable to provide a buffer of at least 1.6km from the edge of urban residential and sewage ponds. This would provide a suitable buffer distance from densely populated areas should appreciable mosquito breeding inadvertently occur. A good example is the Palmerston Wastewater Treatment Plant, situated about 2km from the nearest urban residential area, with these ponds also well designed and well maintained from a mosquito perspective.

4.1.8 Routine mosquito monitoring and control

The extent of routine mosquito monitoring and control would largely depend on the remediation of mosquito breeding grounds within and adjacent to the project site. Full scale remediation, as was carried out for the initial suburbs in Palmerston, resulted in no requirement for routine mosquito monitoring and control in the first 15 years of the town/city, until suburbs began to expand closer to Mitchell Creek. This example should also be followed for the project site, with the exception that there should be no requirement for routine mosquito control within the project site. Survey and control efforts to protect the project site should focus on the very large tidal swamps in Kings Creek and the southern part of the Howard River tidal catchment, and possibly the Section 65 paperbark swamp.

At the least, fortnightly routine adult mosquito trapping should be implemented, to determine when aerial control of distant swamps is required, and determine when drain maintenance/localised mosquito control is required within the project site.

4.1.8.1 Aerial mosquito control program

The two main swamps that require aerial control would be the very large Milners Swamp and associated upper tidal mangroves of Kings Creek, and the southern part of the Howard River coastal floodplains, potentially including the vast Howard Springs swamp. The main mosquito to target would be the northern salt marsh mosquito *Ae. vigilax*, during the late dry and early wet season. *Culex annulirostris* may also need to be targeted during Murray Valley encephalitis and Kunjin virus risk periods, but only when adult mosquito monitoring traps near the future urban areas indicate dispersal from Milners Swamp and Howard Springs swamp.

Dependant on the final outcome of rectification measures, freshwater swamps within 1.6km of future urban areas may need to be included in aerial control operations. Ideally, Dutchies Lagoon should also be aurally controlled for mosquitoes when major breeding events occur, although this is unlikely to occur due to private ownership, and aviation regulations likely restricting aerial operations close to residences.

An aerial control program would need to be underpinned by a thorough larval mosquito survey program, as breeding sites within each swamp system would need to be determined before spraying occurs. The main swamps mentioned above appear to be beyond the size of swamps currently sprayed in the Darwin urban area, and therefore might require more resources when compared to the Darwin program.

At present, Medical Entomology is funded to carry out mosquito monitoring and control in the urban Darwin area. However, this is an area specific program, and therefore extra resources are not available to expand operations into new areas affected by different swamp systems. The Public and Environmental Health Act nominates the landowner as responsible for preventing mosquito breeding, which typically appears to be NTG and the Commonwealth in greenfield areas. There is no standard model that Australia follows, for example local councils in QLD organise and carry out mosquito control in their local jurisdictions, while in WA the state government provides a pool of funds that participating local councils can apply for and utilise to treat mosquito breeding in their areas.

Overall, the control and monitoring recommendations made in this report are no different to what has been carried out in Darwin. The largest hurdles to overcome would appear to be Milners Swamp being in the Darwin International Airport flight path and located on defence land, and potential safety concerns with regards to the Howard Springs Hunting Reserve swamp. To establish an effective aerial mosquito control program, all relevant stakeholders need to be engaged, and responsibilities determined.

4.1.8.2 Routine ground mosquito survey and control program

It would be ideal to limit the requirement for routine ground mosquito control, as ground control operations can be greatly hampered by site conditions such as extensive weed growth, natural vegetation and boggy conditions, as well as the various environmental hazards encountered in the

Darwin area. Ground surveys and control should ideally be limited to landscaped areas and constructed drains, where such operations would be relatively easy to carry out, and mosquito breeding can be controlled via physical means (e.g. drain desilting, vegetation removal) rather than with insecticide applications. The final requirements of a ground survey and control program would ultimately depend on the extent of mosquito mitigation measures and stormwater infrastructure in the project site, and should be the responsibility of the asset owner/s to fund and implement.

4.1.8.3 Urban buffer zones

The challenges facing the study area appear similar to the construction of Palmerston, and the Darwin northern suburbs, and would be relatively similar to the challenges that would be faced in Weddell, Murrumujuk and Cox Peninsular. Without any modification of the swamps within and nearby to the project site, only a small portion of the project site would fall outside of the standard 1.6km urban residential buffer zone from large and uncontrolled swamps. Therefore, standard urban buffers from swamps within the project site do not appear practical, suggesting mosquito breeding site remediation would be the course of action to consider if widespread urban development is desired.

Rectification of some swamps might ultimately be difficult to carry out, for various reasons such as environmental or cultural significance, or the fact that they are external to the project site and/or are privately owned. Swamps that, to Medical Entomology, might be difficult to clear of mosquito breeding have been mentioned below, along with the recommended urban residential exclusion buffer zone.

There is already a recognised 1km urban residential exclusion buffer from Dutchies Lagoon, which is a reduced urban distance buffer compared to the standard 1.6km buffer, in recognition of the likely distracting benefits of the existing 1km wide rural residential zone around much of the lagoon. This principle should also be applied to areas of the project site nearby to Dutchies Lagoon.

A 1.6km urban exclusion buffer should be applied to the Bronzewing Ave reed lagoon, due to the high mosquito borne disease potential around the lagoon. A 1.6km buffer should be applied to the Section 65 paperbark swamp, if mosquito mitigation options such as modification or aerial control cannot be implemented.

A 3km urban residential exclusion buffer should be applied to the Howard Springs Hunting Reserve swamp. This generally would not cause any additional constraints to the planning of the project site, as this buffer would overlap with the above suggested 1.6km urban exclusion buffer from the Bronzewing Ave reed lagoon. However, due to the importance of the Howard Springs Hunting Reserve swamp, it is worth noting this as a separate buffer distance.

4.1.9 Other biting insects

During field surveys, nuisance levels of tabanids (March flies) were observed biting at the Kowandi North large paperbark swamps. Occasional biting midge complaints have been received by Medical Entomology from Howard Springs residents, with the freshwater breeding *Culicoides marksii* and *Culicoides narrabeenensis* the likely species involved. Biting midges are not known to transmit human disease in Australia, and therefore are likely to be of minor to low nuisance consequence only. March flies can cause a painful bite, with one species known to cause anaphylactic shock in sensitive people. The remediation of swamps may also reduce populations of some of these biting insects.

5 Limitations

The current trapping was carried out during and following on from one of the driest wet seasons for many years, which followed on from an equally very dry wet season. There is some thought that a dry wet season could result in increased abundance of some mosquito species that rely on semi-aquatic and aquatic vegetation (e.g. *Cq. xanthogaster*), while less flooding could lead to reduced wet season *Cx. annulirostris* abundance. Continual trapping during a normal or above average wet season would assist in gaining more information regarding the various swamps and wetlands in the area. The upcoming 2020/21 wet season is predicted to be above average, and therefore it would be worthwhile extending the baseline program into the latter part of 2021.

Studies have shown that fortnightly mosquito trapping can more accurately determine peak freshwater mosquito abundance (Jacups & Whelan 2012). Therefore, it is possible that peak *Cx. annulirostris* and *Anopheles* species levels might not have been determined. Fortnightly baseline trapping in this area is outside of the current capabilities of Medical Entomology.

Important freshwater mosquito species with long flight ranges, such as *Cx. annulirostris* and *Cq. xanthogaster*, might have dispersed up to 5km or more to the project site from the extensive Milners Swamp or Howard Springs Hunting Reserve swamp. This would need to be evaluated after swamps within and nearby to the project site have been remediated, to determine if an expansion of the aerial control program is required to control freshwater species in Milners Swamp and Howard Springs Hunting Reserve swamp.

6 Conclusions

6.1 Mosquitoes

- Follow up baseline trapping confirmed that Holtze and Kowandi North experiences seasonally high to very high salt marsh mosquito (*Aedes vigilax*) problems during the build-up and early wet season months. High to very high numbers were also recorded in the Howard Springs Forestry Reserve during the same period, suggesting a relatively widespread occurrence of this mosquito throughout the project site. As this mosquito breeds in tidal/saline areas, there would be no larval habitats for *Ae. vigilax* in the project site, with this species dispersing into the area from distant tidal swamps associated with Kings Creek and the Howard River. This species is known to fly well over 10km-20km in very high numbers from large tidal breeding grounds.

Aedes vigilax is a day and night biting species, and a vector of Ross River and Barmah Forest viruses. It is one of the most important mosquito species in the subject area. When comparing the seasonal abundance of this species to existing urban areas, levels were similar to the urban fringe of Leanyer, the Darwin suburb with the most mosquito complaints.

- Follow up baseline trapping has confirmed that much of Holtze and Kowandi North experiences seasonally high to very high *Coquillettidia xanthogaster* abundance during the early dry season. This species predominantly bites at night, although can bite during the day in shaded areas near their breeding sites. This species was observed biting during the middle of the day in the Kowandi North large paperbark swamp, along with *Mansonia uniformis*. *Coquillettidia xanthogaster* numbers in Kowandi North and Holtze exceeded numbers in any area in Darwin urban during the same season, while Howard Springs Forestry Reserve results showed similar levels to the peak season numbers recorded near the urban fringe of Karama.

Larval habitats for both of these species have not been confirmed, as larvae attach to the roots of aquatic and semi-aquatic plants and therefore are very difficult to find. The suspected larval habitats are also very large and difficult to thoroughly survey without additional resources. The day biting at the Kowandi North paperbark swamp was suggestive of a potential breeding site, combined with the large coverage of semi-aquatic plants and potentially the submerged roots of the paperbark trees, acting as potential larval habitat. Other potential larval habitats in the study area could be the smaller Kowandi North swamp, and Tall sedge lagoon to the northwest of Dutchies Lagoon. Breeding sites that could cause dispersal to the project site include the Section 65 paperbark swamp and adjacent large sandmining area, the Yarrowonga swamplands, the large grassy Dutchies Lagoon, the reed lagoon south of Bronzewing Ave in Howard River Park, and the small swamps between Howard Springs Nature Park and Howard Springs Rd. The pandanus lined pools within Mitchell Creek could also offer localised habitat for *Cq. xanthogaster* larvae, although the total potential habitat available appears small compared to the various swamps.

It is very likely that Milners Swamp and the Howard Springs Hunting Reserve swamp could be seasonal sources of *Cq. xanthogaster*, as these swamps contain very extensive areas of semi-aquatic plants, and *Cq. xanthogaster* is thought to disperse up to 5km from very large breeding sites. It would be difficult to identify major breeding habitat in the large coastal freshwater swamplands in Shoal Bay, other than by semi-aquatic plant identification, although the list of potential host plants for *Cq. xanthogaster* is not well understood.

- *Culex annulirostris* is the most important mosquito species in the NT, and was recorded in relatively high numbers near Wallaby Holtze Road during the first baseline trapping program, and relatively low numbers elsewhere from a potential pest perspective during the first baseline trapping program. The current trapping has also revealed generally moderate to low numbers in the study area, with

the exception of relatively high numbers nearby to the large Kowandi North paperbark swamp, and in the forestry reserve nearby to the second paperbark swamp downstream of Dutchies Lagoon. Both baseline trapping programs showed a dry season peak in abundance, with July, the peak month. The same breeding sites mentioned for *Cq. xanthogaster* above are also potential breeding sites for *Cx. annulirostris*, with the addition of the grassy swamp areas in the eastern portion of the Forestry Reserve, and borrow pits around Mitchell Creek. *Culex annulirostris* larvae were recovered from within the project site from the Kowandi North large paperbark swamp, and the grassy edges of the Tall Sedge lagoon. *Culex annulirostris* larvae were also detected nearby to the project site in the Bronzewing Ave reed lagoon, and also Dutchies Lagoon in the past.

Culex annulirostris is a vector of Ross River and Barmah Forest viruses, the potentially fatal Murray Valley encephalitis virus, and serious Kunjin virus. The peak overnight levels recorded during the past and current program were around and moderately above the potential virus risk level of 70-100 per trap, with most traps within the project site recording numbers above this threshold at least on one trap night.

Overall, the peak *Cx. annulirostris* levels recorded in the more productive parts of the project site during the dry season were higher than trap catches at the urban edge of Leanyer and Marrara, and similar to the urban edge of Karama in Darwin. Conversely, mid wet season (January and February) *Cx. annulirostris* numbers in the worst affected areas of the project site were lower than Leanyer and Karama, but similar to Marrara.

- *Anopheles* species mosquitoes were recorded in elevated numbers during the first baseline trapping program, with current trapping collecting generally low numbers within the project site from a pest perspective. In contrast, larvae of several *Anopheles* species were readily found at the Kowandi North large paperbark swamp, Yarrowonga swamplands paperbark swamps, Tall sedge lagoon in the Forestry Reserve, and Bronzewing Ave reed lagoon, albeit in relatively low larval densities. Residual pools within Mitchell Creek could also be localised breeding sites during the mid-dry season. *Anopheles* species mosquitoes are considered potential vectors of malaria. Most species regarded as night biting mosquitoes, although one species, *Anopheles bancroftii*, readily bites during the daytime in shaded areas near their breeding sites. *Anopheles bancroftii* was the most common *Anopheles* mosquito recorded within the project site. During the current baseline trapping, adult *An. bancroftii* numbers moderately exceeded the indicative malaria risk threshold level of 10 per trap near the Kowandi North paperbark swamp, and slightly exceeded the threshold at the south arm of Mitchell Creek near the Stuart highway.

The peak season for *Anopheles* mosquitoes was the late wet to mid dry season.

- Urban development has a history of increasing mosquito abundance in the Darwin area, particularly for *Cx. annulirostris* and *Anopheles* species in fresh and brackish water areas, and *Ae. vigilax* in and nearby to tidal areas. The increased mosquito breeding has been linked to changed water flows via increased dry season stormwater flows, and associated nutrients in urban stormwater, which can promote vegetation change (i.e. increased or different semi-aquatic vegetation) along with unseasonal ponding in the receiving area. The project site could also be at risk of increased mosquito breeding in downstream receiving areas, if low flow drainage discharge points are not carefully chosen.
- The swamps within the project site appear to produce appreciable numbers of mosquitoes. Therefore, the mosquito populations should be reduced if widespread urban development is desired across the project site. The aim should be to reduce populations to levels similar to the inner Darwin suburbs. Habitat modification is usually viewed as the most effective form of mosquito control, with a modified environment also easily surveyed and maintained to prevent mosquito problems from

reoccurring. Any habitat modification of natural swamps would likely require a similar investigation carried out for Marlow's Lagoon and the Durack lakes.

- Even with the rectification of nearby mosquito breeding sites, due to the long flight range of some mosquito species, there will still be mosquitoes impacting on the project site, not dissimilar to the northern fringes of Darwin. This would require mitigation via an aerial mosquito control program. The extensive tidal and brackish water swamplands associated with Kings Creek and the southern Howard River area are the likely areas requiring peak season aerial mosquito control. The responsibility for funding and carrying out mosquito control is an issue that would require early discussion and resolution, to avoid any delay to urban development.
- Depending on the final implementation of mosquito mitigation and control strategies, there may be a requirement for urban residential exclusion buffers from any unrectified swamps within 1.6km of proposed urban areas.
- The current trapping was carried out during and after one of the driest wet seasons for many years, which followed on from an equally dry wet season. There is some thought that a dry wet season could result in increased abundance of some mosquito species that rely on semi-aquatic vegetation (e.g. *Cq. xanthogaster*), while less flooding could lead to reduced wet season *Cx. annulirostris* abundance. Further adult mosquito trapping would assist with gaining more information about mosquito abundance near various swamps and wetlands in the area. Fortnightly adult mosquito trapping would be the ideal trapping schedule, however this is beyond the capacity of Medical Entomology to implement.
- The findings, whilst showing significant mosquito problems across large areas of the project site from several mosquito species at different times of the year, is probably not dissimilar to just about all other unmodified potential greenfield sites in the coastal Darwin Region. Other greenfield (potential) future development areas in the Darwin Region also seem to suffer from seasonally high biting insect problems from one or more mosquito or biting midge species.
- The current mosquito problems, whilst generally higher compared to much of Darwin, can be reduced, to achieve similar results to the lesser mosquito prone suburbs in urban Darwin and Palmerston.

7 Recommendations

Recommendations regarding mosquito mitigation can be viewed in the google earth file provided with this report, by clicking on individual polygons. Recommendations are also mentioned below. These recommendations are considered the best option to reduce mosquito populations in the project site. Other options, such as urban exclusion buffer zones in combination with wide rural buffers, have generally not been included as they are lesser options to mitigate mosquito problems, and should only be reserved for those swamps where rectification is unlikely to occur. Mosquito mitigation options via site remediation are not new to the NT, with examples from Darwin, Palmerston, Katherine and even Alice Springs to draw knowledge from.

7.1 Mosquitoes

- An aerial control program of the distant tidal swamps should be implemented, with mosquito breeding site remediation carried out in and adjacent to the project site prior to the first residents moving in. Due to the seasonally high mosquito populations across most of the project site, Medical Entomology would not be in a position to support the land rezoning and urban development until mosquito mitigation programs are implemented.
- To effectively reduce mosquito populations within the project site, the various swamps and wetlands within and nearby to the project site should be modified into deeper water environments that are clear of widespread semi-aquatic plant growth, and have large populations of small fish. Marlow's Lagoon represents an example of modifying a shallow reed swamp into a lake to reduce mosquito breeding. No insecticide control would be required for managed open water lakes, and no urban residential exclusion buffer would be required (e.g. Durack, Gunn).

Alternatively, another option of mosquito control would be filling and/or draining the swamps and wetlands to remove residual surface water, where this is achievable. Removing both wet season (>7 days ponding) and dry season residual ponding would be required to prevent the additional need for localised insecticide control and urban buffers.

It is suggested that the three arms of Mitchell Creek upstream of the Stuart Highway, at the minimum, be provided with a continuous incised channel, and be re-vegetated to have a completely shaded invert, to prevent weed growth and mosquito breeding in the channel. Other stormwater designs, such as concrete lining the channels to the Stuart Highway culvert, would also be a suitable upgrade from a mosquito perspective. Overall however, the handover authority design standard/requirements should be observed.

- The nearby, relatively large old sandmining swamp in Section 65 and 4228 should be cleared of residual ponding, or converted into a deeper (1.8m - 2m) open water lake, similar to Marlow's Lagoon or the Durack Lakes. Medical Entomology generally recommends that all extractive areas/borrow pits within 1.6km of urban residential areas are rectified to eliminate mosquito breeding.
- The Yarrowonga environs mosquito remediation investigation from the 1980's should be re-considered and implemented, to drain/fill the swampland to reduce mosquito breeding. Alternatively, it should be investigated if a lake system similar to Durack could be implemented. Any remediation of this area would also benefit the residents in the eastern portion of Durack. The third option would be to investigate if a peak season aerial control program could be implemented, although insecticide control alone is usually far less effective as habitat modification.
- The Section 65 paperbark swamp should be investigated for rectification via drainage or conversion into a lake. Another option would be to place the swamp on a routine monitoring and peak season aerial control program, combined with a 1km buffer, although this option would not be as effective as habitat modification.

- The current recognised 1km urban residential exclusion buffer from the main Dutchies Lagoon, in combination with a rural residential buffer, can also be applied to the Howard Springs Forestry Reserve within 1km of Dutchies Lagoon. However, as Dutchies Lagoon is privately owned, no mosquito control can be carried out by government or council, and therefore the 1km urban buffer from this large grassy swamp might not be sufficient in the future if mosquito populations ever increase. Ideally, the owner should be approached for discussion regarding habitat modification methods to reduce potential mosquito breeding.
- A minimum 1.6km urban residential exclusion buffer is recommended from the Bronzewing Ave reed lagoon, due to the productive mosquito breeding and large numbers of water birds that seek refuge in the lagoon during the dry season. The abundant water bird population increases the potential risk from Murray Valley encephalitis virus and Kunjin virus in the area. Rural residential could be utilised within the buffer zone, however due to the potential major mosquito borne disease risk, lots within the buffer should be low density (about 2ha in size), but perhaps with a transition zone of smaller rural lots towards the outer limit of the buffer. Day use commercial/industrial would also represent a suitable development type in the buffer zone.
- A 3km urban residential exclusion buffer zone should be applied to the Howard Springs Hunting Reserve swamp. This buffer overlaps with the 1.6km buffer from the Bronzewing Ave reed lagoon, however is worth noting as a separate buffer due to the very high importance of this extensive swamp.
- Low flow stormwater drainage, particularly the discharge points into downstream areas, should be designed in a manner that does not create extensive dry season ponding in receiving areas within 1.6km of future urban residential areas. A shaded creekline with a continuous incised channel would represent a suitable discharge site for stormwater trickle flows. Large catchments, or catchments with schools, shopping centres, sporting ovals, central business districts and industrial, could potentially generate unseasonal stormwater flows. It is recommended that the trunk drainage system, including discharge drains, be designed before development in the area proceeds, and possibly also built during the early stages of development, similar to the initial Palmerston development.
- An aerial mosquito survey and control program is suggested to reduce the magnitude of the seasonal salt marsh mosquito (*Aedes vigilax*) impact on the project site. The swamps likely to require control would be the brackish water areas of Kings Creek/Milners Swamp and the southern portion of the Howard River coastal swamplands. A detailed investigation should be carried out to determine the resources required to deliver a successful aerial larval mosquito control program for this area. It is possible that Medical Entomology could carry out this program due to the unit expertise in mosquito control, if sufficient new funding is provided.

Dependent on final mosquito mitigation works, an aerial survey and control program may also need to cover the Yarrawonga swamplands and Section 65 paperbark swamp.

- Early discussions should be held with the relevant landowners of mosquito breeding sites and the final handover authority, to determine routine mosquito monitoring and control and funding responsibilities. Routine weekly/fortnightly adult mosquito surveillance and larval mosquito control programs (where required) should be implemented by the relevant authorities, by the time the first urban residents occupy the area.

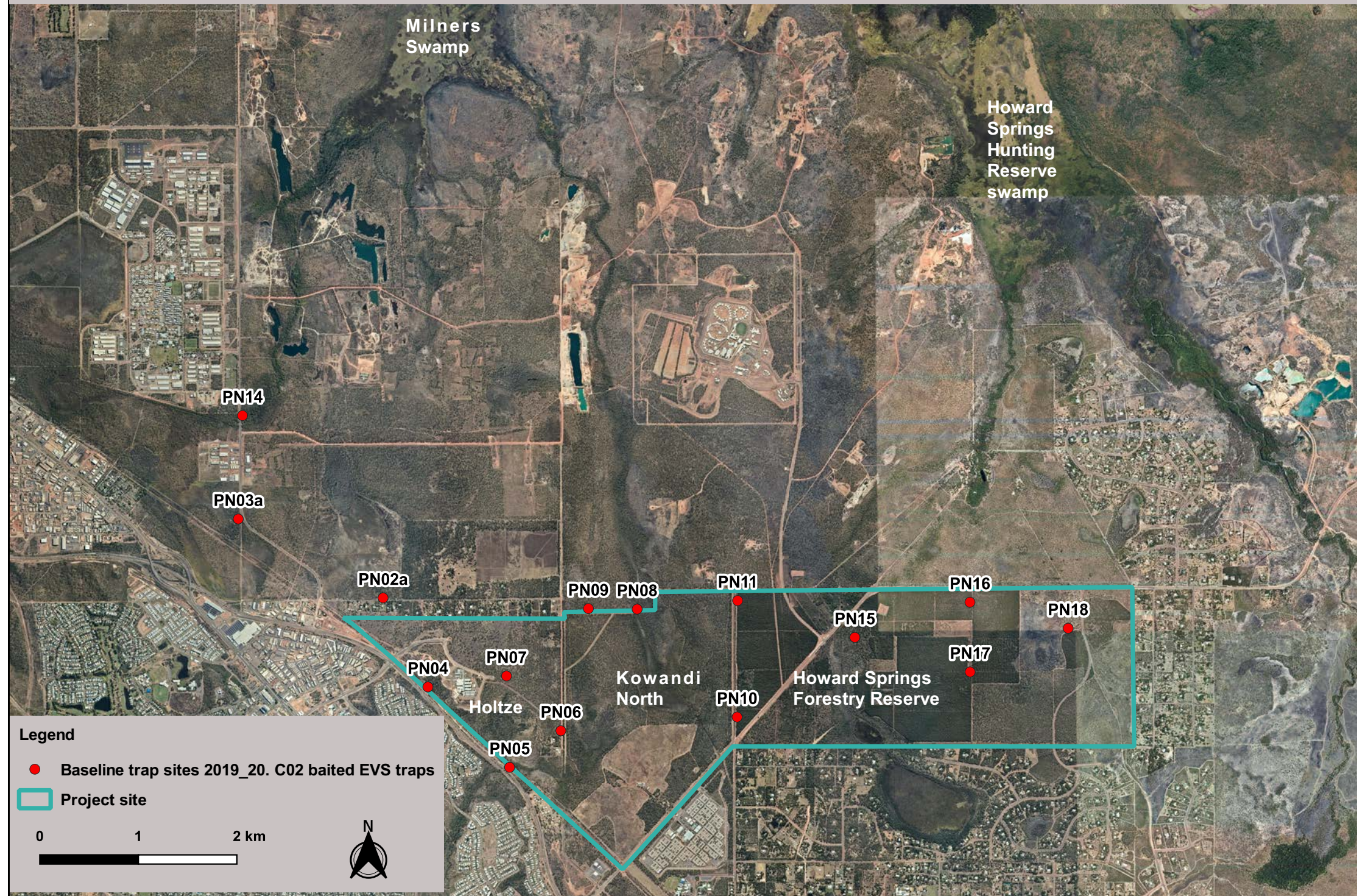
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Figures

Figure 1. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trap sites November 2019 to October 2020.



Figures 2a and 2b. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trapping results. *Aedes vigilax* results from November 2019 to October 2020.

Figure 2a. Monthly *Aedes vigilax* trap results. Total female mosquitoes.

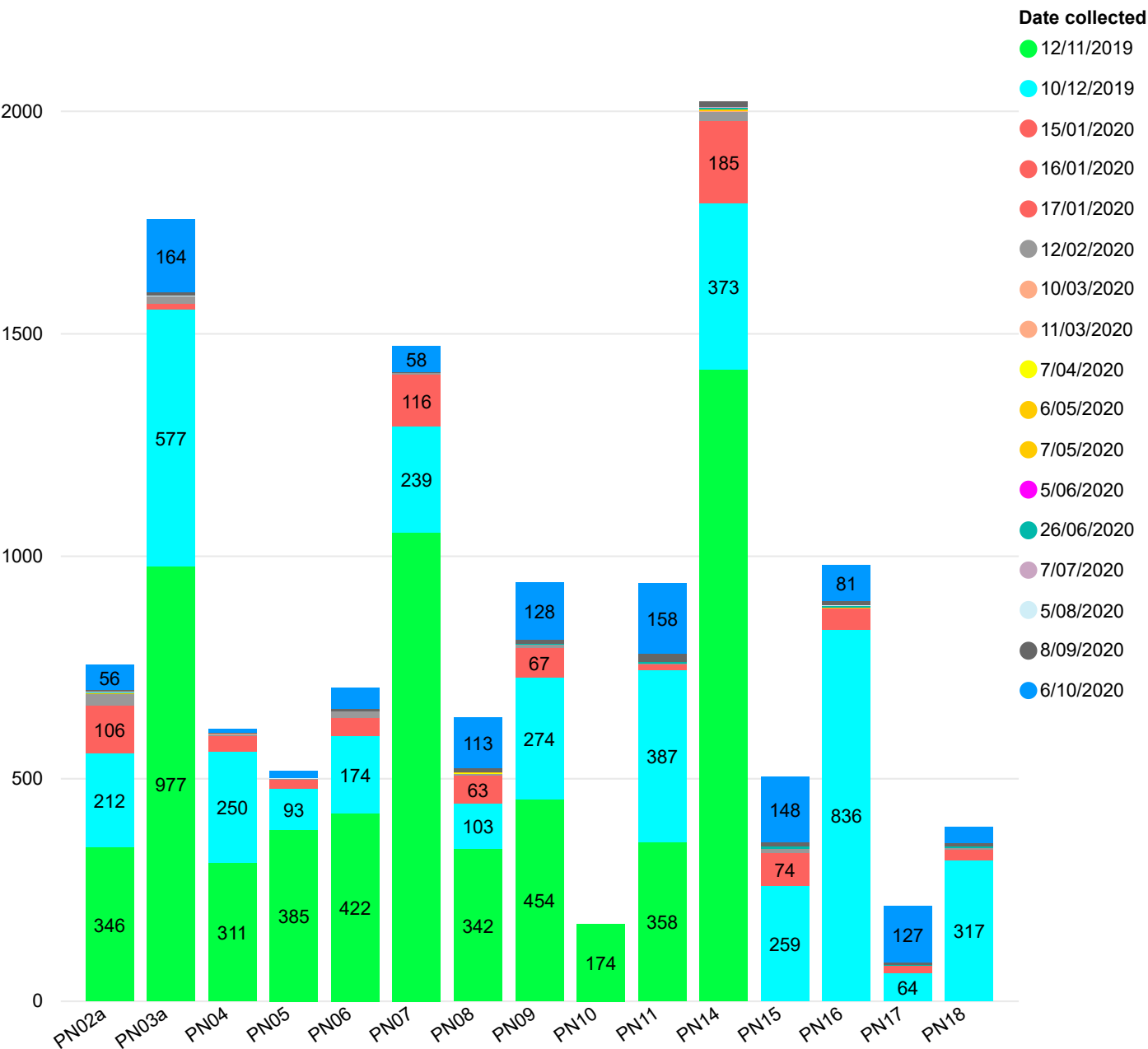
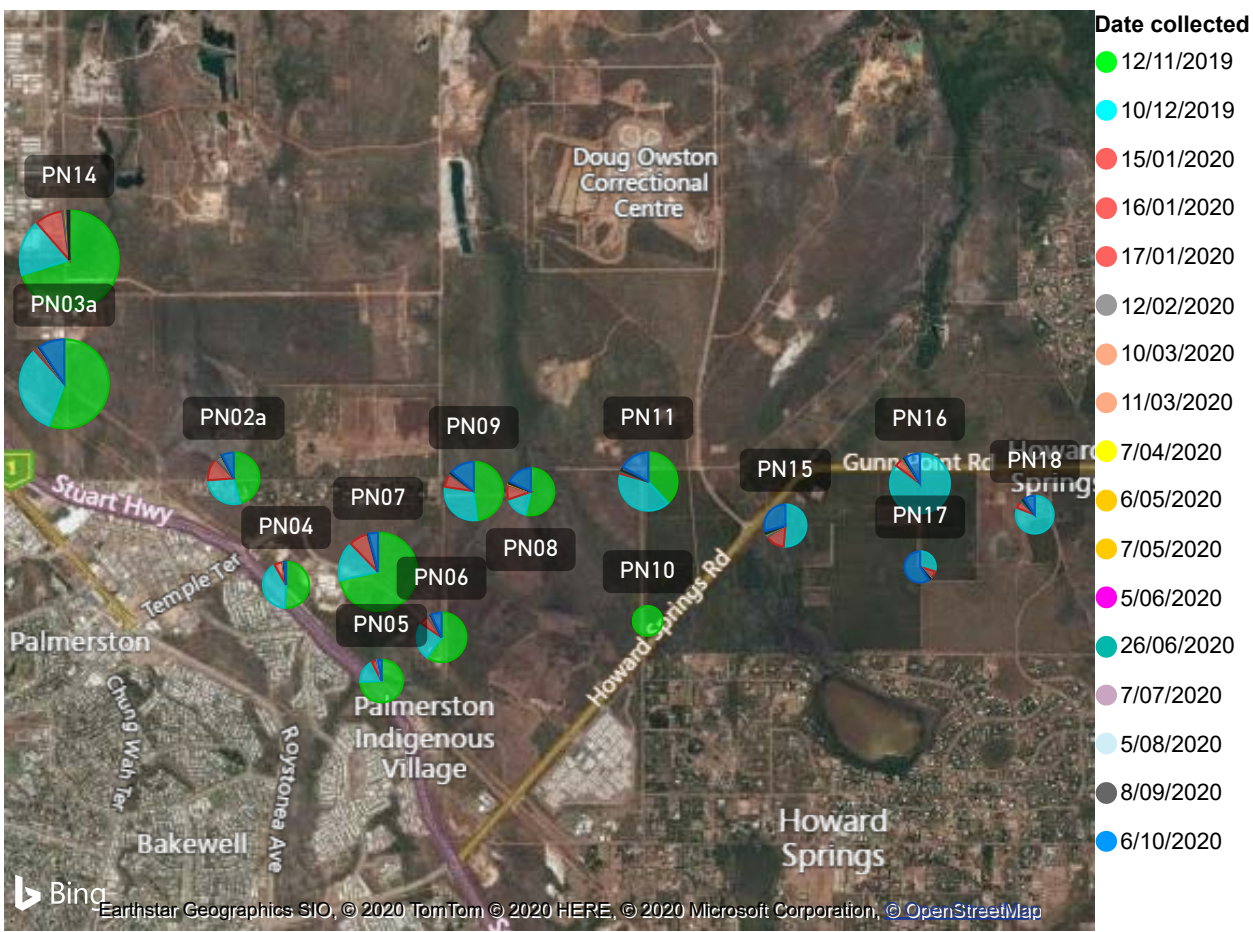


Figure 2b. *Aedes vigilax* spatial distribution all trapping dates.



Notes: Traps were not set at PN15-PN18 in November. They were additional traps added to the program from December onwards. Site PN10 was only set in November. No data available for PN03a in March, and PN04 in June, due to trap failures that were not re-set. PN14 was also a trap fail that was not reset in October.

Figures 3a and 3b. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trapping results. *Culex annulirostris* results from November 2019 to October 2020.

Figure 3a. Monthly *Culex annulirostris* trap results. Total female mosquitoes.

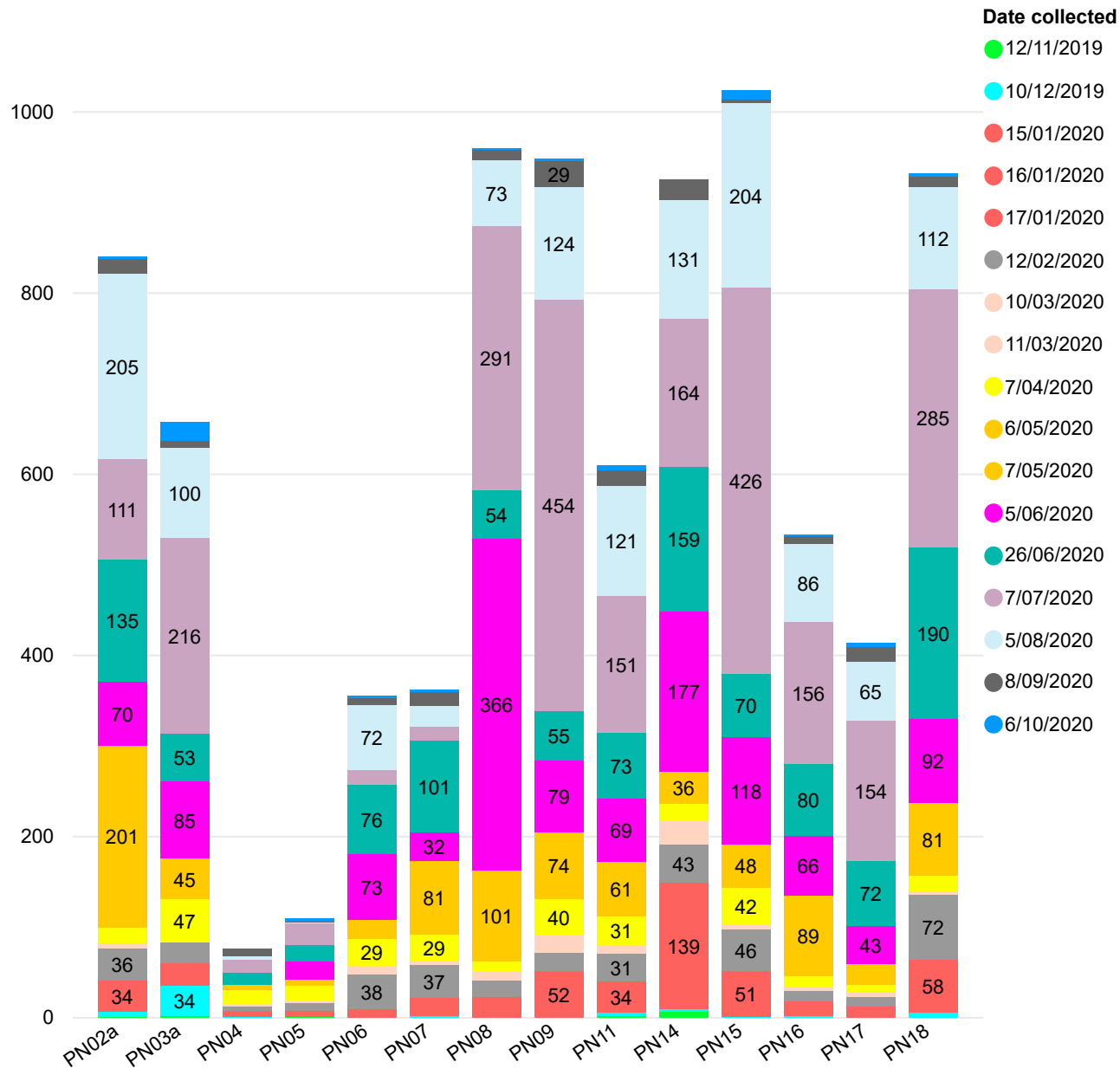
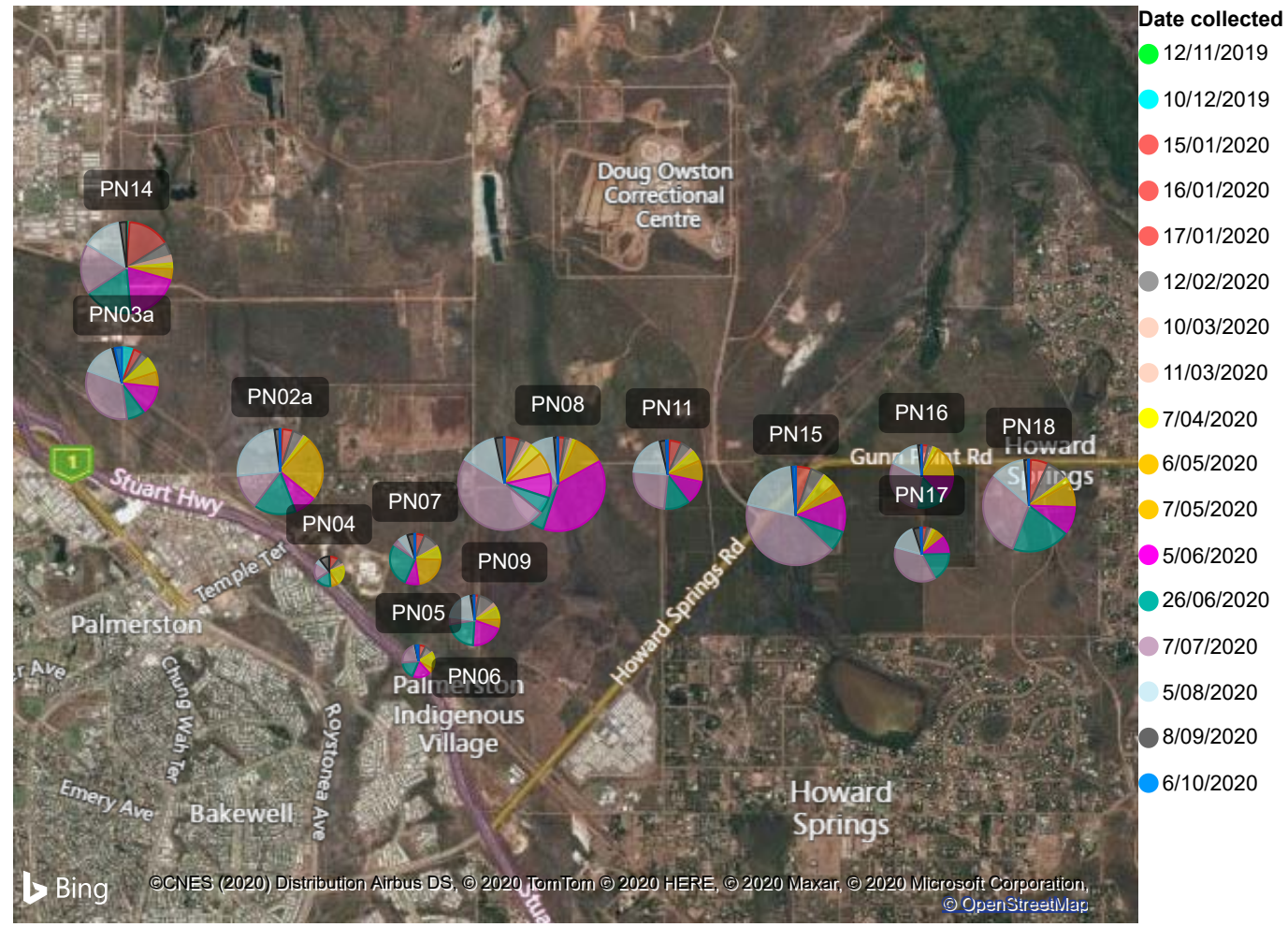
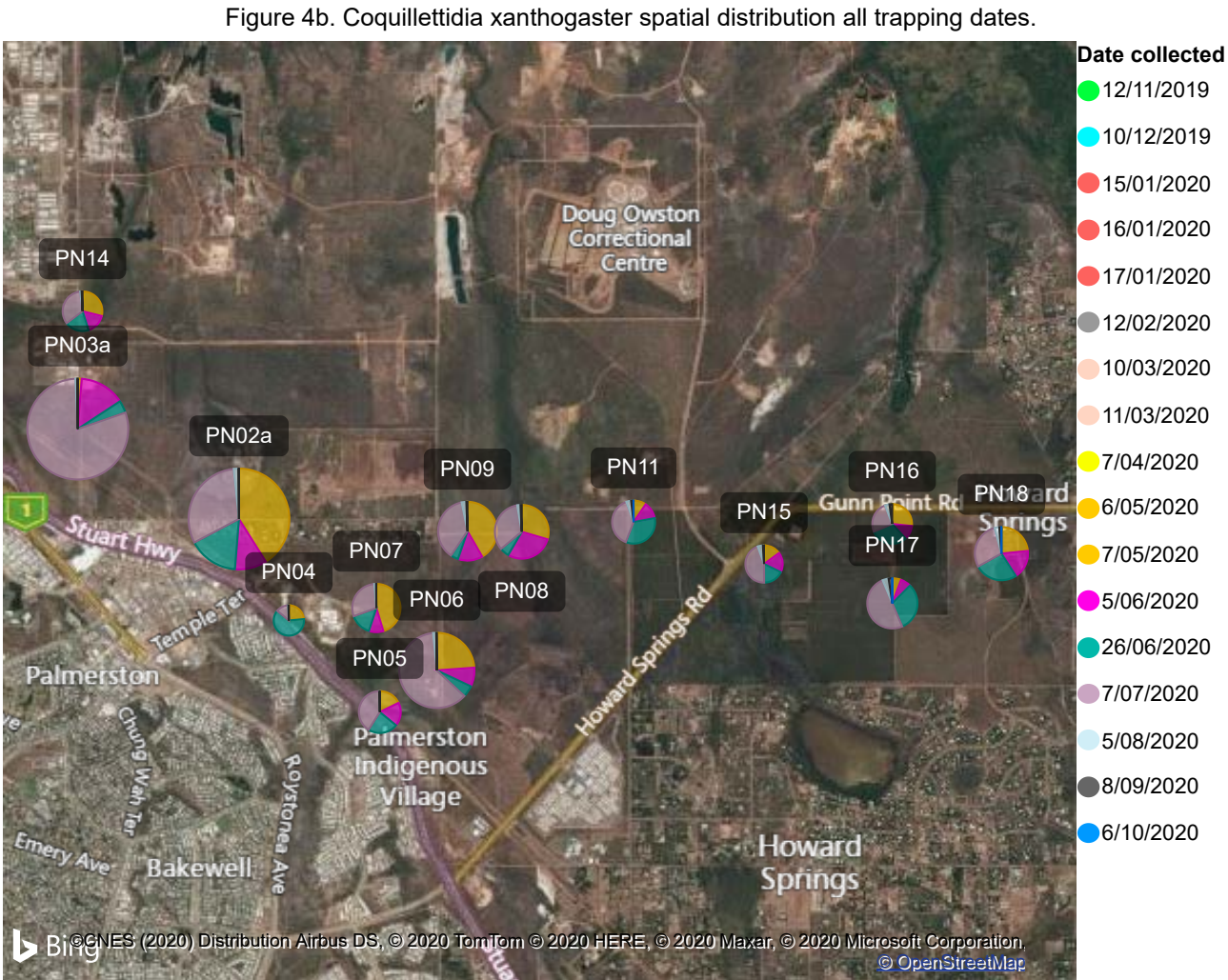
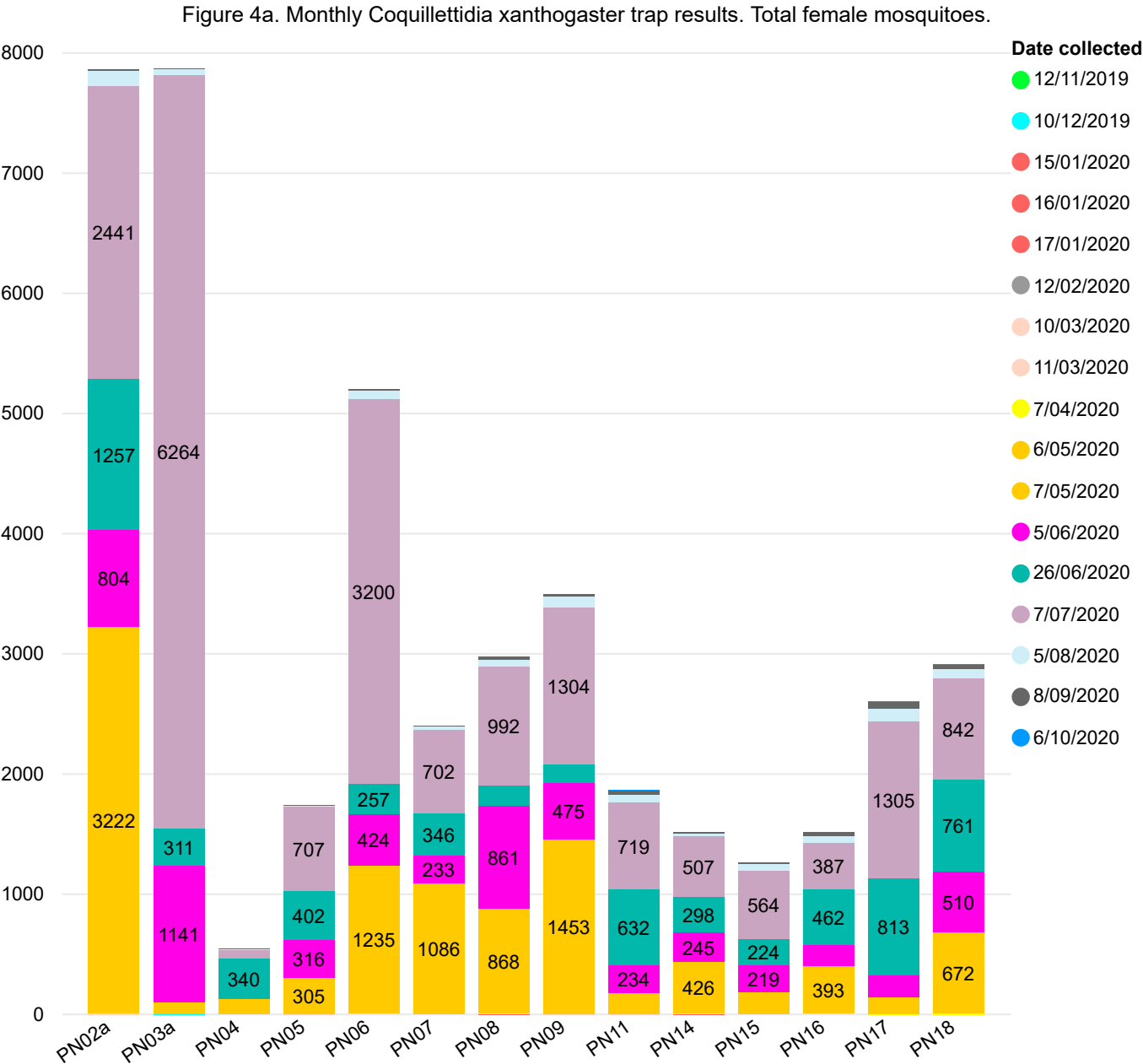


Figure 3b. *Culex annulirostris* spatial distribution all trapping dates.



Notes: Traps were not set at PN15-PN18 in November. They were additional traps added to the program from December onwards. Site PN10 was only set in November. No data available for PN03a in March, and PN04 in June, due to trap failures that were not re-set. PN14 was also a trap fail that was not reset in October.

Figures 4a and 4b. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trapping results. *Coquilleltidia xanthogaster* results from November 2019 to October 2020.



Notes: Traps were not set at PN15-PN18 in November. They were additional traps added to the program from December onwards. Site PN10 was only set in November. No data available for PN03a in March, and PN04 in June, due to trap failures that were not re-set. PN14 was also a trap fail that was not reset in October.

Figures 5a to 5d. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trapping results. Select *Anopheles* species results November 2019 to October 2020.

Figure 5a. Monthly *Anopheles bancroftii* trap results. Total females.

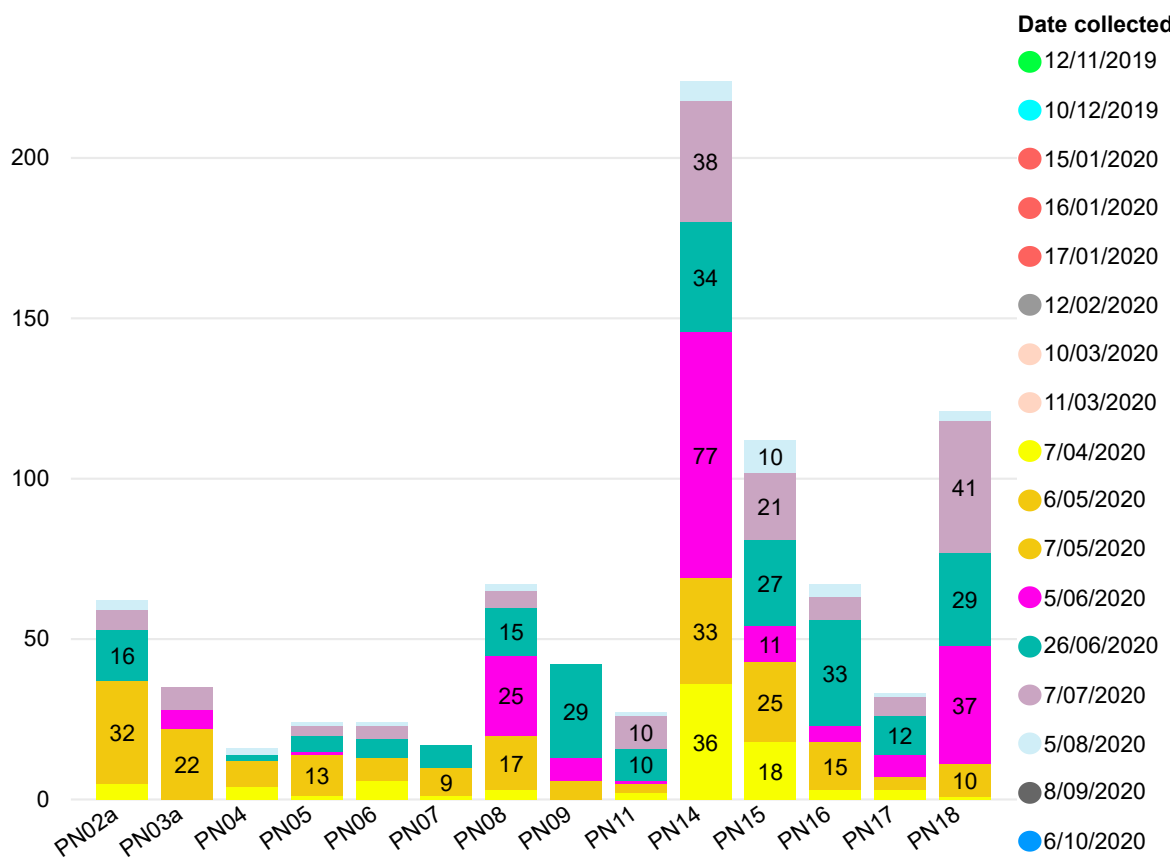


Figure 5b. Monthly *Anopheles meraukensis* trap results. Total females.

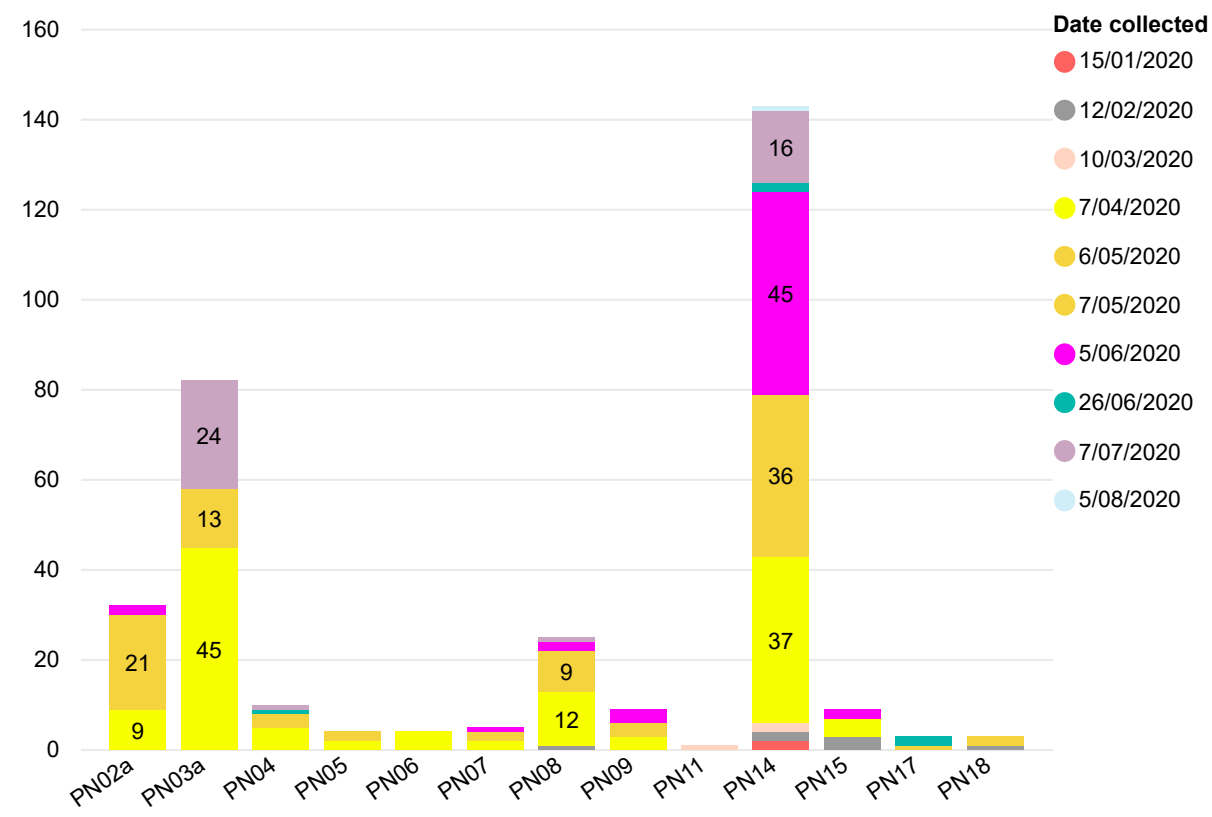


Figure 5c. *Anopheles bancroftii* spatial distribution all trapping dates.



Figure 5d. *Anopheles meraukensis* spatial distribution all trapping dates.

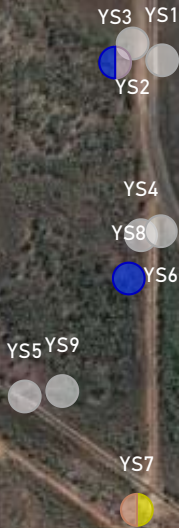


Notes: Traps were not set at PN15-PN18 in November. They were additional traps added to the program from December onwards. Site PN10 was only set in November. No data available for PN03a in March, and PN04 in June, due to trap failures that were not re-set. PN14 was also a trap fail that was not reset in October.

Figure 6. Larval mosquito survey locations and species detection locations. Yarrawonga swamplands, Holtze and Kowandi North.

Yarrawonga swamplands

- Ad. (Ady) catasticta
- An. (Cel) annulipes s.l.
- An. (Cel) farauti s.l.
- Cx. (Lop) hilli
- Nil mosquitoes



Holtze and Kowandi North.

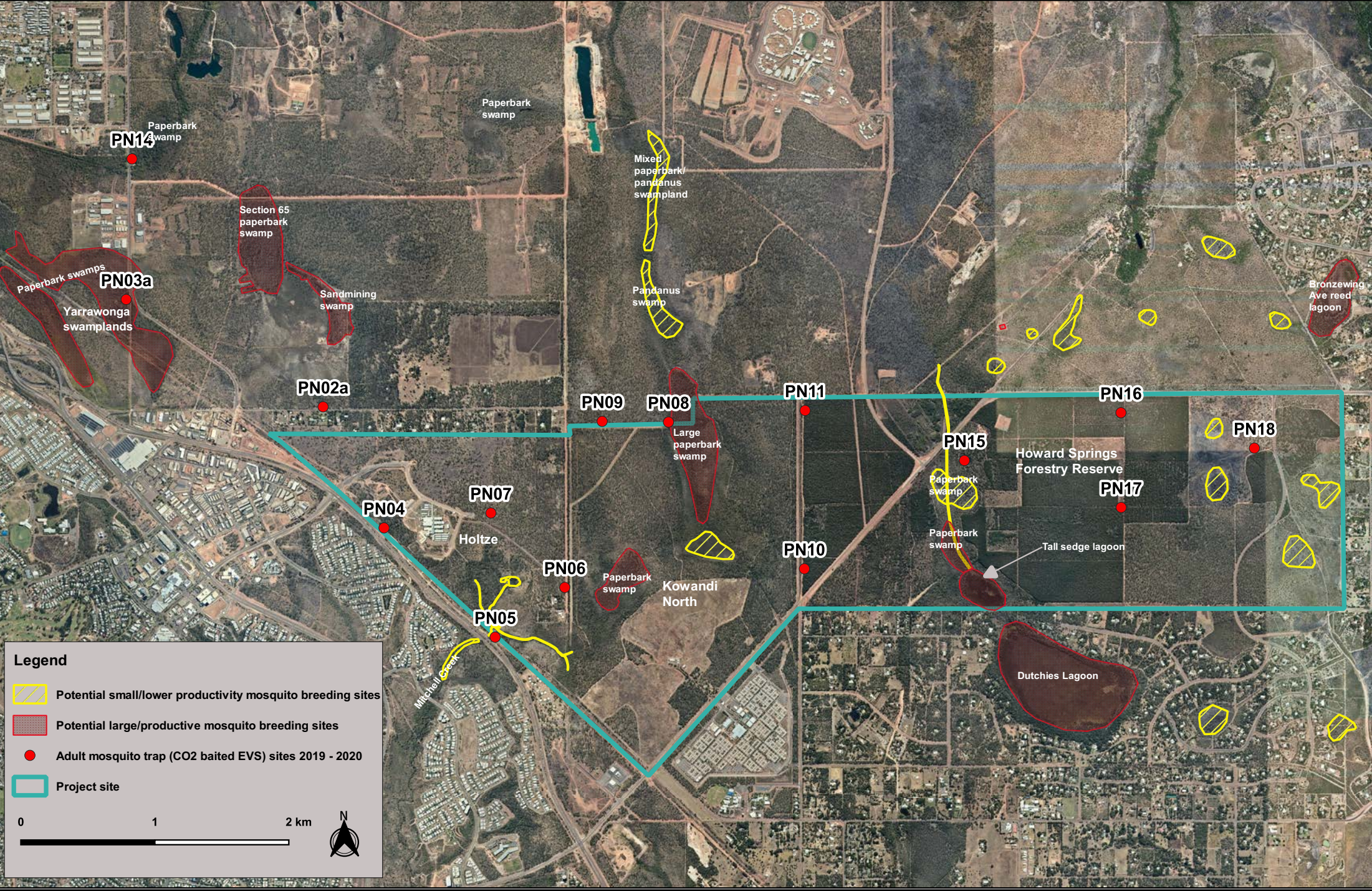
- An. (Cel) annulipes s.l.
- An. (Cel) farauti s.l.
- Cx. (Cux) annulirostris
- Nil mosquitoes



Figure 7. Larval mosquito survey locations and species detection locations. Howard Springs Forestry Reserve and Howard River Park.



Figure 8. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline mosquito investigation November 2019 to October 2020. Potential freshwater mosquito breeding sites affecting the study area.



Tables

Table 1. Holtze, Kowandi North and Howard Springs Forestry Reserve Baseline Mosquito Trapping Program 2019-2020. Total number of all adult female mosquitoes collected in CO2 baited EVS traps from monthly trapping November 2019 to October 2020. Trap results by site.

Trap Site	<i>Ad. (Ady) catascicta</i>	<i>Ae. (Adm) alboscuteallatus</i>	<i>Ae. (Cha) elchoensis</i>	<i>Ae. (Fin) brittini</i>	<i>Ae. (Fin) kachi</i>	<i>Ae. (Fin) notoscriptus</i>	<i>Ae. (Mac) species</i>	<i>Ae. (Mac) tremulus</i>	<i>Ae. (Mol) pecuniosus</i>	<i>Ae. (Och) normanensis</i>	<i>Ae. (Och) vigilax</i>	<i>An. (Ano) bancroftii</i>	<i>An. (Cel) annulipes s.l.</i>	<i>An. (Cel) farauti s.l.</i>	<i>An. (Cel) hilli</i>	<i>An. (Cel) meraukensis</i>	<i>An. (Cel) novaguinensis</i>	<i>Cq. (Coq) xanthogaster</i>	<i>Cx. (Cui) pullus</i>	<i>Cx. (Cux) annulirostris</i>	<i>Cx. (Cux) gelidus</i>	<i>Cx. (Cux) palpalis</i>	<i>Cx. (Cux) quinquefasciatus</i>	<i>Cx. (Cux) sitens</i>	<i>Cx. (Cux) species</i>	<i>Cx. (Cux) vicinus</i>	<i>Cx. (Cux) Vishnui group</i>	<i>Cx. (Lop) cubiculi</i>	<i>Cx. (Lop) hilli</i>	<i>Cx. (Lop) species</i>	<i>Cx. (Lop) species 167</i>	<i>Cx. (Ocu) bitaeniorhynchus</i>	<i>Cx. (Ocu) squamosus</i>	<i>Ma. (Mind) uniformis</i>	<i>mosquitoes unidentifiable (damaged)</i>	<i>Trp. (Trp) magnesianus</i>	<i>Trap failure mosquitoes</i>	<i>Ur. (Ura) moresbyensis</i>	<i>Ur. (Ura) nivipes</i>	<i>Ve. (Ver) funerea</i>	<i>Ve. (Ver) reesi</i>	Total	%	No. of traps set	Ave. per trap night
PN02a	2	0	3	1	7	35	0	1	0	0	756	62	31	1	0	32	0	7861	7	840	5	88	6	7	2	0	20	0	0	0	0	0	18	0	0	0	0	0	0	0	1	9786	14.24	13	752.77
PN03a	2	0	0	0	1	4	0	6	0	0	1757	35	15	3	2	82	0	7874	11	658	12	21	0	9	1	1	4	0	0	0	0	1	53	0	0	4	3	0	0	0	0	10559	15.37	12	879.92
PN04	4	0	0	0	14	26	0	0	0	0	612	16	11	0	0	10	0	544	2	76	1	16	1	13	1	0	2	0	0	0	0	0	4	0	0	2	0	0	0	0	0	1355	1.97	12	112.92
PN05	0	5	0	0	44	15	0	0	0	0	517	24	2	0	0	4	0	1741	18	110	7	7	0	9	0	3	10	0	1	0	0	2	0	17	0	1	0	0	0	1	2	2540	3.70	13	195.38
PN06	0	0	0	0	13	27	0	0	1	0	705	24	6	1	1	4	1	5205	5	355	0	34	0	14	1	3	2	0	0	0	0	1	0	18	0	0	0	0	0	0	0	6421	9.35	13	493.92
PN07	0	0	6	0	0	7	0	13	3	0	1473	17	8	0	1	5	0	2405	4	362	0	74	0	19	0	0	2	0	0	0	0	0	5	1	0	0	0	0	0	0	0	4405	6.41	13	338.85
PN08	0	0	2	0	12	0	0	0	0	0	638	67	1	3	0	25	0	2978	3	960	21	24	0	18	1	0	2	0	0	0	0	1	0	124	0	0	0	0	1	0	1	4882	7.11	13	375.54
PN09	0	0	5	0	7	3	0	0	2	0	941	42	5	0	0	9	0	3495	2	948	5	24	0	14	0	0	6	0	0	0	0	0	0	15	0	0	1	0	0	0	0	5524	8.04	13	424.92
PN10	0	0	0	0	0	0	0	0	0	0	174	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	0	174	0.25	1	174.00	
PN11	9	0	2	0	0	13	0	0	0	0	939	27	1	1	0	1	0	1864	6	610	0	25	0	43	0	0	32	0	0	0	0	0	14	0	0	0	0	0	0	0	0	3587	5.22	13	275.92
PN14	0	0	0	0	46	42	0	0	0	0	2023	224	67	15	0	143	0	1514	4	925	15	9	8	35	0	2	19	0	0	4	1	0	0	210	1	8	1	0	0	1	0	5317	7.74	12	443.08
PN15	0	0	0	0	2	12	0	1	3	1	505	112	0	5	1	9	0	1266	4	1024	2	16	0	35	0	0	8	3	2	0	0	0	1	5	0	0	0	0	0	0	0	3017	4.39	12	251.42
PN16	1	0	0	0	0	1	0	0	3	0	980	67	1	4	0	0	0	1516	1	533	0	56	0	21	0	0	25	1	0	0	0	0	0	1	0	0	0	0	0	0	0	3211	4.67	12	267.58
PN17	6	0	0	0	2	4	0	1	0	0	214	33	0	0	0	3	1	2606	13	414	2	28	0	33	0	0	13	1	0	0	0	0	0	2	0	0	0	0	0	0	0	3376	4.91	12	281.33
PN18	4	0	0	0	0	81	0	0	3	0	392	121	6	0	1	3	0	2916	7	932	16	45	0	9	0	0	2	0	0	0	0	0	12	0	0	0	0	0	0	0	0	4550	6.62	12	379.17
Total	28	5	18	1	148	270	0	22	15	1	12626	871	154	33	6	330	2	43785	87	8747	86	467	15	279	6	9	147	5	3	4	1	4	2	498	2	9	8	3	1	2	4	68704	100.00	176	390.36
%	0.04	0.01	0.03	0.00	0.22	0.39	0.00	0.03	0.02	0.00	18.38	1.27	0.22	0.05	0.01	0.48	0.00	63.73	0.13	12.73	0.13	0.68	0.02	0.41	0.01	0.01	0.21	0.01	0.00	0.01	0.00	0.72	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	100.00				
Ave. per trap	0.16	0.03	0.10	0.01	0.84	1.53	0.00	0.13	0.09	0.01	71.74	4.95	0.88	0.19	0.03	1.88	0.01	248.78	0.49	49.70	0.49	2.65	0.09	1.59	0.03	0.05	0.84	0.03	0.02	0.02	0.01	0.02	0.01	2.83	0.01	0.05	0.05	0.02	0.01	0.01	0.02	390.36			

Notes. Trap PN10 was discontinued after the November 2019 trapping. Traps PN15-18 commenced in December 2019.

Table 2. Holtze, Kowandi North and Howard Springs Forestry Reserve Baseline Mosquito Trapping Program 2019-2020. Total number of all adult female mosquitoes collected in CO2 baited EVS traps from monthly trapping during November 2019 to October 2020. Trap results by date.

Trap site	12-Nov-19	10-Dec-19	15-Jan-20	16-Jan-20	17-Jan-20	12-Feb-20	10-Mar-20	11-Mar-20	7-Apr-20	6-May-20	7-May-20	5-Jun-20	26-Jun-20	7-Jul-20	5-Aug-20	8-Sep-20	6-Oct-20	Total	%	No. of traps set	Ave. per trap night
PN02a	348	234	154			111	10		43	3514		899	1425	2605	335	44	64	9786	14.24	13	752.77
PN03a	983	616	1	1	42	55	1	1	118	189		1248	366	6540	165	39	194	10559	15.37	12	879.92
PN04	315	264	1	60		16	13		36	153		1	363	91	7	23	12	1355	1.97	12	112.92
PN05	392	103	35			35	11		64	341		343	434	744	12	5	21	2540	3.70	13	195.38
PN06	427	182	60			64	12		71	1291		503	343	3223	157	36	52	6421	9.35	13	493.92
PN07	1056	242	141			55	4		45	1194		282	463	759	72	24	68	4405	6.41	13	338.85
PN08	342	110	90			29	16		44	1033		1319	239	1344	141	59	116	4882	7.11	13	375.54
PN09	455	277	129			33	22		54	1	1547	569	241	1768	234	64	130	5524	8.04	13	424.92
PN10	174																	174	0.25	1	174.00
PN11	360	401	58			44	16		40	252		314	732	920	205	76	169	3587	5.22	13	275.92
PN14	1433	387	367			124	56		139	644		660	526	761	167	52	1	5317	7.74	12	443.08
PN15		264	140			67	14		74	264		367	334	1024	279	27	163	3017	4.39	12	251.42
PN16		847	66			15	4		29	508		256	587	595	162	55	87	3211	4.67	12	267.58
PN17		64	36			24	7		15	182		237	909	1492	175	93	142	3376	4.91	12	281.33
PN18		344	99			94	5		43	805		645	1006	1171	233	64	41	4550	6.62	12	379.17
Total	6285	4335	1377	61	42	766	191	1	815	10371	1547	7643	7968	23037	2344	661	1260	68704	100.00	176	390.36
%	9.15	6.31	2.00	0.09	0.06	1.11	0.28		1.19	15.10	2.25	11.12	11.60	33.53	3.41	0.96	1.83	100.00			
No. of traps set	11	14	12	1	1	14	13		14	13	1	13	14	14	14	14	13	176			
Ave. per trap	571.36	309.64	114.75	61.00	42.00	54.71	14.69		58.21	797.77	1547.00	587.92	569.14	1645.50	167.43	47.21	96.92	390.36			

Notes. Empty cells reflects no traps set. The 1 values represent trap fails. The three single values on 16 & 17 January, and 7 May were results from trap resets.

Table 3. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline mosquito investigation. Larval mosquito survey results February and May 2020.

Table 3. Larval mosquito survey results February and May 2020. Average number of larvae per ladle dip*.

Site number and name ▲	Ad. (Ady) catasticta	An. (Cel) annulipes s.l.	An. (Cel) farauti s.l.	Cx. (Cux) annulirostris	Cx. (Cux) species 32	Cx. (Lop) cubiculi	Cx. (Lop) hilli	Nil mosquitoes	Ur. (Ura) albescens
H1. Mitchell Creek borrow pit area in Section 4231 southeast of hospital. Northern pits.									
5 February 2020								0	
H2. Mitchell Creek borrow pit area in Section 4231 southeast of hospital. Southern shallower pits.									
5 February 2020								0	
H3. Mitchell Creek headwaters at Taylor Road dirt track crossing									
5 February 2020								0	
HRP1. Section 3418 large reed lagoon south of Bronzewing Ave									
7 May 2020								0	
HRP2. Bronzewing Ave, road drain that flows into grassy lagoon									
7 May 2020					1	1			1
HSFR1. Portion 2821 open grassy paperbark swamp between Sitella Rd and pine forest									
5 February 2020								0	
HSFR2. Tall sedge lagoon, northwest of Dutchies Lagoon. North east fringe of lagoon.									
7 May 2020					0.2				
HSFR3. Second paperbark swamp north of the Tall sedge lagoon, south of Howard Springs Road. Northern edge.									
7 May 2020								0	
HSFR4. Second paperbark swamp north of the Tall sedge lagoon, south of Howard Springs Road. Southern edge.									
7 May 2020								0	
K1. Section 5623 Kowandi North very large paperbark swamp dissected by the unbuilt section of Gunn Point Rd									
5 February 2020								0	
7 May 2020		0.2	0.2	0.2					
13 May 2020		2	2	2					
YS1. Alongside Thorngate Rd, grassy seepage area opposite paperbark swamp, south of industrial subdivision									
5 February 2020								0	
YS2. Northern grassy edge of paperbark swamp adjacent (west) to Thorngate Rd, south of industrial subdivision									
5 February 2020								0	
YS3. Northern edge of paperbark swamp west of Thorngate Rd, near bend in road									
7 May 2020	0.2	0.2							
YS4. South east portion of Yarrawonga swamp at cross junction of bikepath									
5 February 2020								0	
YS5. Southwest edge of Yarrawonga paperbark swamp from Thorngate Rd, at footpath culvert with flood depth sign									
5 February 2020								0	
7 May 2020								0	
YS6. Yarrawonga paperbark swamp opposite bend in Thorngate Rd, at start of swamp bikepath									
5 February 2020								0	
YS7. Drainage path alongside southern edge of Yarrawonga swamp cut off by the old railway embankment and footpaths									
7 May 2020			0.2				0.2		
YS8. South east portion of Yarrawonga swamp, just inside paperbark zone									
7 May 2020		0.1							
YS9. Southwest edge of Yarrawonga paperbark swamp from Thorngate Rd, inside start of main paperbark forest									
7 May 2020								0	

Notes. *Survey on 13th May was carried out using buckets rather than the standard mosquito dipper (ladle), which was used during the February survey.

For site number. H = Holtze, HRP = Howard River Park, HSFR = Howard Springs Forestry Reserve, K = Kowandi North, YS = Yarrawonga swamplands

Table 4. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline mosquito investigation. Larval mosquito surveys July, August and September 2020.

Table 4. Larval mosquito survey results July, August and September 2020. Average number of larvae per 10L bucket dip.

Site number and name	An. (Ano) bancroftii	An. (Cel) annulipes s.l.	Cx. (Cux) annulirostris	Cx. (Lop) (Lop) hilli	Cx. (Lop) species	Cx. (Ocu) bitaeniorhynchus	Mi. (Mim) chamberlaini metallica	Nil mosquitoes
H4. Mitchell Creek, upstream of Stuart Highway. Southern arm running parralell with railway embankment.								
8 September 2020								0
H5. Mitchell Creek, upstream of Stuart Highway. Eroded pools on upstream side of culvert.								
8 September 2020								0
HRP3. Bronzewing Ave, large reed lagoon south of road. Northern edge.								
1 July 2020	1			1				
18 August 2020			.2					
8 September 2020	0.3		0.3		0.3			
HRP4. Bronzewing Ave, large reed lagoon south of road. Eastern edge.								
18 August 2020								0
* HRP5. Bronzewing Ave, large reed lagoon south of road. Northwest dry season open water edge, below eleocharis reed zone.								
8 September 2020			5					
HSFR2. Tall sedge lagoon, northwest of Dutchies Lagoon. North east fringe of lagoon.								
1 July 2020	1	1	1				1	
18 August 2020						1	1	
8 September 2020								0
HSFR5. Tall Sedge lagoon, shallow grassy wheel ruts in firebreak along eastern edge								
1 July 2020			5					
K1. Section 5623 Kowandi North very large paperbark swamp dissected by the unbuilt section of Gunn Point Rd								
1 July 2020								0
K2. Overflow channel from Section 5623 Kowandi North paperbark swamp. Start of creekline drainage channel.								
1 July 2020								0
K3. Overflow channel from Section 5623 Kowandi North paperbark swamp. End point of channel at pandanus forest.								
1 July 2020								0

Notes.

*This site was surveyed using the standard 300ml/vol mosquito dipper. Nil mosquitoes results from July, August and September were due to sites being dry, rather than no larvae being present.

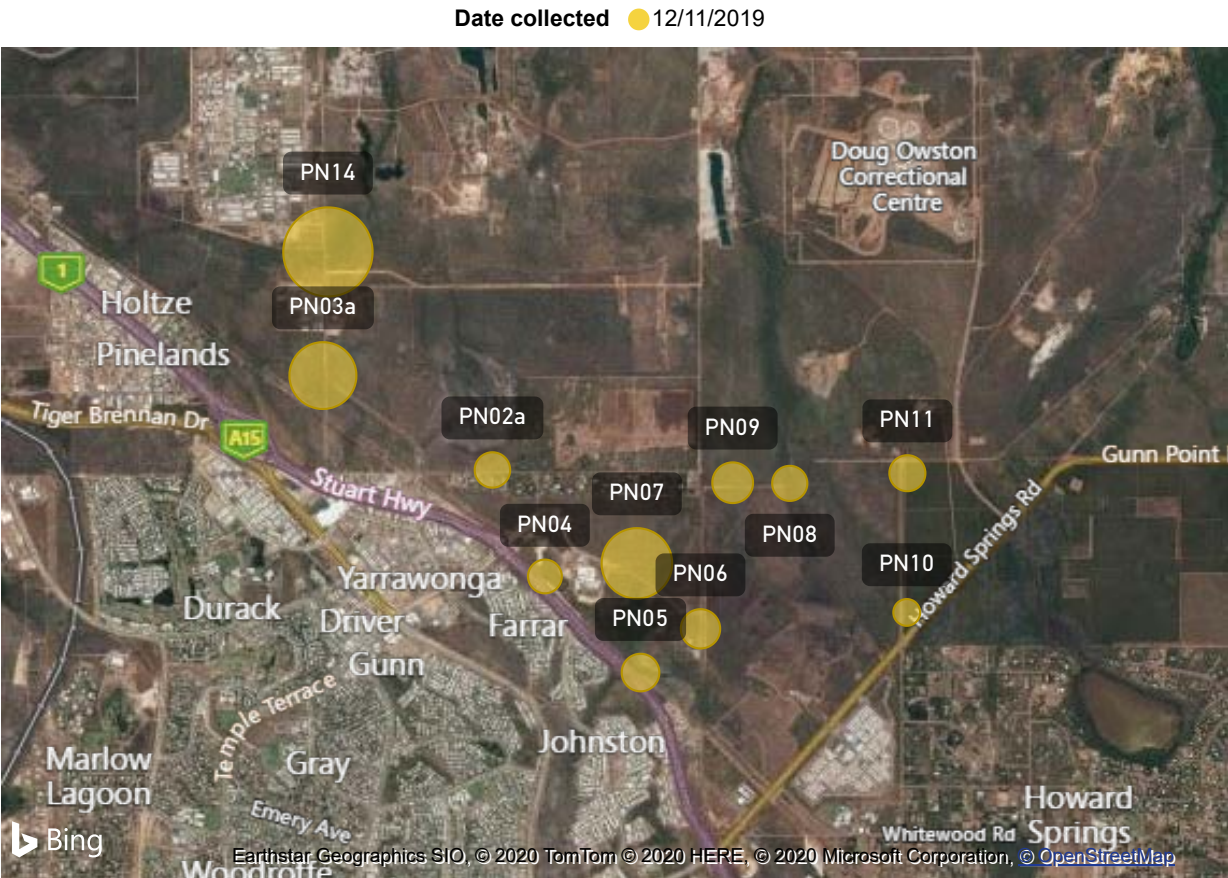
For site number. H = Holtze, HRP = Howard River Park, HSFR = Howard Springs Forestry Reserve, K = Kowandi North

Appendix 1. Individual trap date tables.

Appendix 1. Page 1. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trapping results. Overnight mosquito trapping results 11-12 November 2020.

Overnight trap results 11-12 November 2019. Total female mosquitoes.												
Species name	PN02a	PN03a	PN04	PN05	PN06	PN07	PN08	PN09	PN10	PN11	PN14	Total
Ae. (Adm) alboscuteallatus				3								3
Ae. (Cha) elchoensis							1					1
Ae. (Fin) notoscriptus	1		3	2	5						3	14
Ae. (Mac) species	0		0									0
Ae. (Mac) tremulus		2				3						5
Ae. (Och) vigilax	346	977	311	385	422	1053	342	454	174	358	1420	6242
An. (Cel) annulipes s.l.											3	3
An. (Cel) hilli		2										2
Cx. (Cux) annulirostris	1	2		1						2	7	13
Cx. (Cux) sitiens			1									1
Ve. (Ver) funerea				1								1
Total	348	983	315	392	427	1056	342	455	174	360	1433	6285

Overnight trap results 11-12 November 2019. Spatial distribution of adult female mosquitoes (all species combined)



Appendix 1. Page 2. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trapping results. Overnight mosquito trapping results 9-10 December 2020.

Overnight trap results 9-10 December 2019. Total female mosquitoes.															
Species name	PN02a	PN03a	PN04	PN05	PN06	PN07	PN08	PN09	PN11	PN14	PN15	PN16	PN17	PN18	Total
Ad. (Ady) catasticta		1	3												4
Ae. (Adm) alboscuteallatus				2											2
Ae. (Cha) elchoensis	1					1		1							3
Ae. (Fin) notoscriptus	8		4	4	6					5				19	46
Ae. (Mac) species						0									0
Ae. (Mac) tremulus	1	1													2
Ae. (Mol) pecuniosus												1			1
Ae. (Och) vigilax	212	577	250	93	174	239	103	274	387	373	259	836	64	317	4158
An. (Cel) annulipes s.l.	1	1	1							4					7
Cq. (Coq) xanthogaster		1													1
Cx. (Cux) annulirostris	6	34	1			2			4	3	1	2		6	59
Cx. (Cux) sitiens			5		2		7			2		5		1	22
Cx. (Cux) Vishnui group	5	1		4				2	10		4	3		1	30
Total	234	616	264	103	182	242	110	277	401	387	264	847	64	344	4335

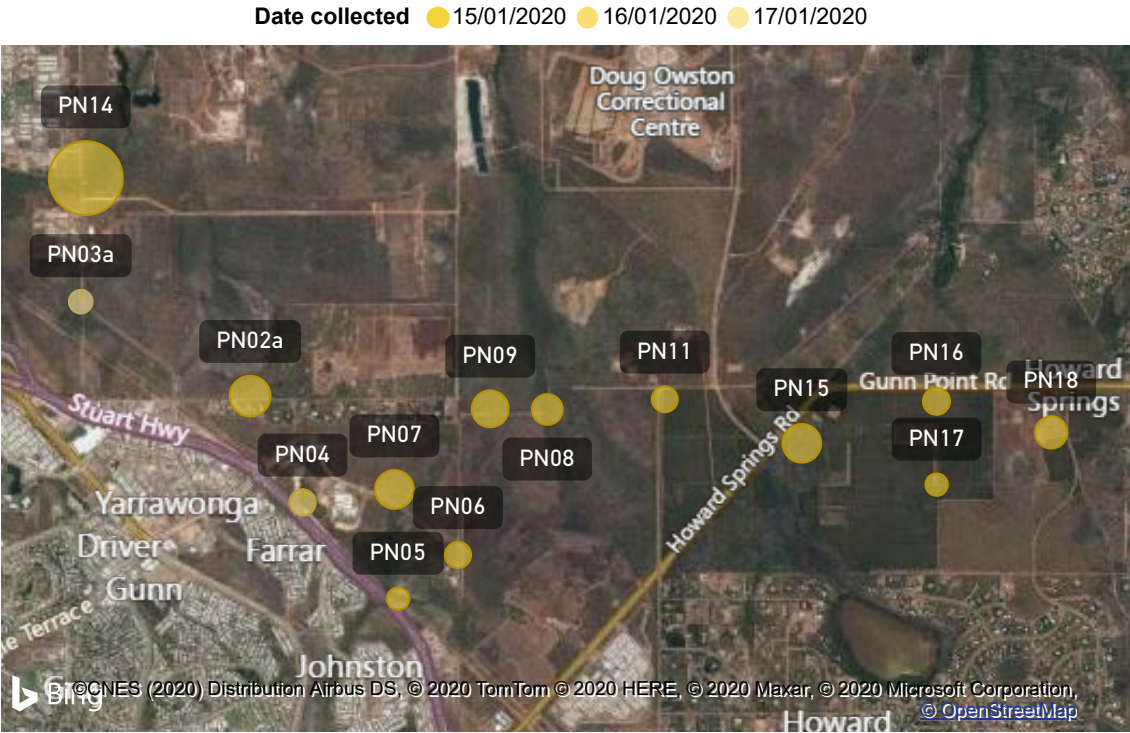
Overnight trap results 9-10 December 2019. Spatial distribution of adult female mosquitoes (all species combined)



Appendix 1. Page 3. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trapping results. Overnight mosquito trapping results 15, 16 or 17 January 2020.

Overnight trap results 15, 16 or 17 January 2020. Total female mosquitoes.															
Species name	PN02a	PN03a	PN04	PN05	PN06	PN07	PN08	PN09	PN11	PN14	PN15	PN16	PN17	PN18	Total
Ae. (Cha) elchoensis							1								1
Ae. (Fin) kochi	3		9	3	1		1			10					27
Ae. (Fin) notoscriptus	6		4	1	5	1		2	3	3	3	1		14	43
Ae. (Mac) species	0							0		0					0
Ae. (Mac) tremulus						2					1				3
Ae. (Mol) pecuniosus														1	1
Ae. (Och) normanensis											1				1
Ae. (Och) vigilax	106	14	35	21	41	116	63	67	12	185	74	47	16	25	822
An. (Cel) annulipes s.l.	1	1	2							5					9
An. (Cel) meraukensis										2					2
Cq. (Coq) xanthogaster							1			2					3
Cx. (Cui) pullus		1	1	2		1	1	1	2	3	1		3		16
Cx. (Cux) annulirostris	34	25	7	7	10	20	23	52	34	139	51	16	13	58	489
Cx. (Cux) sitiens	4	1	2	1	3	1	1	7	6	16	9	2	4	1	58
Tp. (Trp) magnesianus										2					2
Trap failure mosquitoes		2	1												3
Total	154	44	61	35	60	141	90	129	58	367	140	66	36	99	1480

Overnight trap results 15, 16 or 17 January 2020. Spatial distribution of adult female mosquitoes (all species combined)



Appendix 1. Page 4. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trapping results. Overnight mosquito trapping results 11-12 February 2020.

Overnight trap results 11-12 February 2020. Total female mosquitoes.															
Species name	PN02a	PN03a	PN04	PN05	PN06	PN07	PN08	PN09	PN11	PN14	PN15	PN16	PN17	PN18	Total
Ae. (Cha) elchoensis	2						1		1						4
Ae. (Fin) britteni	1														1
Ae. (Fin) kochi	2			5	2		1	4		9	2				25
Ae. (Fin) notoscriptus	9		4	4		4			8	10			4	8	51
Ae. (Mac) species													0		0
Ae. (Mac) tremulus						3									3
Ae. (Mol) pecuniosus											3			1	4
Ae. (Och) vigilax	27	17	4	2	15	5	4	6	2	20	9	1		2	114
An. (Cel) annulipes s.l.	22	2	2			2				35		1		3	67
An. (Cel) hilli					1										1
An. (Cel) meraukensis							1			2	3			1	7
Cx. (Cui) pullus	5	9	1	13	4	3	2		1	1	1	1	9	6	56
Cx. (Cux) annulirostris	36	23	5	9	38	37	18	20	31	43	46	12	10	72	400
Cx. (Cux) gelidus	4	3						1					1	1	10
Cx. (Cux) quinquefasciatus	1														1
Cx. (Cux) sitiens				1	2						1				4
Cx. (Cux) species	2														2
Cx. (Cux) Vishnui group				1	2		2	2	1	2	2				12
Ma. (Mnd) uniformis		1													1
mosquitoes unidentifiable (damaged)						1				1					2
Tp. (Trp) magnesianus										1					1
Total	111	55	16	35	64	55	29	33	44	124	67	15	24	94	766

Overnight trap results 11-12 February 2020. Spatial distribution of adult female mosquitoes (all species combined)



Appendix 1. Page 5. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trapping results. Overnight mosquito trapping results 9-10 March 2020.

Overnight trap results 9-10 March 2020. Total female mosquitoes.															
Species name	PN02a	PN03a	PN04	PN05	PN06	PN07	PN08	PN09	PN11	PN14	PN15	PN16	PN17	PN18	Total
Ae. (Fin) kochi			3	3			2	1		7					16
Ae. (Fin) notoscriptus	1		6	2	1			1	1	11	6				29
Ae. (Och) vigilax			1							3	1				5
An. (Cel) annulipes s.l.			1							3					4
An. (Cel) meraukensis									1	2					3
Cq. (Coq) xanthogaster	1			2			2	1	1	2					9
Cx. (Cui) pullus	2			2	1				2		1			1	9
Cx. (Cux) annulirostris	5		2	1	10	4	10	19	10	25	4	4	5	4	103
Cx. (Cux) sitiens											1				1
Cx. (Cux) Vishnui group	1			1									1		3
Cx. (Ocu) bitaeniorhynchus							1								1
Ma. (Mnd) uniformis							1		1		1		1		4
Tp. (Trp) magnesianus										2					2
Trap failure mosquitoes		2													2
Ve. (Ver) funerea										1					1
Total	10	2	13	11	12	4	16	22	16	56	14	4	7	5	192

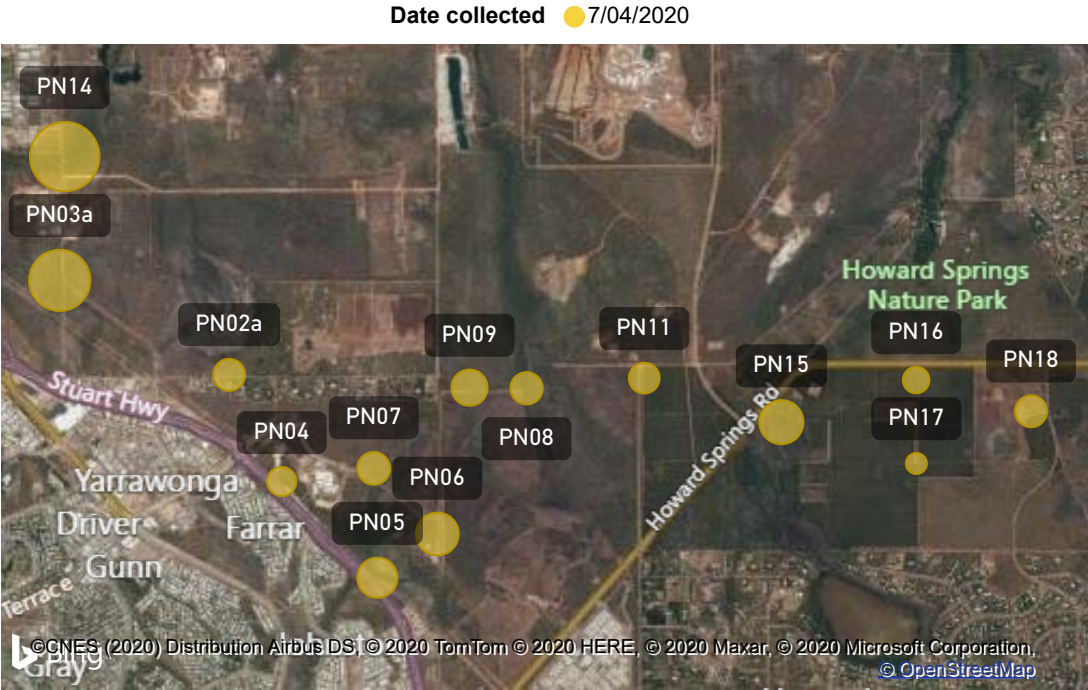
Overnight trap results 9-10 March 2020. Spatial distribution of adult female mosquitoes (all species combined)



Appendix 1. Page 6. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trapping results. Overnight mosquito trapping results 6-7 April 2020.

Overnight trap results 6-7 April 2020. Total female mosquitoes.															
Species name	PN02a	PN03a	PN04	PN05	PN06	PN07	PN08	PN09	PN11	PN14	PN15	PN16	PN17	PN18	Total
Ad. (Ady) catasticta												1			1
Ae. (Cha) elchoensis						2	1	2							5
Ae. (Fin) kochi	1	1		31	10		6	2		12					63
Ae. (Fin) notoscriptus	3		2	1	9				1	5	3			11	35
Ae. (Mol) pecuniosus					1	3		1						1	6
Ae. (Och) vigilax							1			1					2
An. (Ano) bancroftii	5		4	1	6	1	3		2	36	18	3	3	1	83
An. (Cel) annulipes s.l.		7	3	1	1			1		9					22
An. (Cel) farauti s.l.		1								4					5
An. (Cel) hilli														1	1
An. (Cel) meraukensis	9	45	5	2	4	2	12	3		37	4				123
Cq. (Coq) xanthogaster	5	6	5	2	6	5	8	2	4	7	6	11	2	10	79
Cx. (Cui) pullus		1		1				1					1		4
Cx. (Cux) annulirostris	18	47	16	18	29	29	11	40	31	19	42	12	9	17	338
Cx. (Cux) gelidus		1													1
Cx. (Cux) palpalis		1				1	1					2			5
Cx. (Cux) vicinus		1													1
Cx. (Cux) Vishnui group		3		1					1	1					6
Cx. (Ocu) bitaeniorhynchus				2	1										3
Cx. (Ocu) squamosus		1													1
Ma. (Mnd) uniformis	2	3	1	2	4	2		2	1	5	1			2	25
Tp. (Trp) magnesianus										3					3
Ve. (Ver) reesi				2			1								3
Total	43	118	36	64	71	45	44	54	40	139	74	29	15	43	815

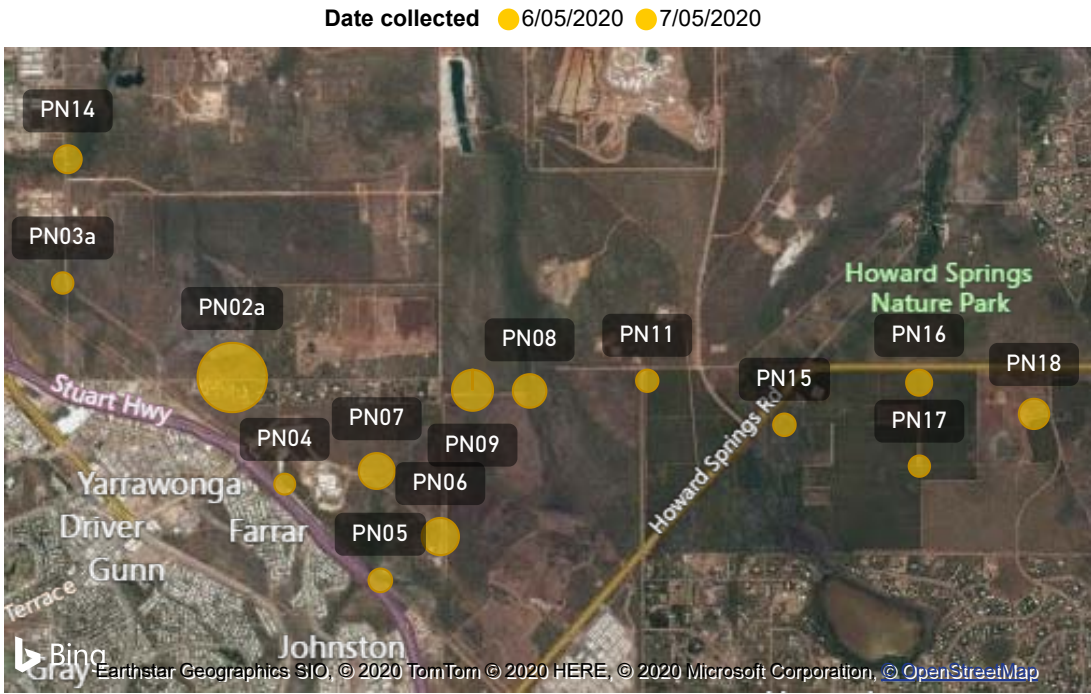
Overnight trap results 6-7 April 2020. Spatial distribution of adult female mosquitoes (all species combined)



Appendix 1. Page 7. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trapping results. Overnight mosquito trapping results 5-6 or 6-7 May 2020.

Overnight trap results 5-6 or 6-7 May 2020. Total female mosquitoes.															
Species name	PN02a	PN03a	PN04	PN05	PN06	PN07	PN08	PN09	PN11	PN14	PN15	PN16	PN17	PN18	Total
Ae. (Cha) elchoensis						2									2
Ae. (Fin) kochi			2	2			2			6					12
Ae. (Fin) notoscriptus	3		1			2				2				27	35
Ae. (Mac) tremulus						2							1		3
Ae. (Mol) pecuniosus								1				1			2
Ae. (Och) vigilax	1		1				2			2	1	1			8
An. (Ano) bancroftii	32	22	8	13	7	9	17	6	3	33	25	15	4	10	204
An. (Cel) annulipes s.l.		2	1	1	3	1				4					12
An. (Cel) farauti s.l.		2					3				1	2			8
An. (Cel) meraukensis	21	13	3	2		2	9	3		36			1	2	92
An. (Cel) novaguinensis					1										1
Cq. (Coq) xanthogaster	3222	92	123	305	1235	1086	868	1453	172	426	183	393	145	672	10375
Cx. (Cui) pullus									1						1
Cx. (Cux) annulirostris	201	45	6	6	21	81	101	74	61	36	48	89	22	81	872
Cx. (Cux) palpalis	11		5		7	5				6	3	2	9	3	51
Cx. (Cux) sitiens						2			7		2	3			14
Cx. (Cux) vicinus					3					2					5
Cx. (Cux) Vishnui group	11		1						2	10		1			25
Cx. (Lop) species										4					4
Ma. (Mnd) uniformis	11	13	2	12	14	2	31	10	6	77	1	1		10	190
Trap failure mosquitoes								1							1
Ve. (Ver) reesi	1														1
Total	3514	189	153	341	1291	1194	1033	1548	252	644	264	508	182	805	11918

Overnight trap results 5-6 or 6-7 May 2020. Spatial distribution of adult female mosquitoes (all species combined)



Appendix 1. Page 8. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trapping results. Overnight mosquito trapping results 4-5 June 2020.

Overnight trap results 4-5 June 2020. Total female mosquitoes.															
Species name	PN02a	PN03a	PN04	PN05	PN06	PN07	PN08	PN09	PN11	PN14	PN15	PN16	PN17	PN18	Total
Ad. (Ady) catasticta	1								1				1		3
Ae. (Cha) elchoensis						1		1							2
Ae. (Fin) kochi	1														1
Ae. (Fin) notoscriptus														2	2
An. (Ano) bancroftii		6		1			25	7	1	77	11	5	7	37	177
An. (Cel) annulipes s.l.	4	1				2	1			2					10
An. (Cel) farauti s.l.										5	4				9
An. (Cel) meraukensis	2					1	2	3		45	2				55
Cq. (Coq) xanthogaster	804	1141		316	424	233	861	475	234	245	219	175	176	510	5813
Cx. (Cui) pullus											1				1
Cx. (Cux) annulirostris	70	85		20	73	32	366	79	69	177	118	66	43	92	1290
Cx. (Cux) gelidus		1					3							2	6
Cx. (Cux) palpalis	11				2	4			2		1		3	2	25
Cx. (Cux) quinquefasciatus										3					3
Cx. (Cux) sitiens	2			3	4	8	8		5	3	8	9	6		56
Cx. (Cux) Vishnui group	2							1	1	2		1			7
Cx. (Ocu) squamosus											1				1
Ma. (Mnd) uniformis	2	11		3		1	53	3	1	101	2		1		178
Trap failure mosquitoes			1												1
Ur. (Ura) moresbyensis		3													3
Total	899	1248	1	343	503	282	1319	569	314	660	367	256	237	645	7643

Overnight trap results 4-5 June 2020. Spatial distribution of adult female mosquitoes (all species combined)



Appendix 1. Page 9. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trapping results. Overnight mosquito trapping results 25-26 June 2020.

Overnight trap results 25-26 June 2020. Total female (F) and male (M) mosquitoes.																															
Trap location	PN02a		PN03a		PN04		PN05		PN06		PN07		PN08		PN09		PN11		PN14		PN15		PN16		PN17		PN18		Total		
Species name	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	
Ad. (Ady) catacticta																2	0								2	0			4	0	
Ae. (Fin) notoscriptus	1	0			1	0			1	0									1	0									4	0	
Ae. (Mac) tremulus			1	1							1	0																	2	1	
Ae. (Och) vigilax	3	0													3	0	4	0	5	0	4	0	4	0	1	0	5	0	29	0	
An. (Ano) bancroftii	16	0			2	0	5	0	6	0	7	0	15	0	29	0	10	0	34	0	27	0	33	0	12	0	29	0	225	0	
An. (Cel) annulipes s.l.	3	0			1	0			1	0					2	0											2	0	9	0	
An. (Cel) farauti s.l.	1	0							1	0							1	0	4	0			2	0					9	0	
An. (Cel) meraukensis					1	0													2	0					2	0			5	0	
An. (Cel) novaguinensis																									1	0			1	0	
Cq. (Coq) xanthogaster	1257	0	311	2	340	2	402	5	257	5	346	0	166	0	149	1	632	2	298	0	224	0	462	0	813	0	761	2	6418	19	
Cx. (Cux) annulirostris	135	0	53	0	13	0	19	0	76	0	101	0	54	0	55	0	73	0	159	0	70	0	80	0	72	0	190	0	1150	0	
Cx. (Cux) gelidus					1	0	3	0							2	0			3	0	1	0			1	0	12	0	23	0	
Cx. (Cux) palpalis	2	0			1	0	1	0			3	0													5	0	2	0	14	0	
Cx. (Cux) quinquefasciatus	3	0																	1	0									4	0	
Cx. (Cux) sitiens					2	0	2	0	1	0	3	0			1	0	6	0	4	0	5	0	2	0			5	0	31	0	
Cx. (Cux) Vishnui group	1	0									2	0					4	0					4	0					11	0	
Cx. (Lop) cubiculi																					3	0							3	0	
Cx. (Lop) hilli							1	0																						1	0
Ma. (Mnd) uniformis	3	0	1	0	1	0							3	0					15	0									23	0	
Tp. (Trp) magnesianus							1	0																						1	0
Ur. (Ura) nivipes													1	0																1	0
Total	1425	0	366	3	363	2	434	5	343	5	463	0	239	0	241	1	732	2	526	0	334	0	587	0	909	0	1006	2	7968	20	

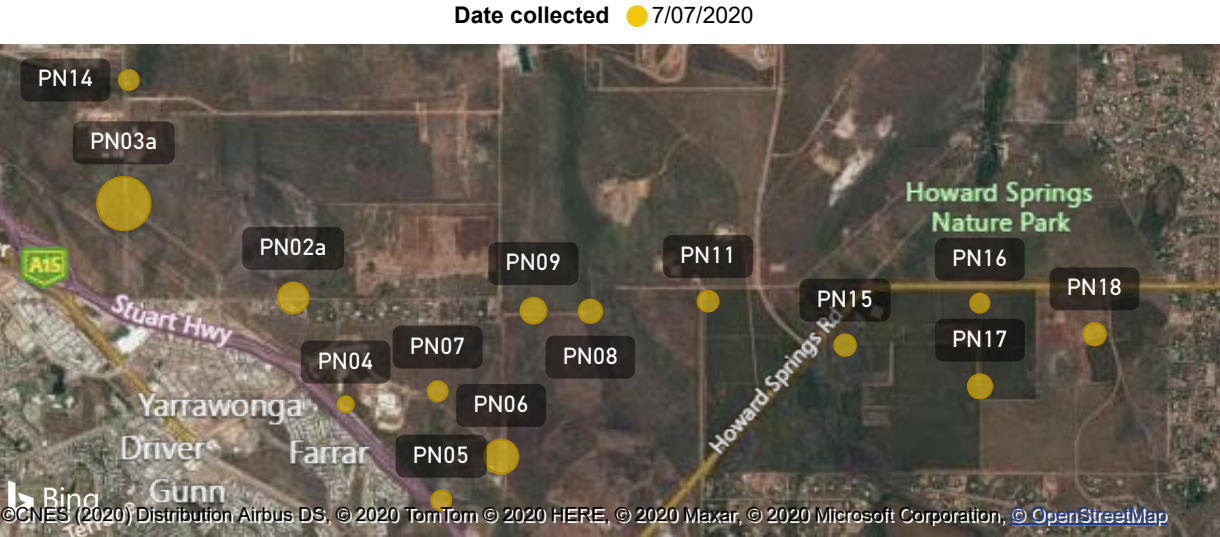
Overnight trap results 25-26 June 2020. Spatial distribution of adult female mosquitoes (all species combined)



Appendix 1. Page 10. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trapping results. Overnight mosquito trapping results 6-7 July 2020.

Overnight trap results 6-7 July 2020. Total female (F) and male (M) mosquitoes.																															
Trap location	PN02a		PN03a		PN04		PN05		PN06		PN07		PN08		PN09		PN11		PN14		PN15		PN16		PN17		PN18		Total		
Species name	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	
Ad. (Ady) catasticta	1	0			1	0											5	0							3	0	2	0	12	0	
Ae. (Fin) kochi																			2	0									2	0	
Ae. (Fin) notoscriptus			4	0																										4	0
Ae. (Mac) species					0	1																								0	1
Ae. (Och) vigilax									1	0									2	0										3	0
An. (Ano) bancroftii	6	0	7	0			3	0	4	0			5	0			10	0	38	0	21	0	7	0	6	0	41	0	148	0	
An. (Cel) annulipes s.l.			1	0							3	0			1	0	1	0											6	0	
An. (Cel) farauti s.l.																			2	0									2	0	
An. (Cel) hilli											1	0																	1	0	
An. (Cel) meraukensis			24	0	1	0							1	0					16	0									42	0	
Cq. (Coq) xanthogaster	2441	55	6264	0	72	2	707	18	3200	0	702	3	992	0	1304	32	719	5	507	4	564	2	387	7	1305	15	842	8	20006	151	
Cx. (Cux) annulirostris	111	0	216	0	14	0	24	0	17	0	16	0	291	0	454	0	151	0	164	0	426	0	156	0	154	0	285	0	2479	0	
Cx. (Cux) gelidus							1	0					14	0					6	0									21	0	
Cx. (Cux) palpalis	46	0			2	0	3	0	1	1	37	0	5	0	2	0	2	0			9	0	33	0			1	0	141	1	
Cx. (Cux) sitiens															6	0	15	0	10	0					12	0			43	0	
Cx. (Cux) vicinus							3	0																					3	0	
Cx. (Cux) Vishnui group					1	0	3	0							1	0	12	0	2	0	2	0	12	0	12	0			45	0	
Cx. (Lop) hilli																					2	0							2	0	
Ma. (Mnd) uniformis			24	0									36	0			5	0	12	0									77	0	
Total	2605	55	6540	0	91	3	744	18	3223	1	759	3	1344	0	1768	32	920	5	761	4	1024	2	595	7	1492	15	1171	8	23037	153	

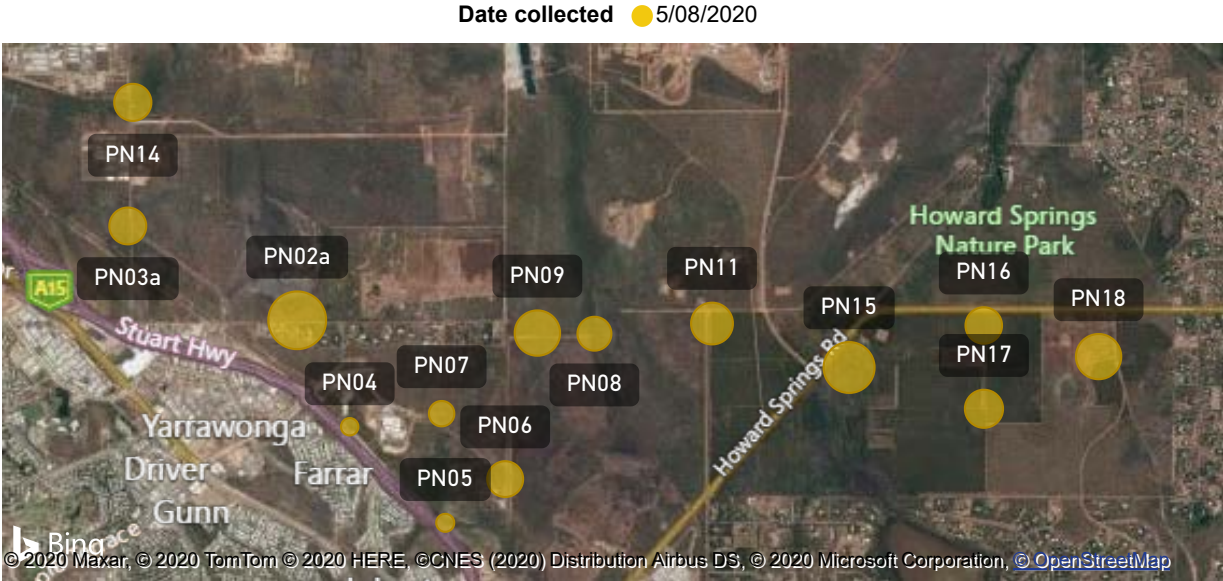
Overnight trap results 6-7 July 2020. Spatial distribution of adult female mosquitoes (all species combined)



Appendix 1. Page 11. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trapping results. Overnight mosquito trapping results 4-5 August 2020.

Overnight trap results 4-5 August 2020. Total female (F) and male (M) mosquitoes.																														
Trap location	PN02a		PN03a		PN04		PN05		PN06		PN07		PN08		PN09		PN11		PN14		PN15		PN16		PN17		PN18		Total	
Species name	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M	Total F	Total M
Ad. (Ady) catacticta			1	0													1	0									1	0	3	0
Ae. (Fin) kochi																									2	0			2	0
Ae. (Mac) tremulus			1	0																									1	0
Ae. (Och) vigilax	1	0	1	0			1	0														1	0	1	0				5	0
An. (Ano) bancroftii	3	0			2	0	1	0	1	0			2	0			1	0	6	0	10	0	4	0	1	0	3	0	34	0
An. (Cel) annulipes s.l.									1	0					1	0			1	0						1	0	4	0	
An. (Cel) hilli																					1	0							1	0
An. (Cel) meraukensis																			1	0									1	0
Cq. (Coq) xanthogaster	120	1	52	2	1	0	4	0	71	0	29	1	58	1	90	2	68	0	16	0	58	0	55	0	102	0	84	4	808	11
Cx. (Cux) annulirostris	205	0	100	0	4	0	1	0	72	0	22	0	73	0	124	0	121	0	131	0	204	0	86	0	65	0	112	0	1320	0
Cx. (Cux) gelidus	1	0	7	0			3	0					4	0	2	0			6	0	1	0					1	0	25	0
Cx. (Cux) palpalis	4	0	3	0			2	0	12	0	21	0	4	0	17	0	13	0	2	0	1	0	11	0	2	0	30	0	122	0
Cx. (Cux) quinquefasciatus	1	0																	1	0									2	0
Cx. (Cux) sitiens																					4	0			1	0			5	0
Cx. (Cux) Vishnui group																	1	0	2	0			4	0			1	0	8	0
Cx. (Lop) cubiculi																						1	0	1	0				2	0
Cx. (Lop) species 167																			1	0									1	0
Ur. (Ura) nivipes													0	1															0	1
Total	335	1	165	2	7	0	12	0	157	0	72	1	141	2	234	2	205	0	167	0	279	0	162	0	175	0	233	4	2344	12

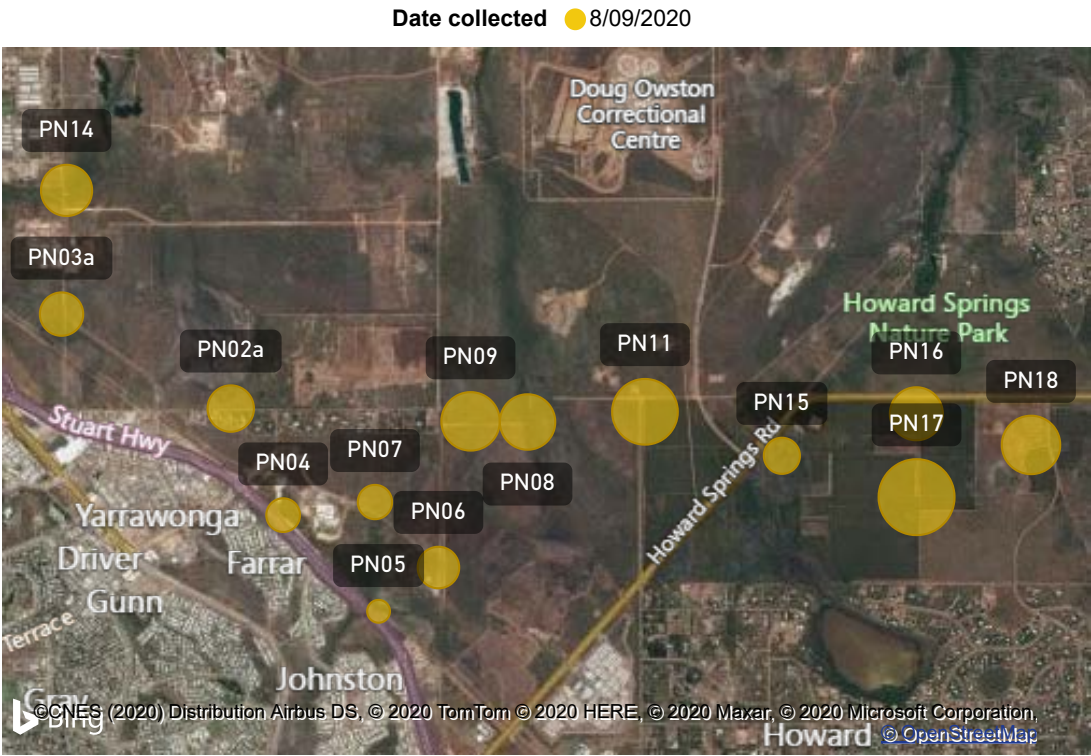
Overnight trap results 4-5 August 2020. Spatial distribution of adult female mosquitoes (all species combined)



Appendix 1. Page 12. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trapping results. Overnight mosquito trapping results 7-8 September 2020.

Overnight trap results 7-8 September 2020. Total female mosquitoes.															
Species name	PN02a	PN03a	PN04	PN05	PN06	PN07	PN08	PN09	PN11	PN14	PN15	PN16	PN17	PN18	Total
Ad. (Ady) catasticta														1	1
Ae. (Fin) notoscriptus										2					2
Ae. (Mac) tremulus		1													1
Ae. (Och) vigilax	4	7	2		4	2	10	9	18	12	9	9	5	7	98
An. (Cel) annulipes s.l.										1					1
Cq. (Coq) xanthogaster	11	7	3	3	12	4	22	21	32	11	12	33	62	36	269
Cx. (Cux) annulirostris	16	7	8	1	7	16	12	29	18	22	4	9	17	12	178
Cx. (Cux) palpalis	13	16	8	1	12	2	14	5	8	1	2	4	9	6	101
Cx. (Cux) quinquefasciatus			1							3					4
Cx. (Cux) sitiens														2	2
Cx. (Cux) species		1	1		1		1								4
Total	44	39	23	5	36	24	59	64	76	52	27	55	93	64	661

Overnight trap results 7-8 September 2020. Spatial distribution of adult female mosquitoes (all species combined)



Appendix 1. Page 13. Holtze, Kowandi North and Howard Springs Forestry Reserve baseline adult mosquito trapping results. Overnight mosquito trapping results 5-6 October 2020.

Overnight trap results 5-6 October 2020. Total female mosquitoes.															
Species name	PN02a	PN03a	PN04	PN05	PN06	PN07	PN08	PN09	PN11	PN14	PN15	PN16	PN17	PN18	Total
Ae. (Fin) notoscriptus	3		1	1											5
Ae. (Mac) species	0												0		0
Ae. (Mac) tremulus						2									2
Ae. (Mol) pecuniosus												1			1
Ae. (Och) vigilax	56	164	8	15	48	58	113	128	158		148	81	127	36	1140
Cq. (Coq) xanthogaster									2				1	1	4
Cx. (Cux) annulirostris	2	21		3	2	2	1	2	5		10	1	4	3	56
Cx. (Cux) palpalis	1	1				1						4		1	8
Cx. (Cux) quinquefasciatus	1														1
Cx. (Cux) sitiens	1	8	3	2	2	5	2		4		5		10		42
Trap failure mosquitoes										1					1
Total	64	194	12	21	52	68	116	130	169	1	163	87	142	41	1260

Overnight trap results 5-6 October 2020. Spatial distribution of adult female mosquitoes (all species combined)

