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INPEX

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DELEGATE OF THE MINISTER FOR LANDS AND PLANNING

ICHTHYS ONSHORE LNG FACILITIES

BITING INSECTS MANAGEMENT PLAN

REV.	DATE	ISSUE PURPOSE	PREPARED	CHECKED	APPROVED
A	22-Feb-12	IFR	K. Rope	M. Cross	B. Ferris
0	20-Mar-12	IFC	T. Lui Yuen	M. Cross	B. Ferris
1	12-April-12	IFC	M. Cross	B. Ferris	B. Ferris

Definitions

Company	INPEX Operations Australia Pty Ltd acting as an agent for Ichthys LNG Pty Ltd
Contractor	The Joint Venture between JGC Corporation , KBR (Kellogg Brown & Root Pty Ltd) and Chiyoda Corporation
EIS	This relates to both the Draft Environmental Impact Statement and the Supplement to the Draft Environmental Impact Statement
Good International Industry Practice (GIIP)	The International Finance Corporation (IFC) (2007) defines Good International Industry Practice as the exercise of professional skill, diligence, prudence and foresight that would be reasonably expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally. The circumstances that skilled and experienced professionals may find when evaluating the range of pollution prevention and control techniques available to a project may include, but are not limited to, varying levels of environmental degradation and environmental assimilative capacity as well as varying levels of financial and technical feasibility.
Ichthys Project	The Ichthys Gas Field Development Project
Site	onshore development area
Subcontractor	Any company to whom Contractor has subcontracted any part of the works

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1. INTRODUCTION

1.1. Project background

INPEX Operations Australia Pty Ltd (INPEX) is working with its partner Total E&P Australia (Total) to develop the Ichthys Field.

This Biting Insect Management Plan (BIMP) details the environmental protection and occupational health and safety management measures and controls necessary to avoid, reduce or mitigate the environmental and social impacts during the activities associated with the Ichthys Onshore Liquefied Natural Gas (LNG) Facilities and its supporting infrastructure.

The onshore development area (Site) occupies approximately 413 hectares and is located at Blaydin Point on the south side of East Arm in Darwin Harbour as shown in Figure 1. The Site is located on Blaydin Point, approximately 16 kilometres south-east of Darwin, Northern Territory, Australia.

Blaydin Point is located in the Middle Arm of Darwin Harbour (Figure 1, Appendix A). The site is bounded by the Elizabeth River to the east and Lightning Creek to the west. The mangroves and adjacent plant communities around Balydin Point provide breeding habitat for mosquitoes and biting midges.

The Environmental Impact Statement (EIS) included a Biting Insects Survey for the Blaydin Point development (Warchot 2009). Warchot's (2009) recommendations included the development of a Biting Insects Management Plan (BIMP) to minimise the impact of biting insects on the Site.

This BIMP meets condition 2(D) of the Northern Territory Government Development Permit DP12/0065.

1.2. Objectives of the BIMP

The key objective of the BIMP is to reduce the health impact of biting insects on workers by minimising the potential for increased biting insect populations on and around the Site as a result of construction activities associated with the onshore development area.

2. APPLICABLE LEGISLATION, REGULATIONS AND GUIDELINES

Legislation applicable to biting insect management at the onshore development area includes:

- *Work Health and Safety (National Uniform Legislation) Act* (NT)
- *Public Health Act* (NT)
- *Public and Environmental Health Act* (NT)
- *Public Health (General Sanitation, Mosquito Prevention, Rat Exclusion and Prevention) Regulations* (NT)

The Medical Entomology Section of the Northern Territory's Department of Health and Families produced a series of guidelines to manage and mitigate biting insect impacts during the planning and construction phases of developments in areas that have potential to produce mosquito breeding habitats. The guideline titles are listed below and complete copies of the guidelines are provided in Appendix B.

- *Guidelines for preventing mosquito breeding associated with construction practice near tidal areas in the Northern Territory*
- *Guidelines for preventing biting insect problems for urban residential developments or subdivisions in the Top End of the Northern Territory*
- *Guidelines for preventing biting insect problems for new rural residential developments or subdivisions in the Top End of the NT*
- *Constructed wetlands in the Northern Territory: Guidelines to prevent mosquito breeding*
- *Previous mosquito problems in Top End of the NT created by construction practice*
- *Guidelines on urban mosquito control drains*
- *Guidelines for Mosquito breeding and sewage pond treatment in the Northern Territory*

All construction personnel, contractors and visitors to the Site are required to be aware of the requirements within this document and use appropriate personal protective equipment (PPE) to minimise the impact of biting insects on the Site. The detailed guideline on appropriate PPE is provided in Appendix C.

3. EXISITING ENVIRONMENT

3.1. Northern Territory biting insects

Biting insects in the Northern Territory consist of biting midges and mosquitoes, both of which are known to be present at the Site. Mosquitoes are potential transmitters of disease to humans. Distribution and abundance of the biting insects vary according to seasonal and other changes in habitat and food availability. The risk of being bitten and/or transmission of disease to humans varies in relation to breeding cycles and abundance. Different species of biting insects have differing patterns of distribution and seasonal changes in abundance.

The probability of being bitten varies according to species-specific feeding ecology, i.e. differing feeding times. *Aedes* spp. tend to feed around sunset while species of *Anopholes* tend to feed at night. Biting-midges are more active around full and new moons, and during the hour before and after sunset and sunrise (Medical Entomology Branch 2009).

The time taken for eggs to hatch or individuals to reach maturity also varies between species. In the Northern Territory most species mature from egg hatch to adult within 10 to 14 days. Species with transient larval habitats such as tidal pools or ephemeral inland flooded areas can mature in around six days (Medical Entomology Branch 2010).

Longevity of biting insect species can influence potential for the transmission of disease. A common disease-carrying mosquito, *Aedes vigilax*, exhibits an enhanced longevity from December to January and poses a higher risk of transmitting Ross River virus and Barmah Forest virus during this time than in other months.

The most significant and most common human pest biting midge species around coastal areas of the Northern Territory is *Culicoides ornatus* (Shivas 1999; Shivas & Whelan 2001; Whelan 2003). Reactions to bites generally include itching, nuisance and discomfort. This can become unbearable if a rate of one to five bites per hour is experienced by someone unaccustomed to them (Warchot and Whelan 2011). A greater health risk is posed should bites progress to skin infections, or are experienced by individuals who are allergic.

The most commonly recorded mosquitoes in the Darwin City, Outer Darwin, Rural Darwin and Palmerston areas in 2009–10 are *Aedes and Culex species* (Medical Entomology Branch 2010), some of which are known carriers of Ross River virus (RRV), the most commonly recorded arboviral disease in the Northern Territory. Significant species and their biological traits (e.g. distribution, habitat, peak abundance) are presented in Appendix D. Images to assist with identification are presented in Appendix E.

3.2. Previous studies

Warchot (2009) undertook a biting insect survey of Blaydin Point in 2008 to fulfil the requirements of the Environmental Impact Statement (EIS) prepared by Company in 2009. The major findings of the study are outlined below.

<u>Midges</u>

- The mangrove biting-midge *C. ornatus* is present in extremely high seasonal numbers during the late dry season (August to November). Very high numbers are present during the early to mid dry season (April to July), while high numbers occur during the wet season. *C. ornatus* is widespread throughout Blaydin Point and the mainland south of Blaydin Point.
- Pest problems caused by *C. ornatus* are severe and unbearable for people without personal protection. This is particularly so during the two hours around sunset and sunrise over the six days around the full and new moons. Dry-season pest problems are significantly greater than wet-season problems, especially during the late dry season.

- *Culicoides ornatus* pest problems can disrupt a workforce and cause secondary effects such as intense itching, infection and scarring. Newcomers to the region will be particularly affected, as they will lack immunity to biting-midge bites.
- The mangrove biting-midge *Culicoides* undescribed *sp*. (near *C. immaculatus*) and *C. flumineus* are likely to cause pest problems for workers in mangrove areas.

Mosquitoes

- Twelve-month baseline trapping and wet-season field surveys were not conducted at Blaydin Point; therefore, mosquito populations affecting Blaydin Point were predicted based on limited trapping, a desktop examination of Blaydin Point and surrounding areas, and an examination of baseline data from the adjacent Wickham Point. The Blaydin Point mosquito community is assumed to be similar to that at Wickham Point.
- Blaydin Point lacks extensive mosquito breeding habitats such as coastal plains, creeks and rivers. Mosquito populations are consequently not likely to be as high as in other some areas of Darwin. Localised mosquito populations will occur at Blaydin Point, and include pest and disease-carrying mosquito species.
- The northern salt marsh mosquito *Aedes vigilax* is present in low and possibly moderate numbers during the late dry and early wet season (September to January). This species will breed in poorly draining upper tidal areas surrounding Blaydin Point. Breeding sites at Blaydin Point would be localised to ground pools in seepage areas and other seasonally flooded depressions, areas of restricted tidal drainage, and vehicle-disturbed areas along the landward mangrove margin, i.e. wheel ruts.
- Important mosquito species such as *Culex annulirostris*, *Culex sitiens*, *Anopheles* spp. and *Coquillettidia xanthogaster* will be seasonally present at Blaydin Point in minor numbers during the wet season. Breeding sites at Blaydin Point would be localised to the ground margin in seepage areas. The monsoon vine forest is likely to contain some areas of wet-season ponding and breeding sites for *Verrallina funerea*, and possibly *Aedes vigilax* if there are tide-influenced depressions near the landward mangrove margin.
- The extractive materials area (EMA) to the south of Blaydin Point is a possible breeding site for *Culex annulirostris*, *Anopheles* spp. and *Coquillettidia xanthogaster* if significant wet-season ponding occurs.
- Mosquito pest problems at Blaydin Point are expected to be minimal, with *Aedes vigilax* the only mosquito likely to be present in numbers sufficient to cause a pest problem. *Aedes vigilax* is an aggressive biter; biting during the daytime in shaded areas as well as at night. It will cause seasonally low and possibly moderate pest problems at Blaydin Point. Other mosquito species are not expected to be present in numbers sufficient to cause appreciable pest problems.
- *Aedes vigilax* will pose a low and possibly moderate risk of RRV and Barmah Forest virus (BFV) transmission during the months September to January, with December and January being the highest risk months due to increased mosquito longevity. *Culex annulirostris*, *Culex sitiens* and *Verrallina funerea* will pose a minor risk of RRV transmission due to expected minor abundance, while *Culex annulirostris* will also pose a minor risk of BFV, Murray Valley encephalitis virus (MVEV) and Kunjin virus (KUNV) transmission.
- The risk for potential malaria transmission at Blaydin Point is likely to be very low, due to the expected minor abundance of *Anopheles* species and there being no endemic malaria in northern Australia.

3.3. Previous studies

Health risks associated with the transmission of mosquito-borne diseases are serious as indicated by the symptoms of the four main viruses present in the Northern Territory. These are listed below and detailed in Appendix F.

- Murray Valley encephalitis virus (MVEV)
- Kunjin virus (KUNV)
- Ross River virus (RRV)
- Barmah Forest virus (BFV)

There is a continual possibility of other arboviral diseases, such as Malaria, Japanese Encephalitis virus (JEV), Dengue fever and Yellow fever, entering and becoming established in the Northern Territory through importation by infected travellers or vessels containing exotic species of mosquito.

The most recent advice delivered by the Centre of Disease Control (CDC) relates to the period March to June 2011, when the MVEV and KUNV diseases were noted as being present in the Northern Territory. Caution was advised for all four diseases known to be in the Northern Territory with residents advised to use personal insect repellent and to avoid outdoor exposure around flooded areas or where mosquitoes are active during that period.

High-risk areas include those subject to inundation, such as mangroves, tidal flats or seasonally flooded areas. Small bodies of pooling surface water (e.g. tidal pools or open drains) provide mosquitoes with suitable habitat for breeding.

The most common potential disease transmitting mosquitoes anticipated at the Site are likely to be *Aedes vigilax* and *Culex annulirostris*. *Aedes vigilax* is a tidal/brackish water mosquito, and *Culex annulirostris* a brackish water/freshwater mosquito. Both species have a high risk of transmitting disease.

Mosquito species with a low potential for disease transmission include *Culex sitiens* (saltwater mosquito), *Verrallina funerea* (brackish water mosquito) and *Aedes notoscriptus*. Anopheles mosquitoes (brackish and freshwater mosquitoes) have no potential for disease transmission (malaria only) unless malaria is introduced into an area from overseas, in which case the risk could be high.

Ross River virus is the most common arthropod transmitted disease recorded in the Northern Territory, with the number of confirmed cases closely linked to periods of increased rainfall, detailed in Appendix G.

3.4. Biting insects habitat

There are differences between habitats used by biting-midges and mosquitoes. 'Tidal mangrove areas provide habitat for biting midges, while coastal plains, shallow lagoons, floodplains and depressions associated with rivers and creeks provide major habitat for mosquito breeding. Biting insects breed opportunistically when habitat and food sources are available. 'Mosquito breeding generally occurs in areas with shallow water pooling, with semi-aquatic vegetation providing harbourage from predators. Activities or events that increase the amount of available shallow water ponding and/or semi-aquatic vegetation growth is likely to increase the breeding of mosquitoes. This may include ecosystem-wide events, such as tidal inundation, or localised events, such as direct disturbance by vehicles and machinery, blockage of tidal flows by roads and other embankments, erosion from stormwater flows or the creation of mud waves by filling activities (Medical Entomology Branch 2009).

Suitable breeding sites for biting-midges occur across the intertidal area of Blaydin Point. *Culicoides ornatus* breeds in the mud under dense mangrove canopies. The greatest breeding occurs on narrow creek banks around Mean High Water Neap (MHWN) (Shivas and

Whelan 2001, Warchot 2012), particularly among the mangrove species *Avicennia marina* (Medical Entomology Branch 2009). These breeding sites cannot be controlled with insecticides. Effective control of the biting-midge *C. ornatus* would be to remove their tidal mangrove breeding sites by permanently flooding or filling their breeding sites from the mean high-water spring tide mark to below the level of occurrence of seaward mangrove (Shivas and Whelan 2001; Warchot 2009). The only method of achieving this would be to remove most of the mangroves within 1.5–2 km of the Site, which would be deemed environmentally unacceptable (Warchot 2009).

Blaydin Point essentially lacks suitable natural habitat for extensive breeding sites of mosquitoes, such as coastal plains, creeks and rivers, however, localised tidal/brackish water depressions and disturbed areas are potential mosquito breeding sites at, and adjacent to Blaydin Point. Warchot (2009) identified the existing extractive materials area (EMA) located south of Blaydin Point as potentially suitable habitat for breeding sites. Recent aerial photography suggests that the shallow depressions created in the EMA have become appreciable mosquito breeding sites, due to colonisation of the depressions with dense semi-aquatic vegetation. This indicates pest and disease mosquito populations in the area are likely to be higher than in 2009. Therefore these depressions would need to be rectified by draining or filling, or a combination of both (Warchot 2012).

There is potential for the creation of additional breeding habitat. Natural or artificial depressions created by construction, stormwater discharge, storm surge or other natural disturbance event may lead to water ponding. Depressions in the surface of the land caused by the development process and artificial receptacles (i.e. empty containers, disused tyres, pipes etc) at the Site could become breeding sites for endemic pest and disease carrying mosquitoes. Artificial receptacles could also be potential breeding sites for exotic dengue carrying mosquitoes. Rubbish items washed onto the shoreline could become breeding sites for endemic disease-carrying mosquitoes and exotic dengue (Warchot 2009). The essential lack of extensive natural habitat across the Site for mosquitoes limits the requirement for an insecticide mosquito control program, assuming that existing mosquito breeding sites are located and rectified, and that new breeding sites are not created (Warchot 2009 and 2012).

Appendix G shows month by month cases of RRV, and shows that peak RRV cases generally occur from January to March inclusive. Seasonal peaks in mosquito populations are correlated with increased RRV cases, but other factors such as mosquito longevity and host vertebrates also playa crucial role in RRV transmission (Warchot 2012)..

4. ENVIRONMENTAL RISK IDENTIFICATION AND ASSESSMENT

4.1. Risk assessment process

A systematic risk assessment process has been adopted by the Project for environmental and social management. This methodology is used to identify activities that have the potential to result in adverse impacts on social and environmental aspects. By developing management measures and controls to reduce the risks identified, “Residual Risks” can be reduced to as low as reasonably practicable (ALARP). The risk assessment process used has been developed in line with Australian Standard (AS/NZS) ISO 31000:2009, *Risk management principles and guidelines* (Formerly AS/NZS 4360:2004).

The risk assessment is undertaken by assessing the likelihood and consequence of impacts on social and environmental aspects from works with consideration of currently planned mitigation measures. The likelihood of an impact can be described as the level of probability that, or the frequency with which, an aspect of an activity will impact upon society and the environment. The likelihood levels applied in this risk assessment have been quantified using five categories, ranging from “slight injury or health effect” (1) to “more than three fatalities” (5) and are based on past experience, frequency or probability depending on the nature of the aspect, the type of activity and the availability of data.

The risk matrix Table 4.1 is used to determine the Present Risk of an impact which is qualitatively ranked using three risk categories: “high”, “medium” and “low”. The risk matrix shown is endorsed by Company and recommended by Contractor for specifically assessing health and social risks.

Further recommendations are made to reduce the Present Risk for impacts identified as high to a Residual Risk that represents the ALARP level; if further recommendations cannot be made the Present Risk is considered the Residual Risk. When critical Residual Risks are identified, these will be addressed by avoiding the activity.

A risk assessment was conducted as part of this Plan as shown in Section 5 *Key activities, impacts and risks*. The outcomes of the risk assessment will be incorporated into the Site environmental risk register. Subcontractors will also be required to prepare a risk register relevant to their scope of work.

The outcomes from the risk assessment and risk register will be used for the activities on site to facilitate the appropriate management of all identified risks.

Table 4.1: Risk Assessment Matrix

Severity	CONSEQUENCES				INCREASING LIKELIHOOD				
	People	Financial	Environment	Reputation	**A** **Never heard of in the industry**	**B** **Heard of in the industry**	**C** **Happened in the Organisation or more than once per year in the industry**	**D** **Happened at the Location or more than once per year in the Organisation**	**E** **Happened more than once per year at the Location**
1	Slight injury or health effect (First Aid)	Slight damage (<A$100k)	Slight effect [localised/immediate area: temporary impact (days)]	Slight impact (Local mention only, quickly forgotten. Freedom to operate unaffected)	Low	Low	Low	Low	Low
2	Minor injury or health effect (Medical Treatment)	Minor damage (A$100k–A$1m)	Minor effect [localised area <1km^2: short term impact (weeks)]	Minor impact (Short-term local concern. Some impact on work)	Low	Low	Low	Medium	Medium
3	Major injury or health effect (Lost Time Injury/Disease)	Moderate damage (A$1m–A$10m)	Moderate effect [area is between 1 km^2 and 10km^2: short-term impact (months)]	Moderate impact (National bad mention. Short-term regional concern. Close scrutiny of work)	Low	Low	Medium	Medium	High
4	Up to 3 fatalities	Major damage (A$10m–A$100m)	Major effect (area is between 10 km^2 and 100km^2: long-term impact)	Major impact (Medium term national concern. Operations/work in part restricted or curtailed)	Low	Medium	Medium	High	High
5	More than 3 fatalities	Massive damage (>A$100m)	Massive effect (Regional scale area is >100km^2: long-term or permanent impact)	Massive impact (Persistent national concern. Operations/work severely restricted)	Medium	Medium	High	High	High

5. KEY ACTIVITIES, IMPACTS AND RISKS

The key activities, potential impacts and residual risk levels identified for biting insects for the onshore development area are listed in Table 5.1.

Table 5.1: Key activities, impacts and residual risk levels for environmental and human health management

Activity	Potential environmental and human health impact	Residual risk level
Introduction of malaria from staff returning from high risk malaria countries	Transmission of malaria parasites to Anopheles mosquitoes from infected human carriers.	Low
Clearing of vegetation for construction activities	Creation of breeding habitat for biting insects through depressions in surface soils and muds.	Medium
Inappropriate disposal of waste on site	Creation of breeding habitat for biting insects in artificial receptacles left on site that are able to pond water.	Medium
Trenching activities	Creation of breeding habitat for biting insects in trenches or poorly backfilled trenches that are able to pond water.	Medium
• Construction of stormwater drains and pits, culverts and storage ponds • The continuous excavation of the existing EMA • Earthworks for the civil works area preparation and construction	Creation of breeding habitat for biting insects in areas that can pond water and become congested with waste material such as vegetation, rubbish and sediment that can pond water.	Medium
Effluent treatment facilities on the site	Creation of breeding habitat for biting insects in facilities not constructed to the appropriate standards.	Medium
• Construction of roads and embankments • Surface-water diversion into sediment basins	Blockage of tidal and surface-water flows by roads, embankments and the sediment basins, providing mosquito habitats	Medium

6. OBJECTIVES, TARGETS AND INDICATORS

The objectives, targets and indicators for biting insect management that have been established for the Project are outlined in Table 6.1.

Table 6.1: Key performance indicators

Objective	Target	Indicator
To prevent the creation of pools of stagnant water that is breeding habitat for mosquitoes	• Zero stagnant pools/ponds on site and in development disturbed areas within 2km of the Site • No drainage lines, depressions or drains to contain vegetation or other waste material which could cause obstruction of flow and pooling of water	• The number of reported stagnant pools/ponds • Records of treatment of ponds for mosquitoes • The number of drainage lines depressions or drains not being kept clear on the Site • Pest mosquito problems
• To decrease the potential for the spread of mosquito-borne diseases to Site personnel • To decrease issues associated with biting midges	• No biting insect–transmitted disease infecting Site personnel • No workers significantly affected by biting midge bites	• The number of reported personnel with insect-transmitted disease. • The number of reported personnel being affected by biting insects.

7. MANAGEMENT MEASURES

7.1. Control and prevention measures

Mosquitoes and biting-midges are likely to impact on Site personnel and visitors to the Site. The severity of the impact will depend on the time of the year, the individual's immunity to the insect, the issue and use of appropriate PPE and provision of suitable working environments. Table 7.1 details the appropriate actions to address human health issues associated with the Site.

7.2. Biting insects habitat

The Site activities have the potential to increase mosquito populations and subsequently increase the potential for mosquito-borne disease transmission. Potential mosquito breeding sites could be created by the inappropriate storage and discharge of stormwater and wastewater, excavation activities, construction of roads and pipelines and disturbance to tidal areas. Actions to reduce the establishment of such habitats and to manage their mitigation or destruction must be taken to reduce this risk. Details of management measures to control the establishment of suitable habitat are provided in Table 7.1.

The Guidelines referred to in Table 7.1 are:

- Guideline 1: *Guidelines for preventing mosquito breeding associated with construction practice near tidal areas in the Northern Territory*
- Guideline 2: *Guidelines for preventing biting insect problems for urban residential developments or subdivisions in the Top End of the Northern Territory*
- Guideline 3: *Guidelines for preventing biting insect problems for new rural residential developments or subdivisions in the Top End of the NT*
- Guideline 4: *Constructed wetlands in the Northern Territory: Guidelines to prevent mosquito breeding*
- Guideline 5: *Previous mosquito problems in Top End of the NT created by construction practice*
- Guideline 6: *Guidelines on urban mosquito control drains*
- Guideline 7: *Guidelines for mosquito breeding and sewage pond treatment in the Northern Territory*

Table 7.1: Biting insect mitigation measures

No.	Mitigation measure	Reference	Timing	Responsibility
	INDUCTIONS			
7.01	The HSES Site induction will address the biting insect risks, PPE required (see Appendix C) to minimise impact and the availability of personal repellents. It will also inform personnel and visitors of any current severe biting insect problems at the Site	Good International Industry Practice (GIIP), Appendix C	All site personnel and visitors to undertake induction prior to entering the Site.	HSES Manager
7.02	Records will be maintained of all site inductions.	GIIP	After each induction	HSES Manager
7.03	A calendar will be made available to all staff (see Appendix H, *2012 calendar*) and visitors informing them of mosquito and biting midges high-risk periods during the year. These periods are associated with tidal cycle, lunar cycle and season.	GIIP, Guideline 1, Guideline 2	At all time	HSES Manager
7.04	Personnel and visitors will be informed about early symptoms associated with mosquito borne diseases and the reporting mechanism to alert management of any suspected illness.	GIIP, Appendix F	As required	HSES Manager
	PERSONAL PROTECTIVE EQUIPMENT			
7.05	All site personnel and visitors are to wear appropriate PPE, which will be provided by the Subcontractor.	GIIP, Appendix C	Appropriate PPE must be worn at all times.	All site personnel and visitors
	SAFE INDOOR WORKING ENVIRONMENTS			
7.06	All offices, mess rooms, guard houses and other such facilities will be fully sealed and air-conditioned with doors that open outwards to inhibit entry of biting insects.	GIIP	At all times	Subcontractor
7.07	Windows will have midge mesh fitted to them to exclude biting insects	GIIP	At all times	Subcontractor
7.08	Electronic aerosol insect sprays will be installed inside each building.	GIIP	At all times	Subcontractor
	SAFE OUTDOOR WORKING ENVIRONMENTS			
7.09	Outdoor recreation and work areas will be treated with an appropriate residual barrier insecticide on an appropriate schedule, to reduce the number of biting midges and mosquitoes in these areas. Outdoor mosquito lanterns or butane powered insect repelling devices are also effective in the outdoor areas	GIIP	As required	Subcontractor

No.	Mitigation measure	Reference	Timing	Responsibility
	INTRODUCTION OF DISEASES			
7.10	Staff returning from high-risk malaria countries that experience fever will be required to leave Site until medically cleared of carrying malaria.	GIIP	As required	All site personnel
	BITING INSECT HABITAT			
7.11	Existing depressions that pond with tidal or rain water will be filled in or a drainage system established to remove potential habitat.	Environmental Commitments Register Item 16.01	As required	Subcontractor
7.12	The onshore development area will be graded to be free of depressions capable of ponding water for periods greater than three consecutive days in tidal areas, and five days in onshore areas, to prevent mosquito breeding. This includes areas underneath demountable buildings, which can accumulate water if levels are not suitable.	Environmental Commitments Register Item 16.01	As required	Subcontractor
7.13	Any receptacle containing ponded water should be disposed of, stored under cover, have drainage holes drilled or treated with an appropriate insecticide on an appropriate schedule.	GIIP, Guidelines 1, 2, 3 and 5	As required	Subcontractor
7.14	Trenches will be appropriately backfilled to match the existing surface level, to avoid the creation of areas that could pond water and breed mosquitoes.	GIIP, Guidelines 1, 2, 3 and 5	As required	Subcontractor
7.15	Machinery-disturbed areas will be rehabilitated to prevent water ponding.	GIIP, Guidelines 1, 2, 3 and 5	As required	Subcontractor
7.16	Natural drainage will be maintained around roads, and pooling stagnant water will be minimised by installing drains and/or culverts, particularly in intertidal areas such as the causeway between Blaydin Point and Middle Arm Peninsula.	Environmental Commitments Register Item 16.01	As required	Subcontractor
7.17	Surface-water drainage channels throughout the CWA will be designed to minimise the creation of breeding habitats for biting insects.	Environmental Commitments Register Item 16.02	At all times	Subcontractor
7.18	Drains will be kept free of vegetation and other flow obstructions, and regular monitoring will be scheduled to maintain this.	Environmental Commitments Register Item 16.02	As required	Subcontractor

No.	Mitigation measure	Reference	Timing	Responsibility
7.19	Stormwater drains will be designed to facilitate effective shedding of water from the site and discharge to a suitably designed sediment trap before discharging into tidal areas.	GIIP, Guidelines 1, 2, 3 and 5	At all times	Subcontractor
7.20	Temporary sedimentation systems will be designed to minimise their potential to become breeding habitats for biting insects.	Environmental Commitments Register Item 16.04	At all times	Subcontractor
7.21	Culverts will be installed flush with the natural surface at all major and minor flowlines that the road embankment will cross. This is particularly important for tidal areas, where the embankment of even minor flowlines can lead to the creation of tide and rain ponding, and subsequent mosquito breeding.	GIIP, Guidelines 1, 2, 3 and 5	As required	Subcontractor
7.22	Any new extractive material areas created by development will be rendered free draining once they are no longer required.	GIIP, Guidelines 1, 2, 3 and 5	As required	Subcontractor
7.23	Sediment ponds will be designed to completely drain within five days, to prevent potential mosquito breeding.	Environmental Commitments Register Item 16.04	As required	Subcontractor
7.24	Sediment ponds are not recommended in tidal areas, due to the high potential for mosquito breeding.	Environmental Commitments Register Item 16.04	As required	Subcontractor
7.25	Sediment ponds designed to retain water will be constructed with steep sides (1:2 slope or greater) and be relatively deep (>1m).	Environmental Commitments Register Item 16.04, Guideline 4	As required	Subcontractor
7.26	Sediment traps receiving dry-season flows will have a deep permanent pool at the inlet site, or a low flow provision to direct low flows to a daily flushed tidal area.	Environmental Commitments Register Item 16.04	As required	Subcontractor
7.27	Water storage ponds will be designed with steep sites (1:2 slope or greater) and be relatively deep (>1m), to minimise the potential for semi-aquatic vegetation growth and mosquito breeding.	GIIP, Guidelines 1, 2, 3, 4 and 5	As required	Subcontractor
7.28	If practical and if water quality permits, hardy native fish from the Middle Arm area shall be stocked in water storage ponds.	GIIP, Guidelines 4 and 6	As required	Subcontractor
7.29	Effluent treatment facilities will be designed and operated in accordance to Department of Health and Families regulations.	GIIP, Guideline 7	As required	Subcontractor

No.	Mitigation measure	Reference	Timing	Responsibility
	MONITORING AND INSPECTIONS			
7.30	Regular inspections for mosquito larvae in high-risk areas will be conducted, for example in temporary sedimentation basins, and controls will be implemented as required.	Environmental Commitments Register Item 16.03	Weekly	Subcontractor
7.31	Subcontractor's actions on site to be reviewed regularly for adherence to the BIMP.	GIIP	Weekly inspections	HSES Manager
7.32	Inspections of Site personnel and visitor PPE. Appendix C details PPE that should be worn on the site. Records to be maintained of all site inspections.	GIIP, Appendix C	Vigilance must be taken during the peak periods of biting insect activity outlined in Appendix H. Weekly inspections of staff and visitor's PPE.	HSES Manager to undertake weekly site inspections.
7.33	Inspections of demountables/buildings will be carried out to repair insect screens and/or windows/door seals and to assess ponding water around and underneath structures.	GIIP	Monthly inspections of building insect screens and seals, and ponding water around structures	HSES Manager to undertake monthly building inspections. Records to be maintained of all building inspections.
7.34	Biting insect survey on site to be carried out by appropriately trained people.	GIIP	Survey to be undertaken twice in the wet season, once in the dry season, and annually. This will generally occur within five days of rainfall.	HSES Manager
7.35	Circulate results of the annual report containing the biting insect survey results	GIIP	Annually	HSES Manager
7.36	Regular wet-season inspections of artificial receptacles on Site.	GIIP	Once a week during the wet season, and as part of weekly inspections and daily site walk arounds	Subcontractor
7.37	A maintenance program will be established to desilt/clear vegetation from stormwater drains and sediment ponds, and repair any erosion in stormwater drains and discharge sites	GIIP, Guidelines 1, 2, 3 and 5	Annually and as required	Subcontractor

8. TRIGGER, ACTION, RESPONSE PLAN

Where visual inspections and/or monitoring indicate there is a deviation from expected results, the trigger, action, response plan (TARP) described in Table 8.1 will be initiated.

Table 8.1: Biting insects management trigger, action, response plan (TARP)

Responsibility	Normal situation	Level 1	Level 2
	• Personnel and visitors are not affected by biting insects. • No new breeding habitats are created on the site for biting insects. • Existing populations of biting insects are controlled effectively. • No exotic mosquito borne diseases are introduced on the site.	**Trigger:** • Personnel and visitors report nuisance of biting insects. • Ponding water is noted on the Site that cannot be immediately rectified. • Biting insect control management methods not effective.	**Trigger:** • Personnel and visitors become ill from biting insects. • Breeding of insects is noted in ponded water. • Biting insect control management methods not effective.
Site personnel and visitors	• Wear PPE and monitor biting insects. • Advise HSES Manager if recently returned from overseas.	Report to the HSES Manager.	• Report to the HSES Manager. • Follow instructions from HSES Manager to remove ponded water. • Attend the site first aid facility or, if advised by first aid staff, a medical clinic or nearest hospital.
HSES Manager	Wear PPE and monitor biting insects.	• Report as an incident. • Review PPE issue and use. • Remove ponded water from Site. • Review construction activities that may create breeding habitat.	• Report as an incident • Staff who are ill on site to be taken to site first aid facility and, if advised by first aid staff, transported to the closest medical centre or hospital. • Communicate any reported illness caused by biting insects to all staff and identify symptoms that they can self-assess for. • Consult with Department of Health regarding the illness caused by biting insects. • Engage suitably trained person/s to undertake site survey of biting insects. • Undertake biting insects control to actively remove new breeding habitats

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10. APPENDICES

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APPENDIX C: PPE REQUIREMENTS

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1:25,000 (at A3)

0 125 250 500 750 1,000

Meters

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

N

LEGEND

- Approximate location of gas export pipeline
- Plant detail
- Cadastre

CLIENTS | PEOPLE | PERFORMANCE

Kellog, Brown & Root
Biting Insect Management Plan

Job Number	61-27890
Revision	A
Date	19 Mar 2012

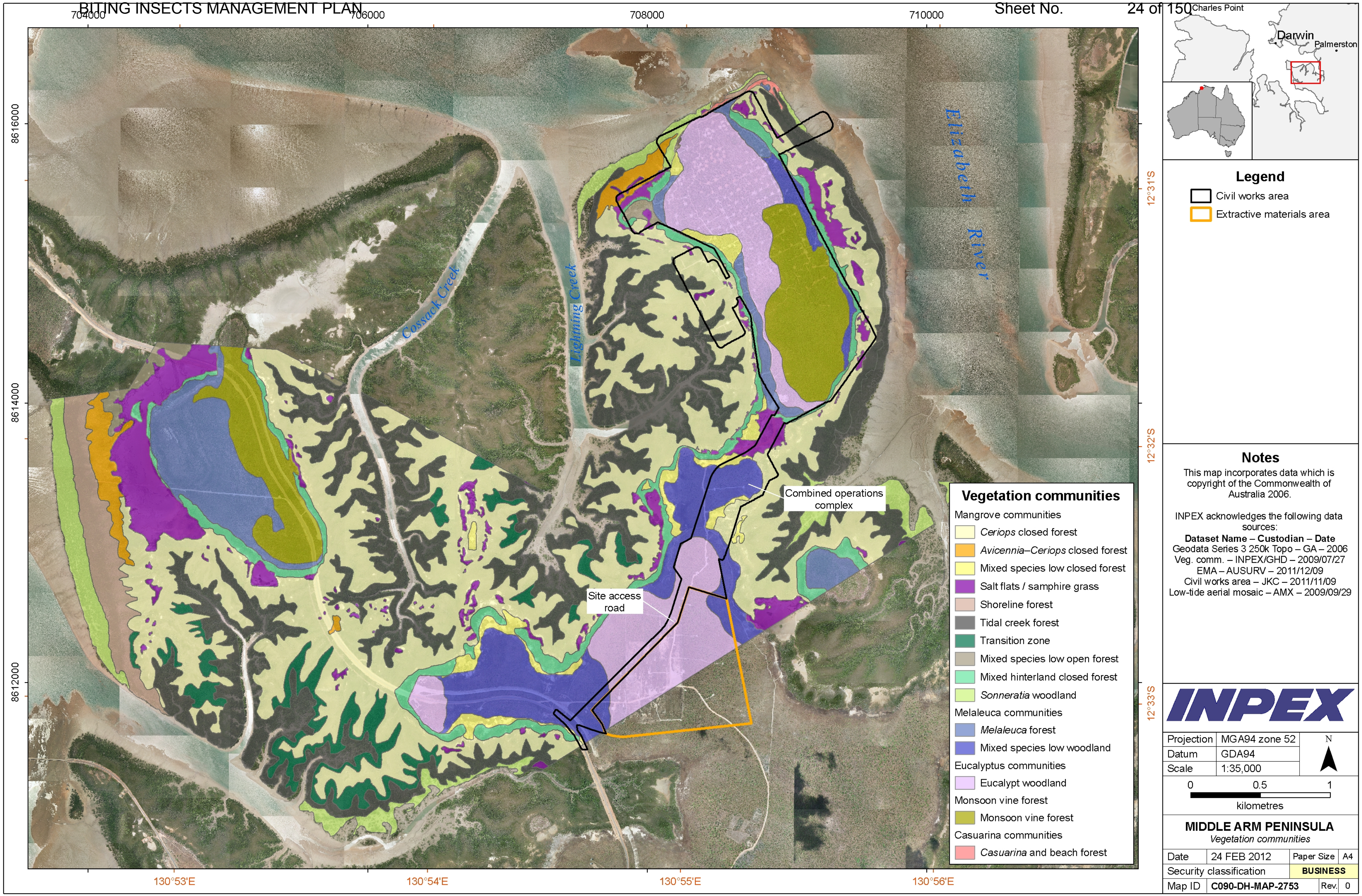
Site location and layout plan

Figure 1

Level 15, 133 Castlereagh Street Sydney NSW 2000 **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com.au **W** www.ghd.com.au

N:\AU\Sydney\GIS\Admin\Projects\61_27890Inpex\Maps\MXD\61_27890_Z001_SiteLocationPlan.mxd

Data Source: Northern Territory Government Department of Landd Cadastre - Aug 2008; Geoscience Australia: 250k Data - Jan 2011. Imagery: Google Earth Pro 2012; Created by: sdwoodger


704000
706000
708000
710000
8616000
8614000
8612000
12°31'S
12°32'S
12°33'S
130°53'E
130°54'E
130°55'E
130°56'E
Cossack Creek
Lightning Creek
Elizabeth River
Combined operations complex
Site access road
Charles Point
Darwin
Palmerston
Legend
Civil works area
Extractive materials area
Notes
This map incorporates data which is copyright of the Commonwealth of Australia 2006.
INPEX acknowledges the following data sources:
Dataset Name – Custodian – Date
Geodata Series 3 250k Topo – GA – 2006
Veg. comm. – INPEX/GHD – 2009/07/27
EMA – AUSURV – 2011/12/09
Civil works area – JKC – 2011/11/09
Low-tide aerial mosaic – AMX – 2009/09/29
Vegetation communities
Mangrove communities
Ceriops closed forest
Avicennia–Ceriops closed forest
Mixed species low closed forest
Salt flats / samphire grass
Shoreline forest
Tidal creek forest
Transition zone
Mixed species low open forest
Mixed hinterland closed forest
Sonneratia woodland
Melaleuca communities
Melaleuca forest
Mixed species low woodland
Eucalyptus communities
Eucalypt woodland
Monsoon vine forest
Monsoon vine forest
Casuarina communities
Casuarina and beach forest
INPEX
Projection MGA94 zone 52
Datum GDA94
Scale 1:35,000
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0 0.5 1
kilometres
MIDDLE ARM PENINSULA
Vegetation communities
Date 24 FEB 2012
Paper Size A4
Security classification BUSINESS
Map ID C090-DH-MAP-2753
Rev. 0

APPENDIX B: DEPARTMENT OF HEALTH GUIDELINES

Northern Territory Government

DEPARTMENT OF **HEALTH AND FAMILIES**

Constructed Wetlands in the Northern Territory

Guidelines to Prevent Mosquito Breeding

Medical Entomology
Centre for Disease Control
NT Department of Health and Families

For further information contact;

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Constructed Wetlands for Water Sensitive Urban Design in the NT Guidelines to Prevent Mosquito Breeding

1.0 Introduction

Constructed Wetlands are designed to manage and treat urban stormwater, and can have various forms such as a simple open lake system, or periodically flooded shallow vegetated basins. Constructed wetlands have the potential to be much more productive breeding sites for mosquitoes compared to natural wetlands due to high nutrient from urban runoff, therefore constructed wetlands in the Northern Territory need to be appropriately designed and managed to prevent mosquito breeding.

Mosquito species that are likely to breed in freshwater constructed wetlands in the Top End of the NT include the major arbovirus vector *Culex annulirostris* (the common banded mosquito), various *Anopheles* species (potential malaria vectors) and the pest mosquitoes *Coquillettidia xanthogaster* (the golden mosquito) and *Mansonia uniformis* (the water lily mosquito). Constructed wetlands in tidal areas could become breeding sites for the northern salt marsh mosquito *Aedes vigilax*, the saltwater *Culex* species *Culex sitiens,* and the saltwater and brackish water *Anopheles* species *Anopheles farauti s.s.* (*An. farauti no.1*) and *Anopheles hilli.*

There may be conflicts between the design for water treatment alone and the design features to prevent mosquito breeding. However it is important to consider the potential for mosquito breeding while designing and constructing wetlands, as both aims can often be accommodated in a compromise design. Constructed water bodies that become mosquito breeding sites will not only affect nearby residents by increasing pest and potential mosquito borne disease transmission, but would incur a significant cost by the managing authority (usually a local council) for associated mosquito survey/control and site rectification.

The purpose of this guideline is to assist developers and land managers in deciding on an appropriate wetland design and management regime, which meets the public health requirements as well as water treatment and other requirements of a constructed wetland.

2.0 Mosquito species and constructed wetlands

<u>The common banded mosquito *Culex annulirostris*</u>

This species breeds in the vegetated margins and pools in permanent and semi-permanent freshwater swamps, creeks and floodways, temporary flooded vegetated ground pools, and in high nutrient water such as effluent discharge and urban stormwater drains. Potential breeding sites in constructed wetlands would include any shallow area containing semi-aquatic or aquatic vegetation, as well as vegetated stormwater drains and channels, areas of high nutrient water pools (ie stormwater pipe outfalls), and flooded vegetated depressions in landscaped areas.

Culex annulirostris is most common within 2km of productive breeding sites, but can disperse up to 15km from major breeding sites. *Culex annulirostris* is the most important vector of arboviruses in the NT. It is recognised as a good vector of Murray Valley encephalitis virus (MVEV), Kunjin virus (KUNV), Ross River virus (RRV) and Barmah Forest virus (BFV). Many other arboviruses have been isolated from this species.

<u>*Anopheles* mosquitoes</u>

Anopheles mosquitoes generally breed in fresh and brackish water swamps or creeks. Potential breeding sites in constructed wetlands include shallow flooded areas containing semi-aquatic vegetation and vegetated stormwater drains and channels. *Anopheles* mosquitoes are usually most common within 1.6km of breeding sites, although some species such as *Anopheles hilli* will fly several kilometres from their breeding sites. Some *Anopheles* mosquitoes such as *An. farauti s.l.* and *An. annulipes s.l.* are regarded as potential vectors of malaria.

The frosty mosquito *Culex gelidus*
This species breeds in freshwater ground pools, swamps and containers. In the NT, this species has often been associated with high organic wastewater ponds in piggeries, abattoirs, dairies and sewage treatment facilities. Potential breeding sites in constructed wetlands would be areas of high nutrient ponding, such as at stormwater pipe discharge sites. This species is a potential vector of Japanese encephalitis virus, MVEV, KUNV, RRV, BFV and other arboviruses.

The brown house mosquito *Culex quinquefasciatus*
This species breeds in septic tanks, polluted stormwater drains, effluent treatment facilities, flooded depressions with high organic content and water filled domestic receptacles. Potential breeding sites in constructed wetlands include high nutrient ponding areas at stormwater pipe outfalls. *Culex quinquefasciatus* is usually most common within 500m of productive breeding sites. *Culex quinquefasciatus* is only a pest mosquito in Australia.

The golden mosquito *Coquillettidia xanthogaster*
This species breeds in swamps, billabongs and creeks with semi-aquatic and aquatic vegetation, particularly semi-aquatic reeds. Potential breeding sites in constructed wetlands would include any shallow flooded areas with semi-aquatic vegetation. *Coquillettidia xanthogaster* is usually most common within 3km of productive breeding sites, and is not regarded as a human disease vector in Australia.

The water lily mosquito *Mansonia uniformis*
This species breeds in similar habitats as *Cq. xanthogaster*, but are more associated with floating vegetation. Potential breeding sites in constructed wetlands would include any shallow flooded areas with semi-aquatic and aquatic vegetation. This species is most common within 2km of breeding sites, and is not regarded as a human disease vector in Australia.

The northern salt marsh mosquito *Aedes vigilax*
Natural breeding sites for *Ae. vigilax* are temporary flooded areas in tidal to brackish swamps, creeks, salt marshes, upper mangrove areas and coastal dune depressions. Constructed wetlands could create breeding sites for this species if they are built in or adjacent to tidal areas. *Aedes vigilax* will breed in depressions within salt influenced wetland systems that periodically dry and then become inundated with tide water, stormwater or rain. This species will also breed in inappropriately landscaped areas surrounding tidal wetlands, and in stormwater drains with tidal influence. *Aedes vigilax* is a major pest mosquito.

Aedes vigilax is most common within 5km of breeding sites, but can fly up to 50km in pest numbers from large breeding sites. *Aedes vigilax* is a vector of RRV and BFV.

The saltwater *Culex* mosquito *Culex sitiens*

Breeding sites for *Cx. sitiens* are the same as for *Ae. vigilax,* although *Cx. sitiens* only breeds when extended saline ponding occurs. *Culex sitiens* is most common within 2km of breeding sites. *Culex sitiens* is regarded as a potential vector of RRV disease, and can be an appreciable pest near productive breeding sites.

3.0 Constructed wetlands and the potential for mosquito breeding

Constructed wetlands can be either relatively simple lake systems, or more complex systems that include shallow areas of flooded semi-aquatic vegetation. It is the shallow vegetated areas of these wetlands that have the greatest potential for mosquito breeding, with their potential rising dramatically as organic loads increase.

Simple freshwater lake systems that are constructed with deep water and relatively steep sides have been built in areas of Darwin and Palmerston, and the lakes themselves have not become significant mosquito breeding sites. The lakes generally have minimal or a thin margin of semi-aquatic reed growth, as well as relatively steep sides and deep water to minimise the extensive colonisation of semi-aquatic vegetation and facilitate fish survival. The potential for mosquito breeding in such lake systems usually only arises if regular maintenance is not conducted to remove silt deposition in inlet areas and excess semi-aquatic reed growth, or when fish populations are eliminated.

Shallow vegetated wetlands provide a favoured habitat for mosquito larvae. The potential for productive mosquito breeding in shallow vegetated wetlands is dependant on the extent and density of semi-aquatic reed growth. Dense shallow mats of fallen reeds in a constructed wetland will give rise to productive mosquito breeding. These dense shallow mats of reeds would provide mosquito habitat both during initial flooding in the early wet season, and during the late wet and early to mid dry season when reeds fall over as water levels recede. Constructed wetlands with extensive shallow areas of semi-aquatic vegetation will require a high degree of maintenance and will be costly to minimise mosquito breeding. Shallow wetlands receiving stormwater flow are also likely to be more productive mosquito breeding sites than comparable natural wetlands, due to the higher nutrient input from stormwater discharge.

Constructed wetlands are also likely to attract animals, which may act as reservoirs of various arboviruses, for example water birds which are hosts for the potentially fatal Murray Valley encephalitis virus, and marcopods (wallabies), which are hosts for Ross River virus. It is therefore important not to have the combination of animal reservoirs and the mosquito vectors of disease, particularly within mosquito flight range of residential areas.

4.0 Risk assessment

There should be a risk assessment conducted to determine the potential for mosquito breeding in constructed wetlands. For example, a shallow constructed wetland within 2km of urban residential areas will pose a high risk of creating pest and arbovirus transmission problems. Mitigation measures to reduce mosquito breeding in such a wetland would be ongoing and costly, and are discussed further in this document. Conversely, a deep, steep sided lake would pose minimal mosquito breeding issues for adjacent residents.

When there are likely to be significant mosquito breeding issues with a particular wetland design, consideration should be given to an alternative design with a lower mosquito breeding potential. An alternative design may reduce the water treatment efficiency of the wetland to some extent, but in most instances there should be a balance between water treatment and public health. Both designs should be compared for positives and negatives from all perspectives (eg Water treatment efficacy, mosquito breeding, public safety, maintenance costs etc), before the final design is chosen. It should be noted that it would be a requirement under the Public Health (General Sanitation, Mosquito Prevention, Rat Exclusion and Prevention) Regulations to prevent mosquito breeding

For each constructed wetland, the time for significant levels of contaminants to settle out of the water would need to be determined, with design and management measures tailored to suit these calculations. For example in Brisbane, it is suggested 72 hours is a preferable period of detention in the macrophyte (vegetation) zone of a constructed wetland to allow removal of contaminants. Therefore there in some situations there may be no need to retain water for periods greater than 3 days in a heavily vegetated shallow area. This would generally avoid mosquito breeding, as mosquito larvae take from 6 to 10 days to complete their aquatic development stages.

5.0 Design considerations

5.1 Siting

Preferably, constructed wetlands should be sited in an open area exposed to wind, to maximise the impact of wave action to disrupt mosquito breeding. To maximise the effect of wind, the water body should be orientated so its long axis is in line with known prevailing wind direction (south-east dry season winds and north-west wet season monsoon winds for Darwin region).

If practical, constructed shallow vegetated wetlands likely to breed mosquitoes should be sited at least 1.6km from any urban residential areas. This would provide a buffer distance to minimise the potential for mosquito breeding to impact on residents. Constructed wetlands in tidal areas should generally be avoided due to the inherent difficulties in constructing and maintaining a wetland in a tidal area. In tidal areas, the inundated areas would generally need to be free draining on a daily basis, or have steep sides around a salt to brackish water lake.

Wetlands should be sited in an area where a relatively simple design can be achieved, as wetlands with simple shapes and a low edge to area ratio have a lower potential to become productive mosquito breeding sites.

5.2 Hydrology

There should be a component of a constructed wetland that permanently retains water throughout the year. For example, a lake should retain water at one end to provide a refuge for fish during the dry season. A constructed wetland that completely dries and then re-floods will lack mosquito predators for a short period after re-flooding, and could become a short term mosquito breeding site. A constructed wetland should however be allowed to recede during the dry season to some extent, to allow maintenance of edges (eg silt and vegetation removal). Lakes or water features in the Northern Territory, with virtually no rain for 5-6 months, need to be designed to retain water during these long periods of no rain, or be periodically topped up with water.

5.3 Aquatic vegetation

The provision of semi-aquatic and aquatic vegetation is generally necessary to remove nutrients from water, and is required to reduce the potential for algal blooms. Relatively sparse or narrow marginal areas of emergent vegetation are unlikely to lead to mosquito breeding, as fish access would not be restricted. Potential problems will arise if regular maintenance is not conducted and semi-aquatic/aquatic vegetation becomes dense and extensive and creates harbourage for mosquito larvae.

Semi-aquatic reeds such as *Typha sp.* and, *Eleocharis sp.* can provide major habitat for mosquito larvae, but are important for removing nutrients from the water. Semi-aquatic reeds can be restricted to small areas of upright vegetation by the use of sub-surface concrete boxes or barriers to prevent rhizome spread. This design will allow predator access and prevent mosquito breeding, while at the same time provide refugia for fish. Semi-aquatic reeds in shallow lakes or basins can quickly spread and create extensive areas of vegetation which will enhance mosquito breeding. If the design of a wetland incorporates flooded semi-aquatic vegetation, there would be a requirement for at least an annual maintenance program to harvest vegetation.

Photo A

Coonjimba billabong in Jabiru, dense *Eleocharis sp.* reeds, shallow margins and very high *Cx. annulirostris* breeding. Ground control with larvicides would be very difficult.

Semi-aquatic reeds should not be allowed to become dense as pictured above (Photo A-Coonjimba Billabong in Jabiru), as this will give rise to high levels of mosquito breeding and ground control with mosquito larvicides in the dense vegetation would be very difficult.

Alternatively, semi-aquatic reeds can be planted along a thin margin at the upper water limit of a steep margin of the wetland. The water level can be seasonally manipulated during the dry season and stranded vegetation can be easily maintained or removed (see Photo B). The spread of rhizomes of semi-aquatic reeds such as *Eleocharis* or *Typha* could be limited by constructing a narrow concrete retaining wall along the wetland margin. Generally if steep sides and deep water (at least 1.5m deep) are provided, the spread of reeds would be restricted to the shallow upper margin.

Photo B

Gardens Golf Course Lake, small stand of *Typha spp.* reeds, stranded during dry season. Allows easy maintenance.

The same principles also apply to other semi-aquatic plants such as sedges, with sparse vegetation unlikely to lead to mosquito breeding. Aquatic plants such as water lilies are recommended for smaller shallow wetlands, as they provide shade for fish.

Annual maintenance is generally required to remove dead semi-aquatic vegetation, either by physical removal or by burning. Semi-aquatic vegetation that has begun to spread beyond their desired location should also be physically removed, or controlled by herbicide.

5.4 Water quality

Water quality in constructed lakes should be maximised by utilising some form of mechanical aeration, which can be achieved by using fountains or waterfall features. Well circulated, oxygenated water bodies are less likely to produce algal blooms and are less likely to produce fish death. The use of fountains in smaller water bodies is also useful to disturb the water surface and disrupt mosquito breeding. Smaller fountains located near the margins of a lake could be utilised to create disturbance to the shallow edges where mosquito breeding usually occurs. Mechanical aeration would be particularly important during the late dry season, when temperatures are high and oxygen levels are likely to be low.

Photo C

Gardens Golf Course Lake, mechanical aeration, steep vegetation free margin.

5.5 Lake systems

Lake systems should be simple in design, and generally should have steep sides (at least 1V:2H) and relatively deep (1.5 to 2m) wet season stabilised water level. There can be areas of semi-aquatic vegetation and aquatic vegetation provided to treat water, although vegetation should be limited to relatively small stands that are regularly maintained by harvesting/physical removal, or extensive vegetated areas that are only flooded for 2-4 days. Stormwater should flow into the deepest section of any lake.

There may be issues with public safety when providing steep edges. In those instances when shallow edges are required, a concrete vertical lip (200-300mm) should be provided at the lake margin to maximise the effect of wave action. The shallow area of the lake adjacent to the vertical lip would need to be maintained free of semi-aquatic vegetation. The concrete lip can be aesthetically acceptable if constructed appropriately (see Photo D).

Photo D

George Brown Darwin Botanical Gardens water feature. Shallow water, concrete vertical edges.

5.6 Constructed wetlands with shallow vegetation treatment zones

These types of wetlands include a shallow vegetated component (marcophyte zone) to treat stormwater, and a deep lake or deep pools to provide refuge for fish. These wetlands require careful design considerations, as the shallow vegetation treatment zones could become productive mosquito breeding sites.

Dry season flows need to be directed into the deepest section of the permanent lake or deep pool within the wetland system. This deeper section is where fish and other aquatic predators are likely to be present, and where the potential for semi-aquatic vegetation growth is minimal. Silt traps would be required where stormwater drains lead into the constructed wetland.

<u>5.6.1 Wetlands with detention vegetation zones</u>

Wetlands that have vegetated components which detains water for a period of 48-72 hours, with water then draining into a lake or deep pools are unlikely to become significant mosquito breeding sites. Detention in an extensively vegetated area for 48-72 hours would not breed mosquitoes, as this period of time would not allow full larval development. This detention period should still provide removal of fine sediment and soluble pollutants. This type of design is appropriate for any proposed shallow constructed wetlands within 2km of residential areas in the Northern Territory.

There should be periodic inspections during the wet season to ensure the detention zone does not pond water for greater than 3-4 days. Any shallow depressions that pond water for greater than 4 days should be earmarked and rectified during the following dry season. Annual maintenance would be required to remove dead vegetation, and harvest or remove vegetation that has become dense or spread to other areas of the wetland.

5.6.2 Wetlands with retention vegetation zones

This design includes a shallow vegetation area that ponds water for extended periods, with a lake/deep pools provided for fish refuge during the dry season. Wetlands with shallow heavily vegetated treatment zones, which retain water for the duration of the wet season and into the early to mid dry season will breed mosquitoes. This type of design should typically be avoided unless detailed studies indicate these systems can be designed to remove sediment, pollutants and nutrients and not breed mosquitoes.

Wetlands with vegetated retention zones will require a comprehensive monitoring and maintenance program to minimise mosquito breeding. This includes weekly adult mosquito monitoring around the wetlands, as well as monitoring in nearby areas, to establish if mosquito populations are originating from the constructed wetland. Weekly larval surveys during the wet season to mid dry season would also be required to locate any actual mosquito breeding within the shallow vegetated component of the wetlands. Annual maintenance such as vegetation removal and silt removal would also be required, as well as regular visual inspections to ensure there are suitable fish populations. This monitoring and maintenance program would need to be conducted by the landholder or responsible authority.

Wetlands designed with vegetated retention zones need to have an emergency drainage provision provided, which will allow the shallow component to be drained over a period of a few days. The emergency drainage would be utilised if significant mosquito breeding is located and mosquito larval control operations are unlikely to be effective (ie if ground control is impossible due to dense vegetation, lack of required personnel). This could be achieved by installing a pipe system or contour system in the lowest point of the shallow area, to direct water to the lower lake/deep pool component. A gate in the bund wall separating the shallow vegetated retention zone from the deep lake, with a provision to close and open when needed, could an option for emergency drainage (ie similar to a lock system for a marina). The shallow area would require annual maintenance to ensure there are no isolated depressions that could pond water for extended periods after it has been drained, and to ensure the emergency drainage system is in working order.

5.7 Constructed wetlands in or adjacent to tidal areas

Constructed wetlands in or adjacent tidal areas have the great capacity to breed mosquitoes. This is due to saline mosquito species such as *Aedes vigilax* and *Culex sitiens* being able to breed in high numbers in vegetation free shallow water areas.

It is very difficult to achieve a depression free surface in tidal areas, particularly in shallow extreme upper tidal areas that are infrequently inundated by tides. These areas tend to have minimal slope, and subtle changes in vegetation growth or silt deposition can create shallow depressions conducive to mosquito breeding. A relatively deep (1-2m), steep sided tidally influenced lake with a tidal water retaining barrier is one design that can be recommended for water retention in tidally affected areas. This design has worked very well at Vesteys Beach in Darwin (see Photo E).

Photo E

Vesteys Lake, steep margins, fish, no semi-aquatic vegetation. Tidally influenced. No mosquito breeding.

5.8 Silt traps

Silt traps are required to capture coarse sediments and minimise silt deposition in wetlands. Silt traps are best designed with a hard floor (eg concrete) and steep sides (preferably concrete), with a suitable access ramp for machinery. Silt traps need to be positioned at stormwater discharge points. Due to the likelihood of dry season flows, there should be provisions provided in all silt traps to dam or divert dry season flows to a deep section of the receiving lake or water body, so annual maintenance can be performed. Silt should be removed from the silt trap on at least an annual basis by the responsible authority. Silt traps with vegetation should be designed to completely drain within 3-4 days, alternatively silt traps should incorporate a design that does not include vegetation.

Photo F

Stormwater outfall at Palmerston.Silt trap. Dense *Typha spp.* growth, algal bloom, likely mosquito breeding. Lack of maintenance.

5.9 Stormwater drains

All urban stormwater drains leading into constructed wetlands must be the standard underground stormwater pipe or concrete invert open drain, to prevent the creation of mosquito breeding within stormwater drains. This includes ensuring all stormwater road side entry pits, grate inlet pits and letterbox pits are free draining, and ensuring grassed swale drains have concrete low flow inverts when there is the likelihood of low flows during the dry season. Dry season low flows must be directed into the deepest section of any water body.

5.10 Landscaping

Appropriate landscaping of areas surrounding constructed wetlands is vital, as poorly draining surrounds has caused many mosquito problems around constructed wetlands in Darwin. Appropriate grades would need to be applied to all landscaped areas surrounding wetlands, to allow the sheetflow of water into the wetland. More extensive and wider surrounds may need swale drains with concrete inverts leading into wetlands.

Photo G

Poor landscaping in a Darwin park adjacent to lake. Wet season mosquito breeding affecting nearby residents.

Photo H

Concrete invert open drain. Surrounding areas graded to flow into drain. Dry season flows directed to lake.

5.11 End point of discharged water

There must be no dry season discharge of water from a constructed wetland, unless the discharge is directed to a lake of the sea via an appropriate drain that will not give rise to mosquito breeding. Constructed wetlands without an appropriate end point for dry season discharge water should have sufficient capacity to retain water, or be appropriately managed to prevent the dry season discharge of water.

Wet season overflows from constructed wetlands should be directed to the 4.0m AHD level for those developments adjacent to tidal areas, or to a defined river or free draining creekline for those developments away from tidal areas. The overflow should be suitably designed and maintained such that it will not have the capacity to breed mosquitoes.

6.0 Maintenance

Before the construction of any lake system or water sensitive urban design strategy, the relevant authority that will assume control of the water feature would need to be determined. The relevant authority would then need to develop a mosquito management plan in consultation with the developer and Medical Entomology of DHCS, to ensure the water feature is managed appropriately by the relevant authority to avoid any appreciable mosquito breeding.

Management measures would involve annual maintenance such as; removing silt from sediment traps; removing silt from lakes/deep pools; harvesting semi-aquatic vegetation from shallow treatment zones and lakes/deep pools; burning/removal of dead vegetation from the shallow treatment zone; rectification of surface depressions in shallow treatment zones; desilting and removal of vegetation from open drains and filling and grading landscaped areas to remove surface depressions.

7.0 Mosquito monitoring

Any wetland with a retention vegetation zone should have a mosquito monitoring program established for the life of the wetland. Mosquito monitoring should involve adult trapping once a week at the wetland, and at a site at least 500m away from the wetland, to allow an evaluation of the origin of mosquito numbers at the wetland site. Recommended adult mosquito traps would be carbon dioxide baited Encephalitis Virus Surveillance (EVS) traps, as they are the same traps used in most other parts of the NT. Indicator mosquito species in the adult mosquito traps would be the species with a low effective flight range (eg *Anopheles* species, *Mansonia uniformis*, and *Culex quinquefasciatus*, and also *Culex annulirostris*).

Larval mosquito surveys are required on a weekly basis during the wet season and early to mid dry season for any shallow flooded vegetated retention areas. Larval surveys involve surveying in shallow areas with dense vegetation growth with a 300ml ladle. A larval density* of 1 larvae per 2 ladle dips or higher is likely to indicate a potential mosquito problem for adjacent residents. If the larvae are identified as important pest or disease mosquitoes and if the breeding area is large, some form of mosquito control would be required, such as draining the retention area or using a suitable mosquito larvicide. An evaluation of the cause of the breeding should then be conducted, with rectification measures implemented to prevent further breeding.

*Please note that these larval densities are only suggested threshold levels. If complaints from residents or adult trapping reveals significant pest mosquito problems despite larval counts being lower than the threshold, then the threshold will need to be re-evaluated.

8.0 Mosquito control

Mosquito control capabilities is vital for constructed wetlands. In general biological control agents such as fish are the most efficient method of controlling mosquito breeding, providing fish have sufficient access to all areas of the wetland. Fish species to be used in constructed wetlands must be sourced from local waterways, to prevent the introduction of exotic fish species. In general the rainbow fish (*Melanotaenia spp.*) are very hardy and should be stocked in all wetlands. Other fish species that can be stocked in constructed wetlands include blue eyes (*Pseudomugil spp*), glass perchlets (*Ambassis spp.*), grunters (*Leiopotherapon spp.*) and gudgeons *(Mogurnda spp.*).

Along with fish, annual vegetation maintenance should keep mosquito breeding to minimal levels. However, there may be periods of high mosquito breeding that would require temporary insecticide control until the cause of the breeding is rectified. The use of insecticides can quickly control mosquito breeding, but is not recommended as a long term strategy due to potential issues with insecticide resistance, long term cost of maintaining a mosquito control program and the possibility of the insecticide applications not being able to target all areas of breeding. Mosquito breeding can be controlled with the specific and ecological friendly insecticides *Bacillus thuringiensis* var. *israelensis, Bacillus sphaericus* or methoprene until a solution to prevent/minimise mosquito breeding is implemented.

9.0 Summary

Constructed wetlands can potentially create habitat for mosquito larvae. There are however specific design and management options that can be used to minimise or prevent mosquito breeding. The general wetland design and management requirements by the responsible authority are listed in order of priority. This information is also displayed in Appendix 1.

1. Wetlands constructed as a deep (1-2m wet season stabilised water level), steep sided (at least 45^0 angle or 1V:2H) lake, with stormwater discharged to the deepest point via a silt trap. Management requirements include annual removal of silt and semi-aquatic vegetation.

2. Wetlands with detention vegetation treatment zones. The wetland should include a deep, steep sided lake/deep pools with dry season flows directed to the deepest point, while the vegetation treatment zone should only pond water for a period of 3-4 days. Management requirements include annual inspections of the lake margins and removal of silt and marginal vegetation, and annual inspections of the vegetation treatment zone, with maintenance conducted to remove silt, isolated depressions and dead or lodged vegetation.

3. Wetlands with retention vegetation treatment zone. There should be a main lake/deep pools provided with deep and steep sides. Dry season water should discharge into the deepest point of the lake. There should be an emergency provision provided in the retention zone to allow rapid drainage into a lake/deep pool if mosquito breeding becomes a problem. A weekly adult mosquito monitoring and larval mosquito monitoring program is required to ensure mosquito populations do not reach pest or public health risk levels. Annual maintenance is required to remove vegetation from the retention zone, remove silt and rectify isolated depressions in the retention zone, and remove semi-aquatic vegetation and silt from the main lake.

In conclusion, constructed wetlands have the potential to create new mosquito breeding sites that could impact on the public health of nearby residents. Design aspects and management options should be carefully considered before construction commences. Each wetland will require a case by case analysis using these guidelines, which have been developed to assist developers and land managers in choosing a suitable design.

Prepared by Allan Warchot and Peter Whelan

Medical Entomology
May 2008

10.0 References and further reading

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Appendix 1

Constructed wetlands

Design options

- Lake
- Wetland with shallow detention zone
- Wetland with shallow retention zone

Mosquito breeding potential

- Low
- Low-moderate
- High

Design requirements

Lake (Low)

•Deep water (1-2m wet season stabilised water level), steep sides (1V:2H)

•No dry season discharge from lake

•Wet season overflow to mangrove margin, river or creek.

•Isolated areas of semi-aquatic vegetation along lake margin

•Silt trap at stormwater discharge into constructed wetland

•Mechanical aeration of lake

•Suitable landscaping

Wetland with shallow detention zone (Low-moderate)

•Deep (1-2m wet season stabilised water level), steep sided (1V:2H) lake or deep pools

•Mechanical aeration of lake/deep pools

•Shallow detention zone should only detain water for 3-4 days.

•Dry season flows to lake/deep pools.

•Silt trap at stormwater discharge into constructed wetland

•No dry season discharge from system

•Wet season overflow to mangrove margin, river or creek

•Isolated areas of semi-aquatic vegetation along lake margin

•Suitable landscaping

•Not recommended for tidal areas

Wetland with shallow retention zone (High)

•Deep (1-2m wet season stabilised water level), steep sided (1V:2H) lake or deep pools.

•Mechanical aeration of lake/deep pools

•Shallow retention zone with isolated areas of semi-aquatic vegetation

•Emergency drainage structure in retention zone

•Dry season flows to lake/deep pools.

•Silt trap at stormwater discharge into constructed wetland

•No dry season discharge from system

•Wet season overflow to mangrove margin, river or creek

•Suitable landscaping

•Not recommended for tidal areas

Maintenance and monitoring requirements

Lake (Low)

• Annual inspections of silt trap and lake margins. Remove silt and semi-aquatic vegetation

•Annual inspections of overflow drain. Remove silt and semi-aquatic vegetation, repair erosion.

•Stock with local native fish

Wetland with shallow detention zone (Low-moderate)

•Annual inspections of silt trap and lake/deep pool margins. Remove silt and semi-aquatic vegetation

•Periodically inspect detention zone during wet season to ensure complete drainage within 3-4 days.

•Annual inspections of detention zone. Remove silt and depressions, harvest semi-aquatic vegetation.

•Annual inspections of overflow drain. Remove silt and semi-aquatic vegetation, repair erosion.

•Stock with local native fish

Wetland with shallow retention zone (High)

•Annual inspections of silt trap and lake/deep pool margins. Remove silt and semi-aquatic vegetation.

•Annual inspections of overflow drain. Remove silt and semi-aquatic vegetation, repair erosion.

•Annual inspections of retention zone. Harvest semi-aquatic vegetation, remove depressions

•Annual inspections of emergency drainage structure. Maintain in working order

•Weekly adult mosquito monitoring at wetland and at a site over 500m away (by landholder or responsible authority)

•Weekly larval mosquito surveys during wet season to mid dry season in shallow retention zone (by landholder or responsible authority). Mosquito control as necessary.

•Stock with local native fish

Northern Territory Government

DEPARTMENT OF **HEALTH**

Guidelines for Preventing Mosquito Breeding Associated with Construction Practice near Tidal Areas in the NT

Medical Entomology
Centre for Disease Control
Northern Territory Department of Health
Darwin NT

June 1988
Updated February 2011

Contents

Guidelines for Preventing Mosquito Breeding Associated with Construction Practice near Tidal Areas in the NT

1.0 Introduction

There have been many instances of construction in or near tidal areas in the Top End of the Northern Territory that have resulted in ecological disturbance and subsequent mosquito breeding. Many of the deleterious disturbances have been the result of little or no recognition of the ecological consequences of construction practices, either during the construction period or on completion of the project. Much of the deleterious ecological disturbance can be avoided or minimized by consultation between engineers or construction authorities and people with ecological expertise.

One of the most significant impacts of construction in or adjacent to tidal areas is the creation of new sources of pest and potential disease causing mosquitoes. The creation of new mosquito breeding sites can have an enormous bearing of the quality of life, land values, costly rehabilitation measures, mosquito control programs and most importantly, the health and legal implications involved in an outbreak of mosquito-borne disease.

2.0 Aim of Guidelines

These guidelines are intended as a checklist for planners, engineers or any supervisory officers, responsible for the planning or implementation of any construction activity near tidal areas, in order to prevent the creation of mosquito breeding sites.

They are also intended to be used as a checklist in the preparation and evaluation of any Preliminary Environment Report or Environmental Impact Statement. In this way it is hoped that the 'potential for additional mosquito breeding areas will be recognized and avoided in the planning or implementation phases of any construction project, so that later costly or environmentally disruptive rectification works will not be necessary.

These guidelines should be used by the relevant construction or advisory authorities. Any doubts on the potential for creating mosquito breeding sites on any project can be referred to the Senior Medical Entomologist of the Northern Territory Department of Health.

3.0 Mosquitoes of Public Health Importance

Background information on mosquito biology, breeding sites, potential diseases and specific control measures can be found in "Mosquitoes of Public Health Importance in the Northern Territory and their Control" (1984), available from the Department of Health. Of the 100 species of mosquitoes in the Northern Territory, fifteen (15) species can breed in the intertidal zone, at least at certain sites and some times of the year. These include the principal vectors of malaria, Ross River virus, Murray Valley encephalitis, and a number of other arbovirus diseases, as well as some species regarded as the most important human pest species.

Salt Water Mosquitoes	**Common Name**	**Importance**
Anopheles hilli	Saltwater Anopheles	Potential malaria vector
Culex sitiens	Saltwater Culex	Localized pest species
Aedes alternans	Scotch Grey	Negligible pest
Aedes vigilax	Northern Saltmarsh mosquito	Major pest and disease vector
Brackish Water Mosquitoes	**Common Name**	**Importance**
Anopheles farauti s.l.	Australian malaria mosquito	Major malaria vector
Verrallina funerea	Brackish forest mosquito	Important mosquito local pest
Brackish to fresh water mosquitoes	**Common Name**	**Importance**
Culex annulirostris	Common banded mosquito	Major pest and disease vector
Anopheles bancroftii	Black malaria mosquito	Potential malaria vector and pest
Anopheles annulipes s.l.	Australian Anopheles mosquito	Potential malaria vector
Anopheles meraukensis	Freshwater reed Anopheles	Pest species
Coquillettidia xanthogaster	The golden mosquito	Important pest species
Mansonia uniformis	Aquatic plant mosquito	important pest species

3.1 Malaria

Malaria was only eradicated in the Northern Territory in 1962 and many communities in the Northern Territory remain vulnerable to malaria reintroduction, particularly those communities which are near large sources of *Anopheles* mosquitoes. Each year up to thirty malaria cases are imported into the Top End from overseas, and the Department of Health investigates and follows up each case. With increasing numbers of people living in remote areas with large mosquito populations, or adjacent to mosquito sources in expanding urban areas, the potential for malaria reintroduction is increasing. In particular circumstances, adult mosquito control measures near urban areas may be necessary, but problems due to lack of access, thick vegetation, or the proximity to urban areas, may prevent or reduce the effectiveness of these measures. We need to reduce these potential problems by reducing the mosquito breeding areas adjacent to urban areas.

3.2 Arbovirus Diseases

Each year there can be from 100 to 400 cases of Ross River virus disease reported in the Top End. These are laboratory confirmed cases only, and it is thought the number of clinical cases is very much higher. Many of these cases have likely sites of transmission in towns adjacent to particularly productive mosquito breeding areas. With a tropical lifestyle and an expanding population, it is becoming increasingly necessary to provide mosquito free urban areas.

4.0 Mosquito Breeding Sites in Coastal Areas

The breeding sites of the various mosquito species are illustrated in Fig. 1. The area of greatest potential for mosquito breeding lies within the upper high tide zone (from 7. 3m to 8.0m A. C. D. in the Darwin area). In addition, the region up to 1.0m above maximum high tide can be a significant mosquito breeding area, as this region is usually the recipient of seepage, rain water and silt inputs being transported to the tidal areas. These regions have the capacity for both natural and human disturbances that can lead to significant increase in mosquito breeding.

The intertidal areas of wide expanse, thick vegetation, very flat topography, and fresh water inflows are the largest sources of mosquitoes. These large tidally influenced marshes (e. g. Leanyer Swamp) have variable salinity water which is shallow and thickly vegetated and is the ideal breeding habitat for most of the important mosquito species. Natural tidal marshes such as these can be extended and made much more productive sources of mosquitoes with increased silt, nutrient and water inputs from urban and industrial developments.

Any construction practice that increases the flow of water, silt or nutrients, or interrupts or prolongs the drainage through these areas, has the capacity to increase the amount of mosquito breeding. This is particularly so in the upper high tide area, where the often naturally self draining margin of the mangroves can be easily disturbed and result in the pooling of tidal water. Such sites can be quite small, but extremely productive in the numbers of salt water mosquitoes such as *Aedes vigilax.*

At present the Northern Territory Government and the Darwin City Council have a continuing mosquito engineering control program around urban Darwin, to rectify past poor construction practices. The annual expenditure is in the region of $300 000.

This annual expenditure included funds for the construction of drains and a proportion to permanently upgrade those drains that repeatedly breed mosquitoes. The program will need to be relatively long term to rectify all the past poor construction practices and achieve a relatively mosquito free city, particularly when poor construction practices are still proceeding. In contrast, planners of the new satellite city of Palmerston considered the potential for mosquito breeding at an early stage. The siting of the urban areas, the rectification of existing mosquito breeding areas, the design and endpoints of the storm drains, and reclamation works in Palmerston have resulted in a relatively mosquito free urban environment. This consideration in the planning stage has been a very cost effective solution.

5.0 Construction practices that can result in mosquito breeding

Mosquito problems created by previous construction practices are detailed in Appendix I.

5.1 Sand Extraction

Deposits are usually found in low lying areas along swamps and creeks or close to the tidal areas. Any sand extraction activity has the capacity to produce wet season flooded depressions or waterfilled borrow pits that quickly become colonized with aquatic or semi aquatic vegetation and result in new mosquito breeding areas. These areas can be extremely productive, particularly if the borrow pits have some tidal influence, as this can eliminate may of the freshwater aquatic predators of mosquito larvae. Those sand extraction areas that are deep enough to penetrate the water table can become perennial mosquito sources.

5.2 Storm Water Drainage

Storm water drain construction can produce mosquito breeding sites by poor placement of berm material and the disruption of normal drainage patterns. If the disruption of drainage is in tidal areas it can create extreme mosquito problems.

Open unlined storm drains with relatively permanent dry season flows can be mosquito sources, particularly if the drain receives organic nutrients from urban run off or industrial processes.

If storm drains with considerable dry season flows are directed into low lying areas, particularly in the upper high tide zone, considerable ecological disturbance can result in dramatic increases in mosquito breeding.

5.3 Road embankments and Access Roads

Road embankments and access roads can result in impoundments or impedance of normal drainage patterns and frequently cause at least wet season pooling. Detailed topographic and vegetation surveys are usually necessary to avoid such disturbances.

5.4 Water Retention in Tidal Areas

The construction of water retention features can result in altered vegetation patterns that can give rise to mosquito breeding. Water retention in standing mangrove areas which results in the death of mangroves can create extremely productive sources of the salt marsh mosquito, the salt water *Anopheles* or the salt water *Culex* mosquito. Inundation of disturbed tidal areas by high tides, rain or waste water can result in emergence of large numbers of mosquitoes. Meticulous planning or water retention features is necessary to avoid creating mosquito breeding sites. Aspects that need particular attention include the final water level, the quality and salinity range of the impounded water, the maintenance drainage capability, the potential vegetation growth in or at the edges, and the inflow of silt.

5.5 Land Fill Operations

Land fill in tidal areas can disrupt previously self draining areas and result in pooling of water. This is particularly so if the land fill has silt laden run off and is sited in a complex drainage pattern. Pollution and vegetation growth at the edge of land fill operation in water can eliminate or restrict the normal activity of aquatic predators and give rise to mosquito problems.

5.6 Sewage Pond Construction

The siting of sewage ponds is one of the most important factors in reducing potential mosquito problems. Correct siting of ponds is vital near coastal areas, as disruption of mangrove drainage patterns cancreate new breeding sites, and access and service embankments can impound water to create additional mosquito breeding sites.

Maintenance needs, such as emptying certain ponds, can cause extreme mosquito problems unless the pond contents can be channelled or discharged directly to a daily flushed tidal area. These maintenance practices need to be considered in the planning stages and should be important factors in the choice of a site.

The type of ponds, particularly the depth, size and bank material can have a large bearing on whether the ponds are mosquito sources.

5.7 Urban Subdivisions

When urban subdivisions are poorly sited near pre-existing mosquito sources, or sites that have the potential to become sources, it is very likely that there will be public pressure at a later date to rectify the mosquito breeding. Sometimes the rectification works can be extremely expensive, or severely disrupt natural features such as swamplands. It is logical to avoid such costly rectification works or possible destruction of animal and fish habitats, by the correct siting of urban subdivisions.

The Department of Health has recommended avoiding large and uncontrolled tidally influenced mosquito breeding areas by having a 1.6km buffer between the breeding areas and the proposed urban development.

This buffer is very relevant for those large salt marsh swamps with fresh water input such as Leanyer Swamp and Howard Swamp, but it is of little relevance for very small areas that are not very productive, or that can be easily controlled or rectified.

If urban areas are built near these large and at present uncontrollable mosquito breeding areas, then attempts will be necessary to control the breeding. Examples of types of physical control methods recommended include:

1. Swamp drainage by a system of channels
2. Tidal bunds, tide gates and an internal drainage system
3. Steep sided relatively deep (greater than 2.0m) excavated fresh water lake
4. Salt water lake.

Insecticide control for extended periods should not be contemplated as a control measure around urban areas, as there can be no certainty that such methods will be effective in the longer term.

6.0 Guidelines for Construction Practice

Borrow Pits and Excavations

1. No borrow pits, extractive industry or excavation should be conducted within the tidal zone, unless provision is made to prevent ecological changes.

2. Borrow pits or extractive operations should not excavate to a base level below maximum high tide level.

3. Cover material and vegetation should not be pushed into the tidal zone. There should be no impedance of overland flow into the tidal zone.

4. All borrowing or extractive areas should be rehabilitated immediately upon completion of the operation such that all operational areas are completely self draining.

5. Vehicle disturbed areas such as wheel ruts and compacted soil areas should be rectified as soon as practical to prevent water ponding.

6.2 Storm Water Drainage

1. Drains should be constructed to discharge direct into regularly flushed tidal areas, such as tidal creeks or a formalized channel dug back from a tidal creek. In Darwin 100 year flood drains should be constructed to the 3.7 AHD level and low flow drains to the 3. 5 AHD (or below this level if silt accumulation is a potential problem).

2. Drains through tidal areas need to be of dimensions that will not result in silt accumulation in or near the drain. Low flow drains should be installed wherever there is the possibility of longer term dry season flows. Such drains can be either impervious above ground inverts or sub soil pipes.

3. Low flow drains should be installed wherever there is the possibility of longer term dry season flows. Such drains can be either impervious above ground inverts or sub soil pipes.

4. Access along all drains is necessary for regular maintenance.

5. Drains through tidal areas should follow the course of existing creeks or flow lines wherever possible.

6. Drains for mosquito control purposes should be only of dimensions that are necessary to drain over a period of 2 to 3 days for tidal areas, and 4 to 5 days for fresh water, unless there are other considerations requiring larger drains.

7. Silt traps should be installed in drains that are likely to carry considerale silt loads. This is particularly necessary in large urban drains during subdivision construction.

6.3 Embankments and Access Roads

1. No embankments should be constructed across tidal areas unless provision is made for sufficient tidal exchange to prevent any considerable ecological change. If upstream impoundments of tidal water are completely flushed at least once in 7 days, there is usually no significant mosquito breeding in the impounded tidal water.

2. Embankments should have provision for complete drainage of upland areas at least over a period of less than five days after flooding. This particularly applies to areas near the tidal limit, which would only be reached by tides once in 10 to 14 days.

3. Embankments for land reclamation purposes should have an internal drainage system with tide valves at the embankment. If upland flows are diverted around the reclamation area, the diverted flow should be discharged direct to the major tidal drainage line immediately seaward of the embankment.

4. Vehicle access along the upper high tide zone should be restricted as much as possible, to prevent the creation of vechile disturbed areas that could pond tide and rainwater.

6.4 Water Retention in Tidal Areas

1. An ecological and hydrological study should be undertaken before any water retention feature is constructed in a tidal area.

2. Those aspects that are considered critical to the success of an aquatic feature include:

   the levels and seasonal fluctuations in salinity; the possible aquatic and semi aquatic vegetation changes likely to occur; the effect on aquatic animal life; the number of days under tidal influence; the depth of the retained water; inputs of organic and other pollutants into the system; the' source., amounts. and quality of possible top up water; the provisions for periodic maintenance; possible ecological effects seaward of the retention.

3. If the tidal regime in the water feature is significantly reduced or eliminated, all existing mangroves in the retention area should be removed.

4. Silt traps should be constructed at all significant silt entry points.

5. Regular vegetation maintenance or control programs will be necessary. The provision of 1:1 side slope or impervious margins should be considered to reduce maintenance needs.

6. There should not be any small cut off areas at any height level of the water.

6.5 Land Fill in Tidal Areas

1. Land fill operations should not impede any established drainage patterns, either by the land fill operations, or possible erosion from the fill area.

2. There should be drainage provisions all around the base of sanitary land fill operations, and these drains should discharge direct to a daily flushed tidal system.

6.6 Sewage Pond Construction

1. Sewage ponds should be sited preferably on bare mud flat areas or land backed in preference to existing mangrove areas to minimize ecological disturbances.

2. The siting of ponds should not result in any impedance to pre-existing drainage lines,either landward or within the tidal area.

3. Pond drainage during maintenance should be direct to daily flushed tidal areas.

6.7 Urban Subdivision

1. A mosquito buffer zone for the exclusion of urban residential development is recommended within 1.6km of large and uncontrolled tidally influenced mosquito breeding areas, unless specific biting insect studies indicate this can be modified.

2. No urban residential developments are recommended within 1km of extensive areas of mangroves, unless biting midges are not likely to be a significant problem.

3. Any subdivisions bordering tidal areas should incorporate a buffer distance between the high tide level and property boundaries, so that access is possible for management purposes, and to prevent the creation of new mosquito breeding sites.

7.0 Consultation

Medical Entomology of the Northern Territory Department of Health is available for advice on what may constitute a potentially significant mosquito breeding site. In some instances where detailed entomological investigations are necessary, 12 months entomological monitoring may be required before the detailed planning stage. For significant entomological investigations, it may be necessary for the developer to engage an entomological consultant.

Consultation for any project within a tidally affected area may be required with the Northern Territory Department of Lands and Planning, or the Environmental Assessments section of the Northern Territory Department of Natural Resources, Environment, the Arts and Sports.

Peter Whelan Senior Medical Entomologist , NT Deartment of Heath 2011

Northern Territory Government

DEPARTMENT OF HEALTH

Appendix 1

Northern Territory Government

DEPARTMENT OF **HEALTH**

Previous mosquito problems in the Top End of the NT created by Construction Practice

Medical Entomology
Centre for Disease Control
Department of Health and Families
Darwin NT
1987

Previous mosquito problems in the Top End of the NT created by Construction Practice

1.0 Sand Extraction

Bynoe Harbour

Sand extraction on a beach area in Bynoe Harbour resulted in an area of mangroves being bulldozed and pushed further into a tidal area to form a retarding barrier. Fresh water inflow into the retarding basin resulted in an area of impounded water varying from brackish to salt, depending on tidal movement. The large quantities of dead and dying mangroves contributed to high levels of organic matter and flotsam. The area proceeded to breed very large numbers of salt marsh mosquitoes and a range of other pest and potential disease carrying mosquitoes.

Casuarina Beach

Sand mining at Casuarina Beach was carried out behind the frontal dunes, to a depth below high tide level. Although initially the pits only collected freshwater, the weakened frontal dunes soon collapsed, allowing tidal entry into the pits.

The result was a range of fresh, brackish and tidal water pools, with mangroves and dense salt water couch grass, providing ideal habitats for a large range and huge numbers of mosquitoes. These mosquitoes seriously disrupted the recreational use of the nearby park, and affected nearby residential areas and the hospital area.

2.0 Storm Water Channelization Ludmilla Creek

During the installation of storm water drainage in the Ludmilla area, a large channel was constructed through the upper reaches of the Ludmilla mangroves to convey the increased storm water further downstream. The spoil from the channelization was thrown up on the sides of the channel to form a continuous embankment. This embankment disrupted the free drainage of the nearby mangrove and mud flat areas, resulting in cut off tidal depressions throughout the upper reaches of mangroves. These depressions created the breeding sites for hordes of salt marsh mosquitoes that plagued the general area for many years until rectified by the re-establishment of a drainage system under the combined mosquito engineering control group.

3.0 Storm Water Discharge, Sandy Creek, Tiwi

The construction of storm water drainage in the Tiwi area resulted in the discharge of storm water into the upper reaches of Sandy Creek along Rocklands Drive. With residential development, this extensive drainage system had considerable dry season flows from overwatering and wash down activities, which transformed the seasonal drainage line into a permanently flowing creek. Ecological changes occurred in the creek and for a considerable distance downstream into the mangrove areas of Sandy Creek. Fresh water and brackish water reeds began growing beneath mangroves and on former bare mud flat areas.

Silt accumulation caused drainage pattern changes and pooling of both fresh and tidal waters over considerable areas. Some areas of mangroves died while others colonized new areas. These ecological changes led to the creation of a range of mosquito breeding habitats and serious mosquito pest problem.

4.0 Road Embankments and Access Tracks

Tiger Brennan Drive

During the construction of the Tiger Brennan Drive extension, a large area of mangroves was cut off from regular tidal influence by an earth embankment. Some areas of the mangroves were flattened and left in situ, while other areas were bulldozed clear, leaving deep machinery tracks. Inadequate temporary drainage pipes were installed which were too small to allow sufficient drainage of impounded water, sited too high to allow complete drainage, and yet sufficient to allow tidal ingress and water level fluctuations. This situation led to a stagnant brackish water impoundment, with periodic tidal flooding of sheltered shallow water and artificial depressions. The resultant emergence of salt marsh and other species of mosquitoes required regular surveys and mosquito control operations in areas of inaccessible swamp. Notwithstanding that the affected area will soon be landfilled for future commercial development, even short-term impoundment of brackish water provides an unacceptable environment that promotes mosquito breeding.

Access Tracks

Access tracks, particularly those constructed by Electricity or Sewerage authorities, are frequently just above tidal reach, due to the positioning of many of their facilities. These tracks sometimes have inadequate drainage provisions which can interupt overland water flow into tidal areas or disrupt tidal drainage patterns. This can result in the retention of water in drainage lines and creeks, creating swampy areas, or cause pooling on the uphill sides of the track. In some instances, when drainage is constructed under the road, scouring on the downhill side of the drain can result in depressions that can fill after rain or high tides.

5.0 Water Retention Features in Tidal Areas

Examples of the range of problems created by water retention in tidal areas can be illustrated by the construction of the Frances Bay Mooring Basin, the old Fannie Bay Golf Club dam, the Gove alumina final retention pond and Palmerston Lake on the Darwin City Council Golf Course. All of these projects had water retained either permanently or temporarily during construction, and were periodically under water level fluctuations by tidal or storm water influence. Each impoundment exhibited a range of salinities and resulted in vegetation changes which included either death of mangroves, growth of fresh or brackish water reeds, death of fish or other aquatic mosquito predators or prolific algal growth.

Any of these factors can result in prolific breeding of mosquitoes. The ecological modifications caused by the construction has usually been considerable and the mosquito breeding can only be alleviated by expensive or critically timed water management procedures.

In the Frances Bay mooring basin, the mangrove death and coincident mosquito breeding was caused by the embankment of an area of mangroves upstream of the mooring basin, with inadequate provision for stormwater drainage from the impounded area.

The Old Fannie Bay Dam (now Lake Alexander) mosquito problems arose from the creation of a non draining tidal depression which was periodically flooded by high tides.

Extensive algal growth and colonization by dense reeds in the Palmerston Lake resulted from infrequent tidal entry, inadequate pumping capacity for top up sea water, inflow of organic rich storm water and the insufficient side slope and depth of the impoundment.

The Gove waste water retention pond was created by impounding a large area of mangroves behind an embankment. The low salinity and high PH of the impounded water caused the death of a large area of dense mangroves and destroyed all aquatic life except for periodic pulses of enormous numbers of mosquito larvae. The periodic plagues of salt marsh mosquitoes from this area precipitated industrial problems and ushered in a mosquito control program which was frequently inefficient. The large area of mosquito breeding and the inaccessibility of the breeding areas by a tangle of dead mangroves hindered larval control, and adult mosquito control by fogging was restricted by the lack of all around access to cope with varying wind directions.

6.0 Sanitary Land Fill, Leanyer Dump

Urban refuse fill into the edge of a salt marsh resulted in areas of polluted marsh becoming significant mosquito breeding sites as the normal aquatic predators such as fish beetles and bugs were eliminated. Other areas became breeding sites by poor placement of the fill creating cut off pools or silt runoff interrupting surface drainage patterns. Additional problems were created by depressions left by the operation of machinery on the salt marsh floor. In one instance, the stockpiling of a large number of tyres without a covering of soil led to appreciable numbers of artificial container breeding mosquitoes affecting nearby suburbs.

7.0 Sewer Line Construction

The installation of sewer lines, by the nature of gravity flow requirements, are invariably installed near the tidal zone. The creation of mosquito breeding has been caused by the construction of embankments to carry pipes across tidal areas, the subsidence of excavations, or the pushing of earth and debris into the mangroves. An embankment across a former tidal creek in Coconut Grove resulted in changing a free draining section of tidal creek into a dense swampy fresh water reed swamp. The ecological changes were not confined to upstream of the embankment. Continued seepage through the embankment caused mangrove species change in the tidal area below the embankment and the resultant root growth and silt accumulation created a series of brackish and saline cut off pools. A section of the control zone sewerage scheme bordering tidal areas of Fannie Bay created depressions by machinery disturbance and subsidence of earth cover. More recent installations for the Trade Development Zone created additional mosquito breeding sites by pushing earth and mangroves into the tidal zone.

8.0 Construction of Leanyer Sewage Ponds

The siting of the Leanyer Ponds and associated embankments led to severe disruption of mangrove drainage patterns. One embankment had provision for drainage but the culvert was not installed with any consideration for possible ecological consequences. This area retained fresh water in the wet season, but was still subject to very high tides. Mangroves within. the embankment died and the previous mud flat was transformed into a dense brackish water reed swamp. In addition, the maintenance of certain ponds could only be achieved by effluent release into the impounded area. In the tidal area, the drainage pattern disruptions led to very large areas of mangrove channels and flow lines without the capacity to drain freely at low tides. Subsequent mangrove vegetation growth further aggravated the disruption and resulted in large areas of tidal pooling. The consequences of these practices led to enormous populations of a range of mosquito species, severely affecting nearby residential areas.

Plate 1 This tidally flooded ex-sand mining pit is now the site of prolific breeding by *Aedes vigilax, Culex annulirostris* and *Anopheles farauti s.l.*.

Plate 2 An artificial drain constructed without an outlet to the tidal zone will simply pond and stagnate – and breed mosquitoes.

Plate 3 Inappropriate landfill here has blocked natural drainage on the salt marsh, leading to ponding and mosquito breeding.

Plate 4 Interruption of drainage by nearby roadworks has led to tidally influenced ponding and killed the mangroves: large numbers of the saltmarsh mosquitos, absent before, were a problem here during the construction phase.

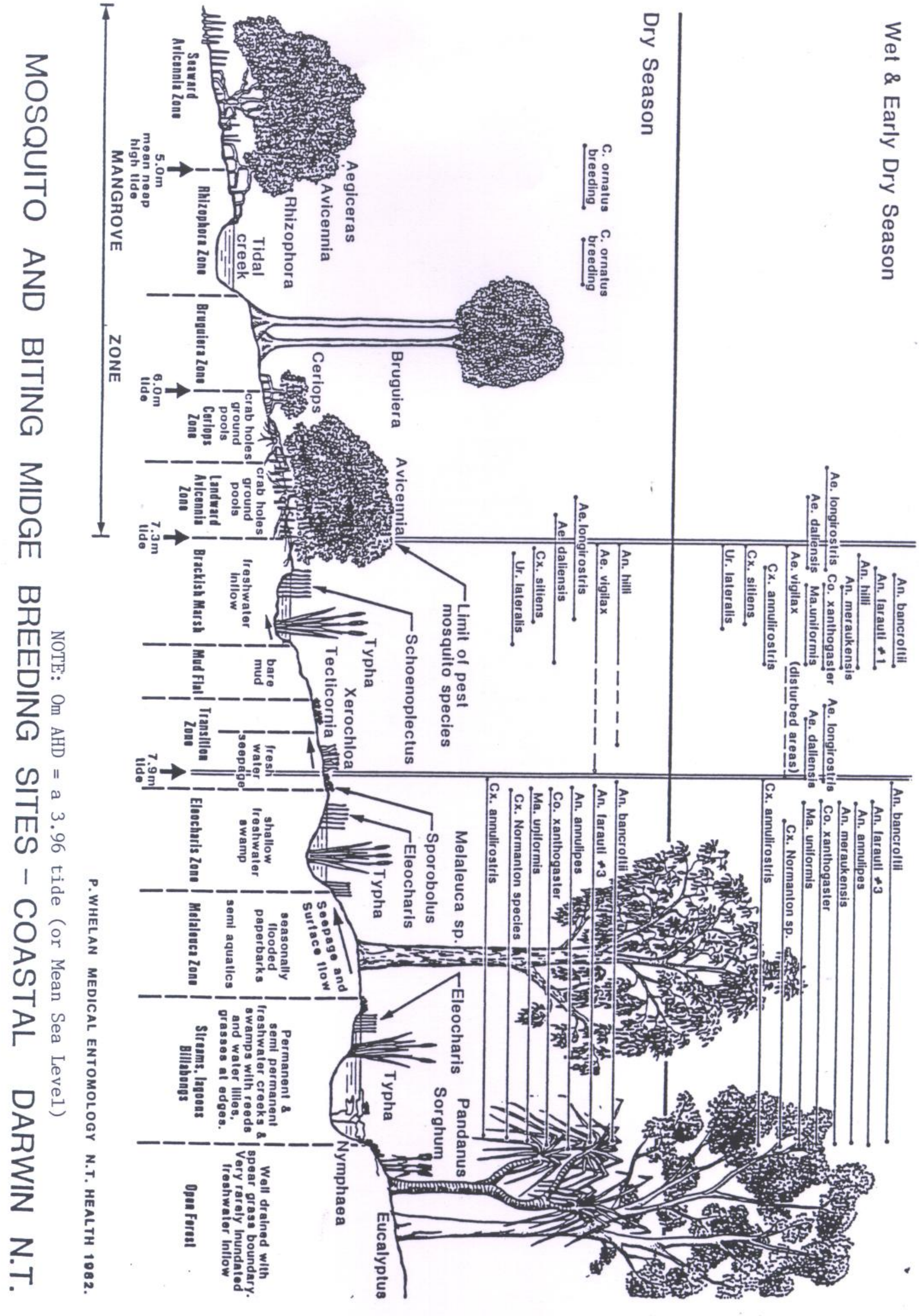
Plate 5 Pooling of stormwater through inadequate drainage creates mosquito breeding sites.

Plate 6 A sand dam placed through mangroves leads to upstream ponding; mangrove death and high numbers of mosquitoes.

Plate 7 Machinery distrubance of the tidal area can give rise to significant numbers of mosquitoes after high tides.

Plate 8 Damming of a mangrove creek for water storage, killed the mangroves and the resultant brackish water gave rise to very high numbers of mosquitoes.

DEPARTMENT OF HEALTH



Guidelines for Preventing Biting Insect Problems for New Rural Residential Developments or Subdivisions in the Top End of the NT

Medical Entomology
Centre for Disease Control
Department of Health and Families
Northern Territory Government
Darwin NT

October 1997
Updated August 2005

Guidelines for Preventing Biting Insect Problems for New Rural Residential Developments or Subdivisions in the Top End of the NT

1. A contour map showing the Q100 line and/or seepage areas is the minimal requirement for informed comment to planning applications. All permanent and semi-permanent swamps, creeks, lagoons or other wet season inundated areas that are in or adjacent to the development should be shown on the development plans

2. Each block must have a minimum of 1ha above the Q100 or seepage line. Any septic tank and absorption trench should be sited on the area above the Q100.

3. There should be no residential development with block sizes of less than 2ha within 1.6km of large or uncontrolled areas of mosquito or biting midge breeding, unless specific medical entomology investigations are carried out. The major potential mosquito breeding areas are seasonally brackish reed swamps or flood plains and relatively large areas of mangroves that are only reached by the highest tides of the year. The major biting midge breeding sites are relatively large areas of dendritic mangroves.

4. Large, shallow brackish swamps and dense forested areas contiguous with these wetlands and their wet season extensions should be excluded from any subdivision.

5. Permanent to semi-permanent fresh water lagoons, billabongs or wetlands that are likely to be, or that are demonstrated significant sources of mosquitoes (including their wet season flood extents), should be excluded from any subdivision unless the water features are contained within one block.

6. Subdivisions with block sizes between 2ha. and 10ha., which are within 1.6km of brackish swamps or the significant permanent to semi permanent wetlands listed above, should have a notification requirement that these habitats are significant sources of mosquitoes and could pose significant pest and disease risks. Subdivisions with block sizes between 2ha. and 10ha., which are within 1.6km of mangrove creeks and rivers, should have a notification that these habitats are significant sources of pest biting midges.

7. Rural landholders of lots of between 2ha and 10ha, within 5km of extensive wetlands including floodplains, coastal marshes and significant lagoons could be subjected to severe mosquito pest problems. Rural landholders within 1.6km of mangrove creeks and rivers would be subject to severe biting midge problems. These landholders should be made aware that local government or Medical Entomology of the Department of Health and Families will not be responsible for biting insect problems in these areas.

8. There must be no impedance of natural flow of surface water by site development (e.g. construction of access roads) to prevent the creation of mosquito breeding sites. Access roads may need to be fitted with culverts of sufficient size to prevent upstream flooding for periods that will enable mosquito breeding. The invert of culverts should be level with the upstream surface level.

9. Erosion prevention structures and silt retention facilities should be constructed where appropriate (e.g. on the down stream side of culverts, dam spillways or storm water drains) to prevent erosion and siltation of water features that will promote the creation of mosquito breeding sites. Erosion prevention structures should also be constructed at the headwalls of culverts, and bends and significant water entry points in storm water drains. Silt retention facilities should be designed to be free draining structures (i.e. drain entirely within 5 days), or if designed to contain water for extended periods they should have steep sides (2:1 slope) with a sloping floor towards the downstream side of the silt trap. Erosion prevention structures will be required at the silt trap overflow or discharge point. Silt retention facilities should be maintained on an annual basis to remove any excess silt and vegetation growth that will enable mosquito breeding.

10. Detention basins should not pond water for periods greater than 5 consecutive days. Detention basins should be constructed with a sloping floor towards the downstream side of the basin. Erosion prevention structures should be constructed on the overflow structure or discharge point of any detention basin. Detention basins should be maintained on an annual basis to remove any silt accumulation. This also applies to any other similar structures that are designed to retard water flows and trap silt.

11. Any artificial depressions (e.g. from extractive industries) within a development with block sizes of less than 10ha, or within 1km of any development boundary, or developments with block sizes less than 2ha, that are capable of holding water for a period greater than 5 consecutive days must be rectified by filling or rendered free draining to prevent the creation of mosquito breeding sites.

12. Storage dams or other constructed water features in developments with block sizes of less than 10ha should be constructed with steep straight sides, have a level bottom and be relatively deep (over 1.8m) to prevent the establishment of marginal semi-aquatic vegetation that will promote mosquito breeding.

13. Drainage reserves or easements should be declared over permanent and semi-permanent swamps, lagoons, creek lines, or other wet season inundated areas within or adjacent to the development.

14. Drainage easements should be declared between water features that will be connected during the wet season, to prevent the impedance of water along natural flow lines within or adjacent to the developments with block sizes less than 2ha.

15. There should be no part of a subdivision below the maximum tide level. There should be an access easement around the maximum tide level in vulnerable areas to allow for the monitoring of mosquito breeding and to prevent the creation of new mosquito breeding sites.

16. Subdivisions adjacent to wetlands or mangroves that contain significant mosquito or biting midge breeding habitat, must have buffer lots with a minimum size of 2ha surrounding the habitat(s). Buffer lots must be rectangular in shape, with the shortest boundary of the lot adjacent to the wetland/mangroves.

By Peter Whelan

Guidelines for Preventing Biting Insect Problems for Urban Residential Developments or Subdivisions in the Top End of the NT

Medical Entomology
Centre for Disease Control
Department of Health and Families
Northern Territory Government
Darwin NT

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Guidelines for Preventing Mosquito Problems for Urban Residential Developments and Subdivisions in the Top End of the NT

Peter Whelan

Minimal Requirements

A contour map showing the Q100 line and/or seepage areas and maximum tidal limit is the minimal requirement for informed comment to planning applications. Contour intervals of 1m between maximum tide limit and 5m above maximum tide limit are required near tidal areas and at least 2m contours are required for other areas, and particularly around wetlands and seepage areas.

All of each block must be above the Q100, seepage line, or maximum tide limit.

Buffer Zones

There should be a buffer zone between urban residential development and significant sources of biting insects.

There should be no urban residential development within 1.6km of large uncontrolled areas of mosquito and biting midge breeding sites, unless specific medical entomology investigations are carried out. The major potential mosquito breeding areas are tidally influenced and seasonally inundated brackish reed swamps or flood plains, and relatively large areas of mangroves that are only flooded by the highest tides of the year. The major biting midge breeding sites are relatively large areas of dendritic mangroves.

Wherever practicable, a semi-rural or rural subdivision should be incorporated into a residential subdivision design to increase the effectiveness of a mosquito or biting midge buffer zone, Incorporating a rural residential or industrial buffer, between major sources of biting insects and the urban component of a subdivision, will generally allow the 1.6km buffer to be relaxed to 1km.

Lot sizes for those rural blocks located entirely within 500m of significant biting insect breeding sites must be 2ha or greater. Rural lots that will only have some portion of land located within 500m of significant biting insect breeding sites must be 1ha or greater, while rural lots located further than 500m from significant biting insect breeding sites must be 0.4ha or greater.

There should be no residential development within 1.6km of actual or planned soil, sand or gravel mining operations or mining leases unless such areas have been rehabilitated to the stage where they are not potential mosquito breeding sites.

There should be no urban development within 1.6km of sewage treatment plants and sites of effluent disposal, unless the facilities have been designed or with documented management plans such that they are not likely to be potential sources of mosquitoes.

Drains

A standard for drains is required for all urban residential development, which includes particular attention to the design and construction of the drains and the location of end points of such drains to prevent mosquito breeding.

Concrete sub soil drains, or open drains with concrete low flow capabilities are required for all urban residential drains and drains from urban facilities that are likely to have dry season low flows. These drains must be conveyed to a suitable end point that will not become a mosquito breeding site. Suitable end points are usually large rivers or daily flushed tidal areas. Guidelines on storm drains are attached as Appendix 1. Sub-soil drainage systems must be entirely free draining. i.e. the invert of all stormwater pits (eg side entry pits, grate pits, letterbox pits etc) must be level with the invert of the outlet pipe. Structures such as Gross Pollutant Traps must not pond water or lead to impeded flow in the sub-soil pipe system.

Stormwater drains may be required to cross adjacent properties to reach a satisfactory end point such as a daily flushed tidal area. Urban stormwater drains must not terminate at the development boundary. When stormwater drains are required to pass through neighbouring properties, the relevant landholder should be consulted and a drainage easement declared on the neighbouring property, to allow the owner of the stormwater drain to conduct annual maintenance.

Water features (dams, ponds, retention basins, detention basins etc)

Dams, ponds, retention basins or other constructed water features within or adjacent to a urban development should be constructed with steep sides (45° or greater) and be relatively deep (1.8m) to prevent the establishment of marginal semi-aquatic vegetation that promotes mosquito breeding. Management procedures for wetlands or water features should be in place to monitor and control mosquito breeding. This can include stocking ponds with native fish such as the delicate blue eye or black lined rainbow fish, and mechanical or weedicide methods to reduce marginal vegetation.

If water sensitive urban design principles are applied to urban development, they must be in accordance to the Medical Entomology guideline 'Constructed Wetlands for Water Sensitive Urban Design- Guidelines to Prevent Mosquito Breeding'.

Detention basins should be constructed as 'dry' basins, with the basin designed to completely drain within at least 5 days of initial water ponding. Detention basins are not recommended in or adjacent to tidal areas, as they will have the high potential to breed mosquitoes.

Access provisions should be provided for all water features within or adjacent to a residential development, to allow machinery access to conduct routine maintenance such as desilting. Overflow provisions will be required for all water features, with an appropriate end point chosen for overflow water and erosion prevention structures constructed at the overflow/discharge point. Water features will need to be placed on an annual maintenance program, to be conducted by the relevant authority.

Easements

Any open unlined stormwater drains in a residential area should have drainage easements to allow periodic maintenance of such drains and be included in a register for maintenance and possible future upgrading when required by the relevant authority.

Drainage reserves or easements should be declared over permanent and semi-permanent swamps, lagoons, creek lines, or other wet season inundated areas within or adjacent to the development.

Drainage easements should be declared between water features that will be connected during the wet season, to prevent the impedance of water along natural flow lines within or adjacent to the development.

Any subdivision bordering freshwater swamp lagoons and other wetlands, waterways and tidal or tidally affected areas should maintain a 40m easement between residential boundaries and the Q100 or highest tide levels so that access is possible for the management of such areas and to minimise disturbance that would create new mosquito sites.

Site Planning

The natural flow of surface water must not be impeded by site development (eg. construction of access roads). Access roads may need to be fitted with culverts of sufficient size to prevent upstream flooding for periods that will enable mosquito breeding.

Any existing artificial depressions within the proposed development, or within 1km of the development boundary, that are capable of holding water for a period greater than 5 days must be rectified by filling or rendered free draining.

Any areas of intensive irrigation (eg. horticulture, landscaped areas, playing field or open spaces) within subdivisions or adjacent to the subdivisions must not create areas where water can pool for a period greater than 5 days.

Erosion and Sediment control

Urban subdivisions will require sediment control during the construction phase, due to the clearing of vegetation increasing the suceptivity of the development area to erosion. Sediment control is required to prevent the siltation of natural drainage lines, flow paths, open drains (including end points) and underground stormwater systems, which can lead to impeded drainage and mosquito breeding.

Although most temporary sediment control structures are removed once development has been completed, they can be short term mosquito breeding sites. Where possible, all sediment control devices should be designed to drain completely within 5 days. Adjacent to tidal areas, water retention should not exceed 3 consecutive days. This is required to prevent mosquito larvae from completing their larval stages.

There may be instances when temporary sediment control structures (eg. silt traps) cannot be designed to drain freely within the specified time to prevent mosquito breeding. For development sites away from tidal areas, mosquito breeding can be prevented by constructing sediment control structures with steep sides (2:1 slope), with a sloping floor towards the downstream side of the sediment control structure, and appropriate erosion control structures constructed at the overflow/discharge point. Regular inspections should be conducted to ensure the sediment control structure remains free of vegetation that can encourage mosquito breeding. Water retention adjacent to tidal areas should be avoided, otherwise weekly surveys by the developer will be required to monitor and control mosquito breeding.

Erosion prevention structures should be constructed where appropriate (eg. on the down stream side of culverts, dam spill ways, along storm water drains and at drain end points) to prevent erosion and siltation of water features that will promote the creation of mosquito breeding sites. Erosion prevention structures should also be constructed at the headwalls of culverts, and bends and significant water entry points in storm water drains.

Septic Tanks, Sewage Treatment and Dispersal

Department of Health and Families (DHF) has certain requirements for the positioning, installation and maintenance of septic tanks, rainwater tanks and the reuse of sewage effluent.

Any septic tank and absorption trench should be sited on the area above the Q100 and not within 40m of the maximum tide limit. Septic tanks must be of an approved design and be completely screened to prevent mosquito entry. All septic tanks approved within urban areas should be entered on a registry for periodic inspection.

All 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.

Guidelines on the requirements for the treatment, storage and disposal of sewage effluent are attached as Appendix 2, with additional requirements available from the DHF Environmental Health Directorate, Health House Darwin (*Policy for the Design of Off Site Sewerage Ponds and the Disposal or Reuse of Sewerage Pond Effluent*).

General Information

Advice on the potential biting insect problems for residential development should be sought from the DHF at the initial subdivision application stage.

Detailed comments on areas for urban development should be sought at the detailed design stage and at least 12 months before the construction stage.

The DHF's Medical Entomology is available for advice on what may constitute a potentially significant biting insect breeding site. In some instances a desktop examination of the plans and topographic information by Medical Entomology may be sufficient to ascertain the necessary information for recommendations on a specific site, but in other instances brief site inspections or longer term studies may be necessary. In some instances where detailed entomological investigations are necessary, up to 12 months entomological monitoring may be required to gather sufficient information before the detailed planning stage, particularly in areas near potential biting insect sources or if reduction in the recommended buffer distance is sought. This service would be provided on a user pays basis.

For significant urban developments, it may be necessary for the developer to engage a consultant to document and advise on rectification of the biting insect problems, with the consultant liaising with Medical Entomology DHF.

Relevant documents on the various aspects regarding mosquito or biting midges are available from:-

Medical Entomology,

Department of Health and Families

PO Box 40596

Casuarina NT 0811

Phone: (08) 8922 8901

Appendix 1

Guidelines on urban mosquito control drains

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

GUIDELINES ON URBAN MOSQUITO CONTROL DRAINS

1. Drains for mosquito control only need to be of dimensions that will drain an actual or potential flooded mosquito breeding site over a period of days, ie. the drain should be as small as possible to achieve the desired aim.

2. Drainage times for flooded areas that come under tidal influence at any time of the year should be three (3) days, while all freshwater areas should drain within five (5) days. If a drain overflows its banks during periods of high tides or heavy rainfall, the overflow water should drain back into the drain within the above times. When drains are constructed in low lying or level areas, any berm of spoil should have regular breaks to allow lateral drainage into the drain such that no pooling occurs outside the drain. In other situations the berm should be placed on the downhill side of the drain to prevent ponding uphill of the berm.

3. End points for drains that have a potential to breed mosquitoes should be such that the drains discharge directly into daily flushed tidal areas, to a formalised channel or creek that drains directly into a daily flushed tidal area, or a large body of water, without flowing through or into any low lying areas of restricted flow.

4. The ultimate standards for urban drains are impervious underground pipes or open lined channels with central low flow inserts. Central impervious low flow capabilities are essential where there is a likelihood of dry season low flows in a particular drain.

5. Earth sided drains that do not have dry season low flows should be formalised, straight, smooth, have broad U shaped inverts where practical and flow direct to suitable end points. Maintenance easements should be included alongside all open earth lined drains.

6. The end point for 100 year flood drains without dry season low flows that flow into tidal areas should be constructed to just below the maximum high tide level or to the fringe of the mangroves, whichever is lower.

7. There should be no vegetation, cut off pools or silt deposits in drains. Drain maintenance such as silt removal, weediciding or vegetation and debris removal for earth lined drains should be programmed on an annual basis. Drains that discharge into dams or lakes will require periodic silt removal at the discharge point into the water body to prevent the establishment of aquatic and semi aquatic vegetation.

8. The invert of the end point of drains that require concrete inverts or have dry season low flows should be below the average high tide level or to a natural well defined tidal creek. A channel could be dug back from a tidal creek to satisfy this requirement. As a guide for Darwin Harbour, the end points of the invert of low flows into tidal areas should be one metre below maximum high tide (at the 7.0 m ACD (3.0 m AHD) level).

9. Open earth lined drains should have erosion prevention drop structures of stone and mesh gabions installed wherever there is a likelihood of erosion within the drain.

10. Silt traps should be constructed in major drains from urban or industrial development areas before the drains enter freshwater or tidal creek lines. This is considered necessary before a new area is developed, particularly if the constructed drainage discharges into relatively wide level areas or to a creek or other water body. Any silt trap should have access for regular maintenance and silt removal.

11. Any land clearing operation should include the rectification of small depressions, particularly in low lying areas or near creek lines, such that no pooling will remain for more than five (5) days after flooding or rain.

Peter Whelan

Senior Medical Entomologist

Medical Entomology Branch, Department of Health and Families

September 1990

Revised June 1997

Appendix 2

Mosquito breeding and sewage pond treatment in the Northern Territory

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

MOSQUITO BREEDING AND SEWAGE POND TREATMENT IN THE NORTHERN TERRITORY

SUMMARY

The majority of effluent treatment in the NT occurs in sewage pond facilities. These sewage treatment facilities can be major sources of pest and vector mosquitoes near urban centres in the Northern Territory. Mosquito breeding is usually associated with inadequate design, operation, maintenance and final effluent disposal practices. This paper outlines the potential problems, gives some examples from previous or present treatment installations and suggests design and operational practices that can reduce mosquito breeding.

INTRODUCTION

Sewage and treated sewage effluent have been major artificial sources of mosquitoes near urban areas in the Northern Territory (Whelan, 1981, 1984, 1988). Nutrient rich sewage has the capacity to produce enormous numbers of mosquitoes, and as treatment facilities are relatively close to communities, they usually give rise to large and continuous problems from pest and vector mosquitoes.

Mosquito breeding is usually associated with inadequate design, operation and maintenance or faulty methods of effluent disposal or dispersal. Some of these practices can be relatively easily rectified, but there is a need for increased awareness of the nature of potential breeding places among planners, designers and operators of sewage treatment facilities.

The object of this paper is to emphasise the need for awareness of potential mosquito breeding in sewage facilities, and to outline some design considerations and operational practices that can reduce mosquito breeding.

MOSQUITO SPECIES

Culex gelidus: ‘The frosty mosquito’. This previously exotic mosquito species was first recorded in the NT sometime around 1996 (Whelan et al 2001), and has been in Australian since at least 1994 (Johnson et al 2006). It has been found breeding in high concentrations in primary, secondary and evaporation waste water ponds in the Top End of the NT, and in other high nutrient water bodies. This species also utilises many other habitats such as stormwater drains, artificial receptacles, septic tanks, and freshwater swamps with emergent vegetation (Johnson et al 2006).

Culex gelidus is a primary vector of Japanese encephalitis virus (JEV) in many parts of Asia (Williams et al 2005), and its introduction into Australia has been a concern. Recent testing of the vector competence of this species indicates it is highly susceptible to Murray Valley encephalitis virus, Kunjin virus and Ross River virus infection, indicating this species poses a potentially significant public health concern (Johnson et al 2006).

Culex quinquefasciatus: 'The brown house mosquito'. This species usually breeds in organically polluted water near human communities. It is frequently found breeding in high numbers in unsealed septic tanks and primary sewage ponds, although it will sometimes be found in organically overloaded secondary sewage ponds.

This is a very important pest species wherever favourable breeding sites exist. The females rarely travel more than two kilometres from their breeding sites. Due to the nature of the breeding sites, this species can be present throughout the year. *Culex quinquefasciatus* is a potential vector of arboviruses including West Nile virus, and is a possible vector of heartworm in dogs.

Culex annulirostris: 'The common banded mosquito', is the most common mosquito in the Northern Territory. It breeds in a variety of natural sites and is commonly found in open, shallow, vegetated freshwater swamps, streams and lagoons.

The most prolific artificial breeding places are in secondary sewage treatment and evaporation ponds and sewage pond effluent (Whelan, 1984, 1988). The larvae are most frequently found in still, sheltered areas where vegetation offers protection from disruptive wave action and aquatic predators.

This species can disperse up to 10 kilometres from the breeding area (Russell, 1986). It is abundant in the 'Top End' of the Northern Territory from January to August and in the southern region from October to April.

Culex annulirostris is the most numerous and common pest species in the Northern Territory, and is an important vector of a number of arboviruses (Russell, 2009). The most important disease carried by this species is the potentially fatal Murray Valley encephalitis. There have been confirmed cases of Murray Valley encephalitis in the Northern Territory, at an average of around one (1) case per year, and Murray Valley encephalitis virus (MVEV) is considered endemic to the Top End of the NT as far south as Tennant Creek (Kurucz et al 2005). *Culex annulirostris* also a vector of Kunjin virus (KUNV) disease, Ross River virus (RRV) disease and Barmah Forest virus (BFV) disease. Ross River virus disease is the most common and widespread mosquito borne disease in the Northern Territory. The most effective long term protection from these viruses lies in eliminating the breeding sites within flight range of urban areas.

Anopheles annulipes s.l.*:* 'The freshwater malaria mosquito' breeds in open, sunlit, temporary and permanent freshwater ground pools, streams or swamps. It is very rarely found in sewage ponds but it is frequently found in the lower organically loaded sewage effluent, particularly where the effluent flows into shallow, densely grassed areas.

The females can disperse up to two kilometres from their breeding places. The species is a potential vector of malaria where sufficient numbers occurs, and is a significant pest species in inland areas where suitable breeding sites exist.

DESIGN CONSIDERATIONS FOR EFFLUENT POND TREATMENT FACILITIES

Site Selection and Design

Disposal of Effluent

Appropriate planning for the final disposal is an important part of site selection. Disposal near the coast is relatively easy, but in inland areas can lead to major problems if appropriate disposal techniques are not used. These are discussed later.

Wind

Ideally ponds should be located in open windy areas since wind and the associated waves play an important part in preventing breeding by disrupting the larvae and pupae at the water surface. Also, wind action can restrict the growth of algae, aquatic floating ferns (*Azolla* sp.) and duck weed (*Lemna* sp.). These floating plants can shelter the larvae from both wave action and aquatic predators, unless they form a complete cover of a pond.

An example of bad siting was at Snake Bay, Melville Island, where small ponds with steep banks were protected from the wind by both a hill and a close, tall eucalypt forest. Colonisation of corner sections by duck weed (*Lemna* sp.) enabled *Cx. annulirostris* to breed in relatively large numbers.

Drainage

The choice of a site should consider the necessity to drain the ponds for maintenance without thereby creating swamps or pools of stagnant water. Effluent release from the final pond has usually been incorporated into design, but provision for emptying the intermediate ponds into suitable areas has often been overlooked.

Site design should ensure that there is no prevention of near site drainage pathways caused by any of the works. New diversionary drains should be constructed with erosion prevention principles to ensure there is no overland flow of surface water to the ponds or the disposal areas. Diversion drains should discharge to suitable endpoints that are free draining. Groundwater seepage from areas surrounding ponds or the ponds themselves should be intercepted by diversion drains to a free draining area. Long term ground water seepage will require drains with concrete inverts to promote flow and prevent vegetation growth.

With ponds constructed near tidal areas, particular consideration must be given to preserving existing tidal drainage patterns, or to ensure no dead tidal pockets are created. If upper mangrove drainage areas are blocked new breeding sites for salt water species of mosquitoes can be created. An example occurred at the Leanyer sewage ponds in Darwin, where considerable engineering work was required to drain non-draining tidal areas created by the location of the ponds and access embankments over tidal mud flats.

Access

Site design should allow for all weather access completely around the installation. Weed growth, tree growth, seepage, erosion and siltation must all be controlled, and fire prevention must be considered. There have been instances in Alice Springs of seepage from large pond systems causing swampy conditions and preventing vehicle access and hence control around the base of the ponds.

Pond Dimensions

Pond Size

Sewage pond size is primarily determined by engineering parameters related to design flowrates, pollution loadings, and the required effluent quality. Frequently there has been little consideration given the effect of pond size on mosquito breeding. Adoption of oversized ponds, either from inaccurate predictions of sewage volume or a desire to provide for future capacity, can lead to the ponds becoming shallow thickly vegetated swamps that are capable of breeding large numbers of mosquitoes.

This situation occurred at Batchelor and Tennant Creek, where the final evaporation ponds became swamplands breeding mosquitoes.

Consideration should be given to the staging of particularly evaporation pond construction, or the use of multiple smaller ponds rather than one large evaporation pond. In most cases, it is the margins of the ponds that provide the mosquito breeding conditions. Multiple small ponds can provide additional maintenance requirements so it is important to optimise the numbers and size of these ponds.

Attempts to reduce short-circuiting through a large pond by installing earthen peninsular barriers can markedly increase the mosquito breeding areas by providing additional margin length, and these are often inaccessible for mosquito control purposes.

Pond Depth

Selection of pond depth is usually dictated by the function of the pond, ie. primary, secondary, or evaporation. Adequate allowance must be made for solids deposition, particularly in primary ponds, otherwise excessive or longer term deposits will lead to siltation at the edges and corners, resulting in colonisation by vegetation and thus creating mosquito breeding locations.

Profiling the pond base, with the deepest side at the effluent entry point, can help alleviate the silt problem, particularly if there is a seasonal variation in input. For evaporation ponds, particularly those with earth sides or those which are operated on a continual basis, a minimum depth of two metres or more is recommended. This is to allow for the periodic drowning of any seasonal growth of grasses or semi aquatic vegetation such as *Eleocharis* sp. and *Typha* sp.

Construction Details

Concrete Margins

Vertical or sloping concrete margins have proven to be the most satisfactory engineering means of controlling mosquito breeding by promoting wave action, and maintaining margins free of vegetation and debris.

Vertical concrete walls have proven the most maintenance free and effective in reducing mosquito breeding. Sloping concrete margins have been tried in a number of locations. While better than unlined ponds, they have the drawback that wave action is damped by the slope. Debris and algae and organic matter can build up and enable emergent vegetation to establish. It is important that they have a concrete rim around the top to prevent landward inflow of water and silt, and sealed verges to prevent vegetation growth.

Concrete lining can be precast for remote locations or constructed in situ, and are cost effective. They should be deep enough to allow for wide variation in water level and should have a concrete lined horizontal bench just above the bottom level of the pond, to prevent establishment of vegetation along the margin in the initial stages of operation, and to prevent silt accumulation in the longer term. Sealed verges around the top of the banks are desirable to facilitate maintenance and to prevent entry of soil into the pond. Walled ponds may still have problems with floatables and wind blown debris in the corners and cut off pools near entry and exit points. Truncated corners and multiple or underwater entry and exit points can help to eliminate these latter problems.

Unlined earth banks

Sewage ponds with unlined earth banks have the greatest capacity for mosquito breeding, particularly those with gentle slopes where marginal vegetation can grow. They are accordingly not recommended, except as temporary or emergency measures. The banks should be constructed using low porosity materials such as compacted clay. If neglected, unlined earth banks can become either eroded, or overgrown with grass, shrubs and even trees such as *Acacia*, *Mimosa* and *Melaleuca* sp. Maintenance and corrective measures can be a major problem.

Other Linings

Various systems have been used to line earth banks as a temporary measure to reduce growth of vegetation, but they have not been entirely satisfactory.

Stone pitching of the margins is not satisfactory as it does not offer sufficient deterrent to vegetation growth, and mechanical maintenance of vegetation is subsequently difficult. Overlapping cement sheets have been used, but have problems with breakage and subsequent weed growth. Various types of bituminous or plastic sheeting have also been tried, and most have shown promise as short to medium term solutions. Problems encountered include inadequate anchoring, weed growth, ultraviolet deterioration, and human interference. The more modern ultra-violet resistant heavy duty plastics, anchored with earth mounds back from the rim of the ponds, have been more successful.

Maintenance

New pond systems

Before commissioning sewage pond systems, a general survey of the whole site should be conducted to ensure that mosquito breeding places have not been inadvertently created. Potential mosquito breeding sites include borrow pits formed during pond construction, pooling of water resulting from site drainage works, and pooling caused by road access blocking drainage paths. Any problems should be rectified before the ponds are commissioned.

Pond maintenance

Pond maintenance is a vital part of pond management. The highest levels of maintenance will be required for earth lined ponds with low and seasonally variable effluent flow rates. Some form of maintenance will be required, even for ponds with vertical concrete margins and sealed verges. Even those ponds in favourable locations, with ideal effluent characteristics, must have adequate provision for people and resources to carry out a regular and defined maintenance program.

Aspects of maintenance frequently overlooked include the regular control and removal of vegetation on the margins or the pond verges, the regular removal of floatables and other flotsam from accumulation points, and the repair of cracks and other failures that can allow pooling or increased soil moisture levels on the banks and subsequent vegetation growth.

For some ponds, a program of water level management may be adopted, which alternately floods and strands marginal vegetation or floatables. The form of maintenance will depend heavily on the pond design, effluent parameters, staff experience and staff availability.

Regrettably, it has been the NT experience that regular and adequate maintenance have been sometimes inadequate to prevent mosquito breeding. If there is any anticipation that regular and adequate maintenance can not be carried out, a maintenance-free design should be chosen.

EFFLUENT DISPOSAL OR DISPERSAL

Problems

Insufficient consideration was given to disposal of the effluent in many of the early sewage treatment facilities in the Territory. It was often assumed that 'adequate treatment' in the ponds was sufficient from an operational point, and therefore discharged treated effluent was frequently allowed to run down the nearest flow line. In practice this effluent often formed flooded, overgrown, stagnant pools that created prolific breeding grounds for *Culex* mosquitoes. Examples were the sewage treatment facilities at Coonawarra Naval Base and Nhulunbuy South in the 1970’s, where there was a lack of provisions for proper disposal.

In some instances, effluent from sewage treatment ponds was channelled or piped just beyond the perimeter fence or to the nearest available low lying area. In some situations, as at Nhulunbuy, the effluent was directed into sand dunes in the belief that infiltration would provide a satisfactory disposal method. This proved totally inadequate because the high organic loads of the effluent and algae invariably sealed against infiltration and resulted in pooling of effluent throughout the dunes.

Even after the final aerobic treatment in evaporation ponds, the resulting 'treated' effluent still retains a great capacity to breed mosquitoes. An example of this was the uncontrolled release of treated effluent into the Il Parpa Swamp area near Alice Springs during the period 1974-2002. The regular release of effluent created a large permanent vegetated swamp and very high numbers of *Cx. annulirostris* and *An. annulipes s.l*. This area has since been partially rectified by drainage measures in the swamp and a reorganisation of discharge practices (Kurucz et al 2002).

Large Evaporation Ponds

In the Northern Territory evaporation ponds, either designed or of 'ad hoc' design have commonly been used for effluent disposal in inland sites. Large evaporation ponds are rarely full to capacity for the entire year, and in many instances are just bunded areas containing effluent to prevent escape to other areas. Because of their large area, the often variable inflow and the variation in climate, large evaporation ponds often become shallow, flooded swamps with dense weed and reed vegetation for at least part of the year. These ponds can become considerable sources of *Culex annulirostris, Culex gelidus, Culex quinquefasciatus* or *Anopheles annulipes s.l.* Also, evaporation ponds that dry up and are then seasonally inundated during rainy periods can become breeding grounds for floodwater mosquitoes such as *Aedes normanensis*. The numerous aspects to be considered in designing large ponds to reduce the amount of mosquito breeding, include:

- initial and regular removal of all emergent vegetation within the evaporation area:
- levelling of the floor of the evaporation area:
- division of the evaporation area into a number of smaller areas;
- constructing a sloping floor to concentrate the water in a sink' area at the effluent entry point;
- concrete lining of the 'sink' area on the floor of the evaporation area and the lining of embankments.

Incorporating some of these aspects into the initial design can be expensive, but the alternatives are to have a regular maintenance program, which could be more expensive in the longer term. The alternative to well designed evaporation ponds is to consider a different effluent disposal method such as dispersal to land, sophisticated tertiary effluent plants, or effluent re-use schemes.

Small Evaporation Ponds

The use of small concrete lined evaporation ponds can be a very effective method of effluent disposal. The best designs incorporate a series of relatively small ponds that can progressively fill by gravity overflow. Such a system may be expensive to construct, particularly if the whole evaporation area required is relatively large. However, the method has the advantage of being relatively maintenance free and it can better prevent mosquito breeding when there are large seasonal variations in effluent volume.

Disposal to the Sea

Disposal direct to the sea or to a daily flushed tidal area is one of the most suitable methods for effluent disposal to prevent mosquito breeding. The critical aspect for tidal creeks is to ensure there is good drainage at low tides. However dispersal at the end of a relatively long, narrow or tortuous tidal creek can result in effluent build up in the creek which can also be pushed higher up the creek line by incoming tides into areas where mosquito breeding sites can develop.

Disposal onto large flat inadequately flushed tidal areas can create breeding sites for freshwater species of mosquitoes, as well as brackish water species such as *An. farauti s.l.* and *Verrallina funerea*, and salt water species such as *Cx. sitiens, An. hilli,* and *Ae. vigilax,* by creating a complex of fresh and brackish water habitats.

Disposal to Rivers

The suitability of discharge to rivers depends upon the volume of flow in the river, the seasonal variability of flow, and the downstream effects of the disposal. This method is unsuitable when the flow in the rivers or creeks is small or subject to wide seasonable variation, as eutrophication or ecological and vegetation changes will lead to mosquito breeding.

Disposal to Land

<u>Large Sprinkler dispersal</u>

This method has been relatively successful in areas where there have been particular problems with other disposal methods. It is most successful onto areas with well-developed stands of trees on well drained areas with soils of good permeability, but the success will depend on adequate resting of the disposal areas and the rate of volumes of effluent disposed to these areas.

Jabiru provided an example of an initially successful sprinkler dispersal scheme. The final effluent was automatically and periodically dispersed via a system of overhead sprinkler heads, onto a fenced area of open native eucalypt forest. Initial problems from fire damage of above ground plastic pipes and algal blocking of spray heads were rectified by the construction of an underground pipe system with tall metal risers and metal sprinkler heads. Over the longer term, this area became a major source of mosquitoes with dead trees, wet season ponding on-site and in downstream off-site flow lines, and tall, dense and uncontrollable grass-weeds in the dispersal site. It has become obvious that the initial site levelling and draining was not adequate, and off site wet season runoff into the disposal area has compounded the effluent ponding problems. The lack of regular slashing of grass led to intense fires that destroyed the trees, and hence reduced evapotranspiration.

Ideally, sites should be relatively level but with good drainage during rainy periods. Off site run-off should be directed away from the disposal site. There should be adequate sprinklers to have areas off-line for up to a week for drying and weed maintenance. Feeder lines to sprayheads should be laid out along contours, rather than at right angles to contours, so that water retained in the lines after the finish of spraying will remain in the lines rather than drain to the lowest sprinkler head. The sprinkler heads should be positioned on mounds of crushed rock to enable better infiltration and to reduce the probability of creating permanent pools of effluent near the sprinkler heads.

The area required will depend upon the volume of effluent to be disposed, and the long-term absorption capacity of the soil and the vegetation. In monsoonal areas, additional site selection and preparation is required to ensure that effluent contaminated runoff cannot pool in nearby flow lines or creeks.

Sprinkler dispersal of effluent can be used for tree and pasture growing or landscape watering, but the National Health and Medical Research Council Guidelines for the Reuse of Waste Water must be adhered to (NH & MRC, 1979). Tertiary chlorination has been used to provide a high quality effluent for drip irrigation and recreational area watering at Yulara. Sprinkler disposal using large spray heads has been successfully used on Blatherskite Park in Alice Springs, but potential problems exist in this area because of the high salinity of the water and rising water tables, which requires regular monitoring of the water table and suspension of irrigation when water tables are high.

<u>Small sprinkler dispersal</u>

When disposing of small volumes of effluent, the use of mini sprinklers fed by irrigation lines is a suitable alternative to drip irrigation. Small sprinklers tend to promote more evaporation compared to drippers by wetting larger areas and allowing greater soil infiltration. In addition it is easier to spot blockages with mini sprinklers compared to drippers. There is however a need to have regular maintenance of dispersal area to prevent grass and weeds from smothering the sprinklers.

<u>Drip Irrigation</u>

Disposal by dripper systems requires a high standard of effluent, usually with a tertiary chlorine treatment, to prevent dripper blockage by algae. Dripper systems can be used for both small or large scale disposal, but is usually only suitable for plantation situations where the vegetation growth at each dripper site can be practically and economically maintained. Drippers held off the ground can reduce root blockages of the drippers. Generally dripper systems are only suitable for the dispersal of small volumes of effluent per unit area or periodic release, and are generally expensive because of their high maintenance requirement.

There has been past issues with drip irrigation at Hermansburg, and Kings Canyon (Whelan 1994). The continuous volume of effluent released in both situations was too high for drip disposal, which created effluent ponding and mosquito breeding. Both systems did not receive adequate maintenance to prevent blockages of drippers, and treatment areas were not appropriately spelled. In both instances, a switch to sprinkler irrigation was required to adequately dispose of the required volumes of effluent over a wider area in the irrigation area.

This method is useful for relatively small volumes of effluent on sandy soil in low rainfall areas. A feeder channel is used to deliver effluent to a ploughed area of small furrows sloping gently away from the feeder channel. Disposal is by infiltration into the sandy soil. When infiltration becomes less efficient, the flow is directed to an adjacent ploughed area, and the original area is allowed to dry out and is reploughed.

This system requires a considerable amount of attention and maintenance, but was used successfully at Perth Airport, largely due to the sandy soils and relatively low effluent volumes per unit area.

Channel Infiltration

In this system, permanent infiltration channels are constructed and effluent flow is directed down a number of groups of channels which are alternatively spelled and maintained. The method can be used on less porous soils than is possible for furrow irrigation. If this method is to be used for the irrigation of tree or bush crops, intensive monitoring is required to ensure viability of the crop in the long term. Small scale use of this method has been tried at Batchelor and at the Katherine Abattoirs, but proved to be relatively labour intensive. A variation of the method has been used on a larger scale at Il Parpa in Alice Springs, for the growth of eucalypt trees. Problems on the larger scale have included high labour input, weed control in the channels, siltation in the feeder channels, rising salinity levels and rising water tables.

Flood Bay Irrigation

The degree of land preparation for flood bay irrigation is usually considerable, as a system of correctly graded flood bays is necessary to allow for efficient flooding and to prevent pooling at the end of the flood bays. The bays are periodically flooded and the effluent is allowed to evaporate or infiltrate in the bays over a period of four to five days. This method has been used successfully to grow eucalypts in Ilparpa in Alice Springs. Problems with flood bay irrigation arise during extended rainy periods, when extended flooding of the bays can occur and can result in mosquito breeding. A more sophisticated delivery system for a flood disposal method has been designed for Gapuwiyak. It incorporates an automatic siphon and a distribution drain designed to release effluent evenly over a very large flood bay.

Vegetated Treatment Ponds

Vegetated treatment or polishing ponds, using large aquatic plants such as Salvinia (water lettuce) or Eichornia (water hyacinth) have been used overseas, but many of these have faced major problems with the maintenance or removal of vegetation, and have become major mosquito breeding sites. This has resulted in expensive re-design or maintenance issues, or in some instances they have had to be decommissioned. There has been some success with prostrate water plants such as duckweed (*Lemna* sp) which can form total cover over ponds, thus denying suitable oviposition sites and preventing air access for larvae. However the pond sizes need to be relatively small so that the duckweed is not blown into corners by wind and wave action.

BIOLOGICAL CONTROL

Biological control, though not usually applicable to primary ponds, can be a very efficient means of controlling mosquito larvae in secondary and evaporation ponds.

The major biological control agents are fish, aquatic beetles and aquatic bugs. Fish can control mosquito larval numbers directly by eating the larvae, or indirectly by eating or disturbing algae or aquatic weeds which provide protection from other predators or wave action. Fish are usually only suitable for the higher oxygenated waters. Several species have shown promise in the Northern Territory, including the herbivorous bony herring (*Nematalosa erebi*), which was successful in reducing surface algae in the former Ludmilla sewage ponds in Darwin, and rainbow fish (*Melanotaenia* sp.), which was a very efficient larval predator in the final evaporation ponds for the Ranger sewage treatment. Other suitable fish species includes the blue eyes (*Pseudomugil* sp.) and gudgeons (*Mogurnda* sp, *Hypseleotris* sp.).

It is essential that marginal vegetation such as couch grass and reeds be eliminated or kept to a minimum, so that fish can have physical access to the mosquito larvae. Actively growing *Eleocharis* sp. and *Typha* sp., with upright stems, may not restrict access. However, when these weed species die or lodge over, they prevent physical access for the fish and enable mosquito breeding.

Aquatic beetle larvae (Family:*Carabidae*) and aquatic bugs (Family:*Belostomatidae*) are the most efficient mosquito larvae predators in secondary and evaporation ponds. The aquatic bugs are able to live in higher organic water than the aquatic beetle larvae, and can be present in very high numbers. Again, physical impedance by thick vegetation at the margins will reduce the effectiveness of these predators. These insect predators can achieve almost total control of mosquito larvae in sewage ponds of suitable water quality, and narrow or sparse vegetation margins.

CHEMICAL CONTROL

The aim of chemical control of mosquito larvae should be to apply the minimum amount of insecticide to prevent the production of adult mosquitoes. Chemical control should not be used as a long term strategy in sewage treatment areas, in order to avoid insecticide resistance and unwanted effects on non-target organisms. However, it may be necessary to apply insecticides during the initial operational period or when proper maintenance has not been carried out. The insecticides of choice to control mosquito larvae in sewage ponds and effluents are either temephos, methoprene, *Bacillus thuringiensis* var *israelensis* (*Bti*) or *Bacillus spaericus* (*Bs*), with *Bs* having advantages over Bti due to its persistence after application. Correct rates for temephos must be strictly adhered to, as over treatment can kill fish and other aquatic insects.

MOSQUITO SAMPLING

Regular inspections for mosquito larvae should be carried out in sewage ponds and their effluents to determine whether breeding is occurring and to determine the necessity for weed control or chemical control. Chemical control with temephos or *Bti* may be necessary at weekly or longer intervals. Methoprene may give longer control if applied as pellets or briquettes. In general briquettes will give the longer residual effect but need to be tethered in netting on sticks near the surface of the water, so that they do not sink into the silt or mud. Methoprene applications do not necessarily kill larvae or pupae, so an experienced operator is required to assess treated areas or take pupal samples and check emergence efficiency. The presence of late instar or pupae with the first two insecticides above indicates that control should have been carried out at shorter intervals. If only first and second instar larvae are present, then either biological control is quite efficient, or the mosquitoes have just started to breed in that area, and continued monitoring is necessary.

Mosquito larval or pupal samples can be collected by dipping into sheltered vegetated zones with a soup ladle. Generally care should be taken not to disturb the larvae by shadows or surface water agitation before dipping, and multiple dips should be performed to adequately assess population numbers. Any larvae collected should be stored in small vials with 70% alcohol or methylated spirits, together with information on collection locality, site, date and collector. Larval or pupal identifications should be checked by an entomologist.

Adult specimens collected by biting or harbourage collections can be sent for identification, packed loosely in tissue paper in a small box, together with all the details of collection.

Chironomid midge pupae or adults are often mistaken for mosquitoes and their presence has often resulted in control programs being instituted where none has been necessary.

SUMMARY

In the past, the design of sewage treatment ponds and their effluent disposal facilities in the NT has been largely dictated by engineering and microbiological principles. Little attention was paid to the possibility of breeding mosquito populations close to residential areas, with the resultant risk to public health. Appreciation of this potential risk followed by the application of design principles and adequate maintenance can reduce this problem. Biological control can then operate effectively. Chemical control can be used for start-up or emergency situations, although should not be relied on for ongoing mosquito control in ponds or effluent disposal areas.

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Mosquito breeding and sewage pond treatment in the Northern Territory

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MOSQUITO BREEDING AND SEWAGE POND TREATMENT IN THE NORTHERN TERRITORY

SUMMARY

The majority of effluent treatment in the NT occurs in sewage pond facilities. These sewage treatment facilities can be major sources of pest and vector mosquitoes near urban centres in the Northern Territory. Mosquito breeding is usually associated with inadequate design, operation, maintenance and final effluent disposal practices. This paper outlines the potential problems, gives some examples from previous or present treatment installations and suggests design and operational practices that can reduce mosquito breeding.

INTRODUCTION

Sewage and treated sewage effluent have been major artificial sources of mosquitoes near urban areas in the Northern Territory (Whelan, 1981, 1984, 1988). Nutrient rich sewage has the capacity to produce enormous numbers of mosquitoes, and as treatment facilities are relatively close to communities, they usually give rise to large and continuous problems from pest and vector mosquitoes.

Mosquito breeding is usually associated with inadequate design, operation and maintenance or faulty methods of effluent disposal or dispersal. Some of these practices can be relatively easily rectified, but there is a need for increased awareness of the nature of potential breeding places among planners, designers and operators of sewage treatment facilities.

The object of this paper is to emphasise the need for awareness of potential mosquito breeding in sewage facilities, and to outline some design considerations and operational practices that can reduce mosquito breeding.

MOSQUITO SPECIES

Culex gelidus**:** ‘The frosty mosquito’. This previously exotic mosquito species was first recorded in the NT sometime around 1996 (Whelan et al 2001), and has been in Australian since at least 1994 (Johnson et al 2006). It has been found breeding in high concentrations in primary, secondary and evaporation waste water ponds in the Top End of the NT, and in other high nutrient water bodies. This species also utilises many other habitats such as stormwater drains, artificial receptacles, septic tanks, and freshwater swamps with emergent vegetation (Johnson et al 2006).

Culex gelidus is a primary vector of Japanese encephalitis virus (JEV) in many parts of Asia (Williams et al 2005), and its introduction into Australia has been a concern. Recent testing of the vector competence of this species indicates it is highly susceptible to Murray Valley encephalitis virus, Kunjin virus and Ross River virus infection, indicating this species poses a potentially significant public health concern (Johnson et al 2006).

Culex quinquefasciatus: 'The brown house mosquito'. This species usually breeds in organically polluted water near human communities. It is frequently found breeding in high numbers in unsealed septic tanks and primary sewage ponds, although it will sometimes be found in organically overloaded secondary sewage ponds.

This is a very important pest species wherever favourable breeding sites exist. The females rarely travel more than two kilometres from their breeding sites. Due to the nature of the breeding sites, this species can be present throughout the year. *Culex quinquefasciatus* is a potential vector of arboviruses including West Nile virus, and is a possible vector of heartworm in dogs.

Culex annulirostris: 'The common banded mosquito', is the most common mosquito in the Northern Territory. It breeds in a variety of natural sites and is commonly found in open, shallow, vegetated freshwater swamps, streams and lagoons.

The most prolific artificial breeding places are in secondary sewage treatment and evaporation ponds and sewage pond effluent (Whelan, 1984, 1988). The larvae are most frequently found in still, sheltered areas where vegetation offers protection from disruptive wave action and aquatic predators.

This species can disperse up to 10 kilometres from the breeding area (Russell, 1986). It is abundant in the 'Top End' of the Northern Territory from January to August and in the southern region from October to April.

Culex annulirostris is the most numerous and common pest species in the Northern Territory, and is an important vector of a number of arboviruses (Russell, 2009). The most important disease carried by this species is the potentially fatal Murray Valley encephalitis. There have been confirmed cases of Murray Valley encephalitis in the Northern Territory, at an average of around one (1) case per year, and Murray Valley encephalitis virus (MVEV) is considered endemic to the Top End of the NT as far south as Tennant Creek (Kurucz et al 2005). *Culex annulirostris* also a vector of Kunjin virus (KUNV) disease, Ross River virus (RRV) disease and Barmah Forest virus (BFV) disease. Ross River virus disease is the most common and widespread mosquito borne disease in the Northern Territory. The most effective long term protection from these viruses lies in eliminating the breeding sites within flight range of urban areas.

***Anopheles annulipes s.l.**:* 'The freshwater malaria mosquito' breeds in open, sunlit, temporary and permanent freshwater ground pools, streams or swamps. It is very rarely found in sewage ponds but it is frequently found in the lower organically loaded sewage effluent, particularly where the effluent flows into shallow, densely grassed areas.

The females can disperse up to two kilometres from their breeding places. The species is a potential vector of malaria where sufficient numbers occurs, and is a significant pest species in inland areas where suitable breeding sites exist.

DESIGN CONSIDERATIONS FOR EFFLUENT POND TREATMENT FACILITIES

Site Selection and Design

Disposal of Effluent

Appropriate planning for the final disposal is an important part of site selection. Disposal near the coast is relatively easy, but in inland areas can lead to major problems if appropriate disposal techniques are not used. These are discussed later.

Wind

Ideally ponds should be located in open windy areas since wind and the associated waves play an important part in preventing breeding by disrupting the larvae and pupae at the water surface. Also, wind action can restrict the growth of algae, aquatic floating ferns (*Azolla* sp.) and duck weed (*Lemna* sp.). These floating plants can shelter the larvae from both wave action and aquatic predators, unless they form a complete cover of a pond.

An example of bad siting was at Snake Bay, Melville Island, where small ponds with steep banks were protected from the wind by both a hill and a close, tall eucalypt forest. Colonisation of corner sections by duck weed (*Lemna* sp.) enabled *Cx. annulirostris* to breed in relatively large numbers.

Drainage

The choice of a site should consider the necessity to drain the ponds for maintenance without thereby creating swamps or pools of stagnant water. Effluent release from the final pond has usually been incorporated into design, but provision for emptying the intermediate ponds into suitable areas has often been overlooked.

Site design should ensure that there is no prevention of near site drainage pathways caused by any of the works. New diversionary drains should be constructed with erosion prevention principles to ensure there is no overland flow of surface water to the ponds or the disposal areas. Diversion drains should discharge to suitable endpoints that are free draining. Groundwater seepage from areas surrounding ponds or the ponds themselves should be intercepted by diversion drains to a free draining area. Long term ground water seepage will require drains with concrete inverts to promote flow and prevent vegetation growth.

With ponds constructed near tidal areas, particular consideration must be given to preserving existing tidal drainage patterns, or to ensure no dead tidal pockets are created. If upper mangrove drainage areas are blocked new breeding sites for salt water species of mosquitoes can be created. An example occurred at the Leanyer sewage ponds in Darwin, where considerable engineering work was required to drain non-draining tidal areas created by the location of the ponds and access embankments over tidal mud flats.

Access

Site design should allow for all weather access completely around the installation. Weed growth, tree growth, seepage, erosion and siltation must all be controlled, and fire prevention must be considered. There have been instances in Alice Springs of seepage from large pond systems causing swampy conditions and preventing vehicle access and hence control around the base of the ponds.

Pond Dimensions

Pond Size

Sewage pond size is primarily determined by engineering parameters related to design flowrates, pollution loadings, and the required effluent quality. Frequently there has been little consideration given the effect of pond size on mosquito breeding. Adoption of oversized ponds, either from inaccurate predictions of sewage volume or a desire to provide for future capacity, can lead to the ponds becoming shallow thickly vegetated swamps that are capable of breeding large numbers of mosquitoes.

This situation occurred at Batchelor and Tennant Creek, where the final evaporation ponds became swamplands breeding mosquitoes.

Consideration should be given to the staging of particularly evaporation pond construction, or the use of multiple smaller ponds rather than one large evaporation pond. In most cases, it is the margins of the ponds that provide the mosquito breeding conditions. Multiple small ponds can provide additional maintenance requirements so it is important to optimise the numbers and size of these ponds.

Attempts to reduce short-circuiting through a large pond by installing earthen peninsular barriers can markedly increase the mosquito breeding areas by providing additional margin length, and these are often inaccessible for mosquito control purposes.

Pond Depth

Selection of pond depth is usually dictated by the function of the pond, ie. primary, secondary, or evaporation. Adequate allowance must be made for solids deposition, particularly in primary ponds, otherwise excessive or longer term deposits will lead to siltation at the edges and corners, resulting in colonisation by vegetation and thus creating mosquito breeding locations.

Profiling the pond base, with the deepest side at the effluent entry point, can help alleviate the silt problem, particularly if there is a seasonal variation in input. For evaporation ponds, particularly those with earth sides or those which are operated on a continual basis, a minimum depth of two metres or more is recommended. This is to allow for the periodic drowning of any seasonal growth of grasses or semi aquatic vegetation such as *Eleocharis* sp. and *Typha* sp.

Construction Details

Concrete Margins

Vertical or sloping concrete margins have proven to be the most satisfactory engineering means of controlling mosquito breeding by promoting wave action, and maintaining margins free of vegetation and debris.

Vertical concrete walls have proven the most maintenance free and effective in reducing mosquito breeding. Sloping concrete margins have been tried in a number of locations. While better than unlined ponds, they have the drawback that wave action is damped by the slope. Debris and algae and organic matter can build up and enable emergent vegetation to establish. It is important that they have a concrete rim around the top to prevent landward inflow of water and silt, and sealed verges to prevent vegetation growth.

Concrete lining can be precast for remote locations or constructed in situ, and are cost effective. They should be deep enough to allow for wide variation in water level and should have a concrete lined horizontal bench just above the bottom level of the pond, to prevent establishment of vegetation along the margin in the initial stages of operation, and to prevent silt accumulation in the longer term. Sealed verges around the top of the banks are desirable to facilitate maintenance and to prevent entry of soil into the pond. Walled ponds may still have problems with floatables and wind blown debris in the corners and cut off pools near entry and exit points. Truncated corners and multiple or underwater entry and exit points can help to eliminate these latter problems.

Unlined earth banks

Sewage ponds with unlined earth banks have the greatest capacity for mosquito breeding, particularly those with gentle slopes where marginal vegetation can grow. They are accordingly not recommended, except as temporary or emergency measures. The banks should be constructed using low porosity materials such as compacted clay. If neglected, unlined earth banks can become either eroded, or overgrown with grass, shrubs and even trees such as *Acacia*, *Mimosa* and *Melaleuca* sp. Maintenance and corrective measures can be a major problem.

Other Linings

Various systems have been used to line earth banks as a temporary measure to reduce growth of vegetation, but they have not been entirely satisfactory.

Stone pitching of the margins is not satisfactory as it does not offer sufficient deterrent to vegetation growth, and mechanical maintenance of vegetation is subsequently difficult. Overlapping cement sheets have been used, but have problems with breakage and subsequent weed growth. Various types of bituminous or plastic sheeting have also been tried, and most have shown promise as short to medium term solutions. Problems encountered include inadequate anchoring, weed growth, ultraviolet deterioration, and human interference. The more modern ultra-violet resistant heavy duty plastics, anchored with earth mounds back from the rim of the ponds, have been more successful.

Maintenance

New pond systems

Before commissioning sewage pond systems, a general survey of the whole site should be conducted to ensure that mosquito breeding places have not been inadvertently created. Potential mosquito breeding sites include borrow pits formed during pond construction, pooling of water resulting from site drainage works, and pooling caused by road access blocking drainage paths. Any problems should be rectified before the ponds are commissioned.

Pond maintenance

Pond maintenance is a vital part of pond management. The highest levels of maintenance will be required for earth lined ponds with low and seasonally variable effluent flow rates. Some form of maintenance will be required, even for ponds with vertical concrete margins and sealed verges. Even those ponds in favourable locations, with ideal effluent characteristics, must have adequate provision for people and resources to carry out a regular and defined maintenance program.

Aspects of maintenance frequently overlooked include the regular control and removal of vegetation on the margins or the pond verges, the regular removal of floatables and other flotsam from accumulation points, and the repair of cracks and other failures that can allow pooling or increased soil moisture levels on the banks and subsequent vegetation growth.

For some ponds, a program of water level management may be adopted, which alternately floods and strands marginal vegetation or floatables. The form of maintenance will depend heavily on the pond design, effluent parameters, staff experience and staff availability.

Regrettably, it has been the NT experience that regular and adequate maintenance have been sometimes inadequate to prevent mosquito breeding. If there is any anticipation that regular and adequate maintenance can not be carried out, a maintenance-free design should be chosen.

EFFLUENT DISPOSAL OR DISPERSAL

Problems

Insufficient consideration was given to disposal of the effluent in many of the early sewage treatment facilities in the Territory. It was often assumed that 'adequate treatment' in the ponds was sufficient from an operational point, and therefore discharged treated effluent was frequently allowed to run down the nearest flow line. In practice this effluent often formed flooded, overgrown, stagnant pools that created prolific breeding grounds for *Culex* mosquitoes. Examples were the sewage treatment facilities at Coonawarra Naval Base and Nhulunbuy South in the 1970's, where there was a lack of provisions for proper disposal.

In some instances, effluent from sewage treatment ponds was channelled or piped just beyond the perimeter fence or to the nearest available low lying area. In some situations, as at Nhulunbuy, the effluent was directed into sand dunes in the belief that infiltration would provide a satisfactory disposal method. This proved totally inadequate because the high organic loads of the effluent and algae invariably sealed against infiltration and resulted in pooling of effluent throughout the dunes.

Even after the final aerobic treatment in evaporation ponds, the resulting 'treated' effluent still retains a great capacity to breed mosquitoes. An example of this was the uncontrolled release of treated effluent into the Il Parpa Swamp area near Alice Springs during the period 1974-2002. The regular release of effluent created a large permanent vegetated swamp and very high numbers of *Cx. annulirostris* and *An. annulipes s.l*. This area has since been partially rectified by drainage measures in the swamp and a reorganisation of discharge practices (Kurucz et al 2002).

Large Evaporation Ponds

In the Northern Territory evaporation ponds, either designed or of 'ad hoc' design have commonly been used for effluent disposal in inland sites. Large evaporation ponds are rarely full to capacity for the entire year, and in many instances are just bunded areas containing effluent to prevent escape to other areas. Because of their large area, the often variable inflow and the variation in climate, large evaporation ponds often become shallow, flooded swamps with dense weed and reed vegetation for at least part of the year. These ponds can become considerable sources of *Culex annulirostris, Culex gelidus, Culex quinquefasciatus* or *Anopheles annulipes s.l.* Also, evaporation ponds that dry up and are then seasonally inundated during rainy periods can become breeding grounds for floodwater mosquitoes such as *Aedes normanensis*. The numerous aspects to be considered in designing large ponds to reduce the amount of mosquito breeding, include:

- initial and regular removal of all emergent vegetation within the evaporation area:
- levelling of the floor of the evaporation area:
- division of the evaporation area into a number of smaller areas;
- constructing a sloping floor to concentrate the water in a sink' area at the effluent entry point;
- concrete lining of the 'sink' area on the floor of the evaporation area and the lining of embankments.

Incorporating some of these aspects into the initial design can be expensive, but the alternatives are to have a regular maintenance program, which could be more expensive in the longer term. The alternative to well designed evaporation ponds is to consider a different effluent disposal method such as dispersal to land, sophisticated tertiary effluent plants, or effluent re-use schemes.

Small Evaporation Ponds

The use of small concrete lined evaporation ponds can be a very effective method of effluent disposal. The best designs incorporate a series of relatively small ponds that can progressively fill by gravity overflow. Such a system may be expensive to construct, particularly if the whole evaporation area required is relatively large. However, the method has the advantage of being relatively maintenance free and it can better prevent mosquito breeding when there are large seasonal variations in effluent volume.

Disposal to the Sea

Disposal direct to the sea or to a daily flushed tidal area is one of the most suitable methods for effluent disposal to prevent mosquito breeding. The critical aspect for tidal creeks is to ensure there is good drainage at low tides. However dispersal at the end of a relatively long, narrow or tortuous tidal creek can result in effluent build up in the creek which can also be pushed higher up the creek line by incoming tides into areas where mosquito breeding sites can develop.

Disposal onto large flat inadequately flushed tidal areas can create breeding sites for freshwater species of mosquitoes, as well as brackish water species such as *An. farauti s.l.* and *Verrallina funerea*, and salt water species such as *Cx. sitiens, An. hilli,* and *Ae. vigilax,* by creating a complex of fresh and brackish water habitats.

Disposal to Rivers

The suitability of discharge to rivers depends upon the volume of flow in the river, the seasonal variability of flow, and the downstream effects of the disposal. This method is unsuitable when the flow in the rivers or creeks is small or subject to wide seasonable variation, as eutrophication or ecological and vegetation changes will lead to mosquito breeding.

Disposal to Land

<u>Large Sprinkler dispersal</u>

This method has been relatively successful in areas where there have been particular problems with other disposal methods. It is most successful onto areas with well-developed stands of trees on well drained areas with soils of good permeability, but the success will depend on adequate resting of the disposal areas and the rate of volumes of effluent disposed to these areas.

Jabiru provided an example of an initially successful sprinkler dispersal scheme. The final effluent was automatically and periodically dispersed via a system of overhead sprinkler heads, onto a fenced area of open native eucalypt forest. Initial problems from fire damage of above ground plastic pipes and algal blocking of spray heads were rectified by the construction of an underground pipe system with tall metal risers and metal sprinkler heads. Over the longer term, this area became a major source of mosquitoes with dead trees, wet season ponding on-site and in downstream off-site flow lines, and tall, dense and uncontrollable grass-weeds in the dispersal site. It has become obvious that the initial site levelling and draining was not adequate, and off site wet season runoff into the disposal area has compounded the effluent ponding problems. The lack of regular slashing of grass led to intense fires that destroyed the trees, and hence reduced evapotranspiration.

Ideally, sites should be relatively level but with good drainage during rainy periods. Off site run-off should be directed away from the disposal site. There should be adequate sprinklers to have areas off-line for up to a week for drying and weed maintenance. Feeder lines to sprayheads should be laid out along contours, rather than at right angles to contours, so that water retained in the lines after the finish of spraying will remain in the lines rather than drain to the lowest sprinkler head. The sprinkler heads should be positioned on mounds of crushed rock to enable better infiltration and to reduce the probability of creating permanent pools of effluent near the sprinkler heads.

The area required will depend upon the volume of effluent to be disposed, and the long-term absorption capacity of the soil and the vegetation. In monsoonal areas, additional site selection and preparation is required to ensure that effluent contaminated runoff cannot pool in nearby flow lines or creeks.

Sprinkler dispersal of effluent can be used for tree and pasture growing or landscape watering, but the National Health and Medical Research Council Guidelines for the Reuse of Waste Water must be adhered to (NH & MRC, 1979). Tertiary chlorination has been used to provide a high quality effluent for drip irrigation and recreational area watering at Yulara. Sprinkler disposal using large spray heads has been successfully used on Blatherskite Park in Alice Springs, but potential problems exist in this area because of the high salinity of the water and rising water tables, which requires regular monitoring of the water table and suspension of irrigation when water tables are high.

Small sprinkler dispersal

When disposing of small volumes of effluent, the use of mini sprinklers fed by irrigation lines is a suitable alternative to drip irrigation. Small sprinklers tend to promote more evaporation compared to drippers by wetting larger areas and allowing greater soil infiltration. In addition it is easier to spot blockages with mini sprinklers compared to drippers. There is however a need to have regular maintenance of dispersal area to prevent grass and weeds from smothering the sprinklers.

Drip Irrigation

Disposal by dripper systems requires a high standard of effluent, usually with a tertiary chlorine treatment, to prevent dripper blockage by algae. Dripper systems can be used for both small or large scale disposal, but is usually only suitable for plantation situations where the vegetation growth at each dripper site can be practically and economically maintained. Drippers held off the ground can reduce root blockages of the drippers. Generally dripper systems are only suitable for the dispersal of small volumes of effluent per unit area or periodic release, and are generally expensive because of their high maintenance requirement.

There has been past issues with drip irrigation at Hermansburg, and Kings Canyon (Whelan 1994). The continuous volume of effluent released in both situations was too high for drip disposal, which created effluent ponding and mosquito breeding. Both systems did not receive adequate maintenance to prevent blockages of drippers, and treatment areas were not appropriately spelled. In both instances, a switch to sprinkler irrigation was required to adequately dispose of the required volumes of effluent over a wider area in the irrigation area.

This method is useful for relatively small volumes of effluent on sandy soil in low rainfall areas. A feeder channel is used to deliver effluent to a ploughed area of small furrows sloping gently away from the feeder channel. Disposal is by infiltration into the sandy soil. When infiltration becomes less efficient, the flow is directed to an adjacent ploughed area, and the original area is allowed to dry out and is reploughed.

This system requires a considerable amount of attention and maintenance, but was used successfully at Perth Airport, largely due to the sandy soils and relatively low effluent volumes per unit area.

Channel Infiltration

In this system, permanent infiltration channels are constructed and effluent flow is directed down a number of groups of channels which are alternatively spelled and maintained. The method can be used on less porous soils than is possible for furrow irrigation. If this method is to be used for the irrigation of tree or bush crops, intensive monitoring is required to ensure viability of the crop in the long term. Small scale use of this method has been tried at Batchelor and at the Katherine Abattoirs, but proved to be relatively labour intensive. A variation of the method has been used on a larger scale at Il Parpa in Alice Springs, for the growth of eucalypt trees. Problems on the larger scale have included high labour input, weed control in the channels, siltation in the feeder channels, rising salinity levels and rising water tables.

Flood Bay Irrigation

The degree of land preparation for flood bay irrigation is usually considerable, as a system of correctly graded flood bays is necessary to allow for efficient flooding and to prevent pooling at the end of the flood bays. The bays are periodically flooded and the effluent is allowed to evaporate or infiltrate in the bays over a period of four to five days. This method has been used successfully to grow eucalypts in Ilparpa in Alice Springs. Problems with flood bay irrigation arise during extended rainy periods, when extended flooding of the bays can occur and can result in mosquito breeding. A more sophisticated delivery system for a flood disposal method has been designed for Gapuwiyak. It incorporates an automatic siphon and a distribution drain designed to release effluent evenly over a very large flood bay.

Vegetated Treatment Ponds

Vegetated treatment or polishing ponds, using large aquatic plants such as Salvinia (water lettuce) or Eichornia (water hyacinth) have been used overseas, but many of these have faced major problems with the maintenance or removal of vegetation, and have become major mosquito breeding sites. This has resulted in expensive re-design or maintenance issues, or in some instances they have had to be decommissioned. There has been some success with prostrate water plants such as duckweed (*Lemna* sp) which can form total cover over ponds, thus denying suitable oviposition sites and preventing air access for larvae. However the pond sizes need to be relatively small so that the duckweed is not blown into corners by wind and wave action.

BIOLOGICAL CONTROL

Biological control, though not usually applicable to primary ponds, can be a very efficient means of controlling mosquito larvae in secondary and evaporation ponds.

The major biological control agents are fish, aquatic beetles and aquatic bugs. Fish can control mosquito larval numbers directly by eating the larvae, or indirectly by eating or disturbing algae or aquatic weeds which provide protection from other predators or wave action. Fish are usually only suitable for the higher oxygenated waters. Several species have shown promise in the Northern Territory, including the herbivorous bony herring (*Nematalosa erebi*), which was successful in reducing surface algae in the former Ludmilla sewage ponds in Darwin, and rainbow fish (*Melanotaenia* sp.), which was a very efficient larval predator in the final evaporation ponds for the Ranger sewage treatment. Other suitable fish species includes the blue eyes (*Pseudomugil* sp.) and gudgeons (*Mogurnda* sp, *Hypseleotris* sp.).

It is essential that marginal vegetation such as couch grass and reeds be eliminated or kept to a minimum, so that fish can have physical access to the mosquito larvae. Actively growing *Eleocharis* sp. and *Typha* sp., with upright stems, may not restrict access. However, when these weed species die or lodge over, they prevent physical access for the fish and enable mosquito breeding.

Aquatic beetle larvae (Family:*Carabidae*) and aquatic bugs (Family:*Belostomatidae*) are the most efficient mosquito larvae predators in secondary and evaporation ponds. The aquatic bugs are able to live in higher organic water than the aquatic beetle larvae, and can be present in very high numbers. Again, physical impedance by thick vegetation at the margins will reduce the effectiveness of these predators. These insect predators can achieve almost total control of mosquito larvae in sewage ponds of suitable water quality, and narrow or sparse vegetation margins.

CHEMICAL CONTROL

The aim of chemical control of mosquito larvae should be to apply the minimum amount of insecticide to prevent the production of adult mosquitoes. Chemical control should not be used as a long term strategy in sewage treatment areas, in order to avoid insecticide resistance and unwanted effects on non-target organisms. However, it may be necessary to apply insecticides during the initial operational period or when proper maintenance has not been carried out. The insecticides of choice to control mosquito larvae in sewage ponds and effluents are either temephos, methoprene, *Bacillus thuringiensis* var *israelensis* (*Bti*) or *Bacillus spaericus* (*Bs*), with *Bs* having advantages over Bti due to its persistence after application. Correct rates for temephos must be strictly adhered to, as over treatment can kill fish and other aquatic insects.

MOSQUITO SAMPLING

Regular inspections for mosquito larvae should be carried out in sewage ponds and their effluents to determine whether breeding is occurring and to determine the necessity for weed control or chemical control. Chemical control with temephos or *Bti* may be necessary at weekly or longer intervals. Methoprene may give longer control if applied as pellets or briquettes. In general briquettes will give the longer residual effect but need to be tethered in netting on sticks near the surface of the water, so that they do not sink into the silt or mud. Methoprene applications do not necessarily kill larvae or pupae, so an experienced operator is required to assess treated areas or take pupal samples and check emergence efficiency. The presence of late instar or pupae with the first two insecticides above indicates that control should have been carried out at shorter intervals. If only first and second instar larvae are present, then either biological control is quite efficient, or the mosquitoes have just started to breed in that area, and continued monitoring is necessary.

Mosquito larval or pupal samples can be collected by dipping into sheltered vegetated zones with a soup ladle. Generally care should be taken not to disturb the larvae by shadows or surface water agitation before dipping, and multiple dips should be performed to adequately assess population numbers. Any larvae collected should be stored in small vials with 70% alcohol or methylated spirits, together with information on collection locality, site, date and collector. Larval or pupal identifications should be checked by an entomologist.

Adult specimens collected by biting or harbourage collections can be sent for identification, packed loosely in tissue paper in a small box, together with all the details of collection.

Chironomid midge pupae or adults are often mistaken for mosquitoes and their presence has often resulted in control programs being instituted where none has been necessary.

SUMMARY

In the past, the design of sewage treatment ponds and their effluent disposal facilities in the NT has been largely dictated by engineering and microbiological principles. Little attention was paid to the possibility of breeding mosquito populations close to residential areas, with the resultant risk to public health. Appreciation of this potential risk followed by the application of design principles and adequate maintenance can reduce this problem. Biological control can then operate effectively. Chemical control can be used for start-up or emergency situations, although should not be relied on for ongoing mosquito control in ponds or effluent disposal areas.

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APPENDIX C: PPE REQUIREMENTS

Standard Personal Protection Equipment

PPE	Details
Avoidance	Avoid being on site during peak feeding periods. For mosquitoes, peak biting is usually from sunset to sunrise with peak biting activity usually in the hour or two after sundown and hour or two before sunrise. Depending on the season, day biting mosquitoes are also likely to affect the site.
Clothing	Full length trousers, socks and shows, and long sleeved shirts to be worn by all Site personnel and visitors. Lighter coloured clothing is less attractive than dark clothing. Clothing impregnated with permethrin or bifenthrin insecticide will offer more substantial protection.
Netting	Normal insect nets will exclude mosquitos but not midges. Screens, nets and tents (if used on the site) can be impregnated or sprayed with permethrin, bifenthrin or any DEET based repellent to repel mosquitoes and provide more substantial protection.
Repellents	Repellents that are effective include those with active constituent of at least 10% Deet (diethyl toluamide) or 9% Picaridin. Repellents have a limited duration of effectiveness and need to be reapplied every 2-4 hours. Other repellents that are not applied directly to the skin include coils, oil lamps, electric vapour pads impregnated with insecticide. Mosquito lanterns and butane gas powered mosquito repelling devices can provide some very good results in repelling mosquitoes and biting midges.
Use of lights	Use of yellow or red lighting around buildings to reduce attractiveness to biting insects.

APPENDIX D: BITING INSECT ECOLOGY

Northern Territory Government
Department of Health and Community Services

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

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Minor update April 2007

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

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1997
Minor update January 2004

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

Flight range

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

Species identities

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

Pest levels

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

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

MAJOR PEST AND VECTOR MOSQUITO SPECIES

IN THE TOP END OF THE NT*

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

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

*** Adapted and revised from P. Liehne et al. “Mosquitoes and biting midge investigation, Palmerston 1982 -85”.**

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

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

SPECIES	IMMATURE STAGES	ADULT STAGES
An. annulipes s.l.	Eggs laid singly on water surface; any freshwater body but numerous near *Eleocharis* reed swamps; temporary or permanent; some receptacles; larvae float on water surface and feed on particles on top of water.	Feeds on a variety of mammals include cattle and humans. Bites at night, especially dawn and dusk. Flies up to 2 km from breeding site; rests in cool shady locations such as stream margins, drains etc.
An. bancroftii	Eggs laid singly. Dark larvae, feeds at water surface; found in heavily shaded fresh to slightly brackish ground pools or swamps, especially in paperbark or *Eleocharis* reed swamps.	Feeds on all mammals readily; will fly up to 4 km from breeding site; bites any time near breeding site, nightly or in shade elsewhere.
***An. farauti s.l.* (Includes *An. farauti, An. hinesorum* and *An. torresiensis*)**	Eggs laid singly on surface; larvae feed on water surface. *An. farauti* breeds in brackish water; *An. hinesorum* and *An. torresiensis* breed in freshwater swamps and pools. Larval habitat often sunlit.	Bites readily at night; feeds on humans, other mammals and birds. Will fly approximately 2 km from the breeding site.
An. hilli	Eggs laid singly on surface; larvae feed at surface; sunlit or shaded brackish to saline ground pools or swamps. Numerous in *Schoenoplectus* reed swamps near coast.	Bites humans, cattle and horses; mainly after sunset. Disperses up to 4 km from breeding site.
An. meraukensis	Eggs laid singly on surface of water; larvae feed at the surface; usually in freshwater *Eleocharis* reed swamps, sunlit or shaded.	Bites readily at dusk, feeds on humans and other mammals.
Ae. vigilax	Eggs deposited singly in the mud or near plant stems in suitable habitats; breeds in tidal pools and marshes, usually those filled by tides in upper tidal zone associated with *Schoenoplectus littoralis* or landward ill draining mangrove areas; larvae browse on substrate.	Major and severe pest species; adults feed very readily on humans, other mammals and birds, day or night; will fly up to 60 km, highest numbers within 5km of breeding sites; shelter in thick vegetation.
Ae. kochi	Eggs laid singly on the axils of *Pandanus* leaves. Larvae feed on detritus and debris in the water collected in the axil space.	Severe pests near the breeding sites. Do not disperse far from the breeding habitat.
Ae. normanensis	Eggs deposited singly in drying mud substrate in poorly draining floodways. Pale larvae can be inconspicuous in colloidal clay suspension water. Tend to dive to bottom when disturbed. Feed by browsing on substrate. Mainly inland rural habitats.	Major pest species. Extreme numbers after flooding rains for 1- 2 weeks. Feeds readily on humans and other mammals, mainly in evening and night. Will fly 3 - 5 km in pest numbers.
Ae. notoscriptus	Eggs laid singly on the sides of tree holes. Dark larvae hang from the surface by siphon and feed by browsing on the substrate. Common in domestic receptacle habitats.	Feeds on humans and all mammals; bites day or evening in the cool shade. Does not disperse widely.
Cx. annulirostris	Eggs deposited as rafts of up to 200 on the water surface; larvae hang from surface and feed on suspended particles; breed in freshwater pools and swamps with emergent vegetation temporary or permanent; will colonize domestic receptacles and breed readily in semi polluted water in storm drains or sewage effluent with vegetation.	Adults are the most common species encountered in the NT and are present throughout the year; feed at night and will bite humans, other mammals and birds; will fly distances of up to 10 km from the breeding site, although common up to 4 km from breeding site.
Cx. quinquefasciatus	Eggs laid as rafts on the surface; breeding grounds are polluted to fresh domestic waters; major sources are septic tanks, leach drains, primary sewage ponds and other polluted ground waters.	Severe domestic pest of humans but will feed on poultry and dogs as well; will feed and rest indoors; bites at night; flies up to 1 km from breeding site.

SPECIES	IMMATURE STAGES	ADULT STAGES
Cx. sitiens	Eggs laid as rafts on surface; brackish coastal ground pools under tidal influence with or without vegetation; larvae hang from the surface and rest on bottom. Feed on suspended matter or on substrate.	Bites mammals and birds at night; pest near coast, will fly up to 5 km but common within 2 km of breeding site.
Cq. xanthogaster	Eggs laid as small raft on the surface; larvae attach themselves to the stems of aquatic plants by a modified siphon and obtain oxygen from the plants; breed in semi-permanent to permanent swamps with emergent vegetation; associated with *Eleocharis* and *Typha* reeds, water lilies and paperbark; larvae feed on suspended material in the water.	Adults are strong fliers and will disperse widely up to 3 - 5 km. Readily feed on birds and mammals including humans; rest in cool vegetation and bite mainly at dusk, also shade during day. Strongly attracted to light and easily disturbed.
Ma. uniformis	Eggs laid as small cluster attached to the under surface of floating leaves water lilies and plant stems; larval habitats and breeding area similar to *Cq. xanthogaster*.	Adults bite humans, other mammals and birds readily at night. Severe pest in cool shade near breeding site during the day and evening; generally does not fly more than 1 - 2 km from breeding sites; strongly attracted to light; adults rest in dense vegetation; pest in the wet season near breeding areas only.
Ve. funerea	Eggs laid singly on moist substrate at edge of breeding area, usually shaded with some salt influence. Dark larvae hang from water surface, generally feeding by browsing on the bottom of the water body.	Vicious biter in cool shaded vegetation near breeding site in day and in evening. Does not continue biting in sun. Do not disperse far from the breeding habitat.
*** Adapted, revised and expanded from P. Liehne et al. "Mosquitoes and biting midge investigation, Palmerston 1982-85". ^ Applicable for general area of Top End north of and including Mataranka, Larrimah, from Victoria River to Roper River mouths.**		

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

PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT
PEST AND DISEASE VECTOR STATUS
Peter Whelan 1997
Medical Entomology Branch, Department of Health and Community Services

Species/	**Nuisance status**	**Disease Vector Status**		**Potential pathogens* vectored in the NT**	**Peak Abundance**
(Common Name)		**Current**	**Potential**		
Aedes vigilax (Salt marsh mosquito)	+++++	+++	++++	RRV BFV	September - January
Aedes normanensis (Floodwater mosquito)	+++++	+++	++++	RRV BFV	January - April
Culex annulirostris (Common banded mosquito)	+++++	+++++	+++++	MVEV, KUN RRV, BFV, JEV, others	January - August
Culex gelidus (The frosty mosquito)	+	+	+++	MVEV, KUNV, RRV BFV, JEV, others	January-April
Culex palpalis (Freshwater banded mosquito)	+++	++	+++	MVEV, KUNV RRV, BFV, JEV, others	January-August
Anopheles bancroftii (Black malaria mosquito)	+++	Nil	+	Malaria (possible)	February - July
Coquillettidia xanthogaster (The golden mosquito)	+++	Nil	Nil	None known	March - August
Mansonia uniformis (Waterlily mosquito)	+++	Nil	Nil	None known	March - June
Anopheles farauti s.l. (Australian malaria mosquito)	+	Nil	+++++	Malaria (probable)	March - June
Culex quinquefasciatus (Brown house mosquito)	+++	+	+	MVEV (possible)	January - Jun
Aedes notoscriptus (Receptacle mosquito)	+	+	++	RRV (probable)	Jan - June
Verrallina funerea (Brackish water mosquito)	+++	+	++	RRV, BFV (probable)	Oct - Jan

LEGEND			
RRV - Ross River virus BFV - Barmah Forest virus	MVEV - Murray Valley encephalitis virus JEV - Japanese encephalitis virus KUNV - Kunjin virus	+ Minor pest on Disease Potential	+++++ Major pest on Disease Potential

* The ability to vector these pathogens has not necessarily been established

PROBLEM MOSQUITO SPECIES IN THE TOP END OF THE NT
INDICATIVE PEST LEVELS
Peter Whelan 2002
Medical Entomology Branch, Department of Health and Community Services

Species	**Main distribution**	**Peak Period**	**CO_2 Trap at Residence ***	**CO_2 Trap at Monitoring Site #**
Aedes vigilax	Top End, north of Wave Hill, Larrimah and Borroloola	September - January	20	50
Aedes normanensis	Subcoastal Top End south to Ti Tree	January - April	30	50
Culex annulirostris	NT wide	January to August	50	600
Anopheles bancroftii	Top End north of Victoria and Roper River, south to Larrimah	February - July	30	300
Coquillettidia xanthogaster	Top End north of Victoria and Roper River, south to Larrimah	March - August	30	300
Mansonia uniformis	Top End south to Larrimah	March - June	30	200
Anopheles farauti s.l.	Top End north of Port Keats inclusive, Pine Creek, and Numbulwar	March - June	30	50
Culex quinquefasciatus	NT wide, primarily near residential areas	January - June	20	30
Aedes notoscriptus	NT wide, generally near residential areas	January - June	30	30
Verrallina funerea	Top End primarily coastal and sub-coastal but occasionally south to Larrimah	Nov - March	20	200

Pest Levels

* Indicative significant pest threshold levels (mosquitoes per CO_2 trap per night) at residence for relatively unprotected people at peak biting times.

Indicative significant pest threshold levels (mosquitoes per CO2 trap per night) in residential areas from monitoring sites close to but outside of residential areas, and for monitoring sites between the residential areas and major mosquito breeding areas that are within 2km of residential areas.

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

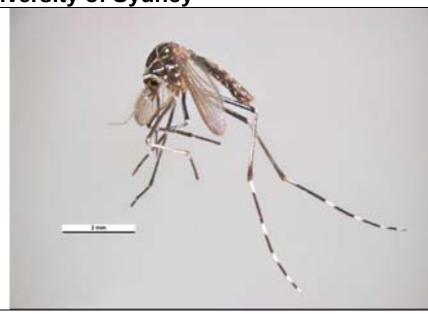
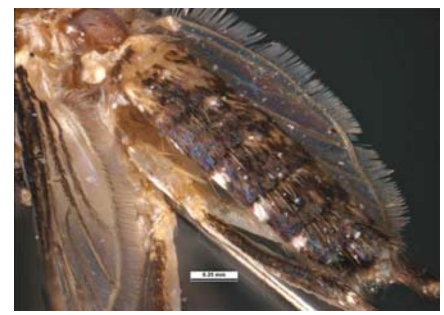
APPENDIX E: IMAGES OF SIGNIFICANT BITING INSECT SPECIES

Images of significant biting insect species

Name	Lateral view	Dorsal view	Abdomen view
Anopheles annulipes s.1	 **Simon Hinkley and Ken Walker, Museum Victoria**		
Anopheles farauti s.l. *(Australian malaria mosquito)*			
Anopheles hilli	 **University of Sydney**		

Name	Lateral view	Dorsal view	Abdomen view
Anopheles meraukensis	 **University of Sydney**		
Culex sp.		 **Harding, C. MAF Plant Health & Environment Laboratory**	
Culex annulirostris (Common banded mosquito)	 **Harding, C. MAF Plant Health & Environment Laboratory**		

Name	Lateral view	Dorsal view	Abdomen view
Culex quinquefasciatus (Brown house mosquito)			
Culex sitiens	 **University of Sydney**		
Coquillettidia xanthogaster (The golden mosquito)	 **University of Sydney**		

Name	Lateral view	Dorsal view	Abdomen view
Mansonia uniformis (Waterlily mosquito)	 **University of Sydney**		
Ochlerotatus notoscriptus (Container mosquito)			
Ochlerotatus tremulus			

Name	Lateral view	Dorsal view	Abdomen view
Ochlerotatus vigilax (Salt marsh mosquito)			

Source: Unless stated, all images are attributed to S. Hinkley and K. Walker at the Museum of Victoria

APPENDIX F: ARBOVIRUS INFORMATION

Arboviruses in the Northern Territory

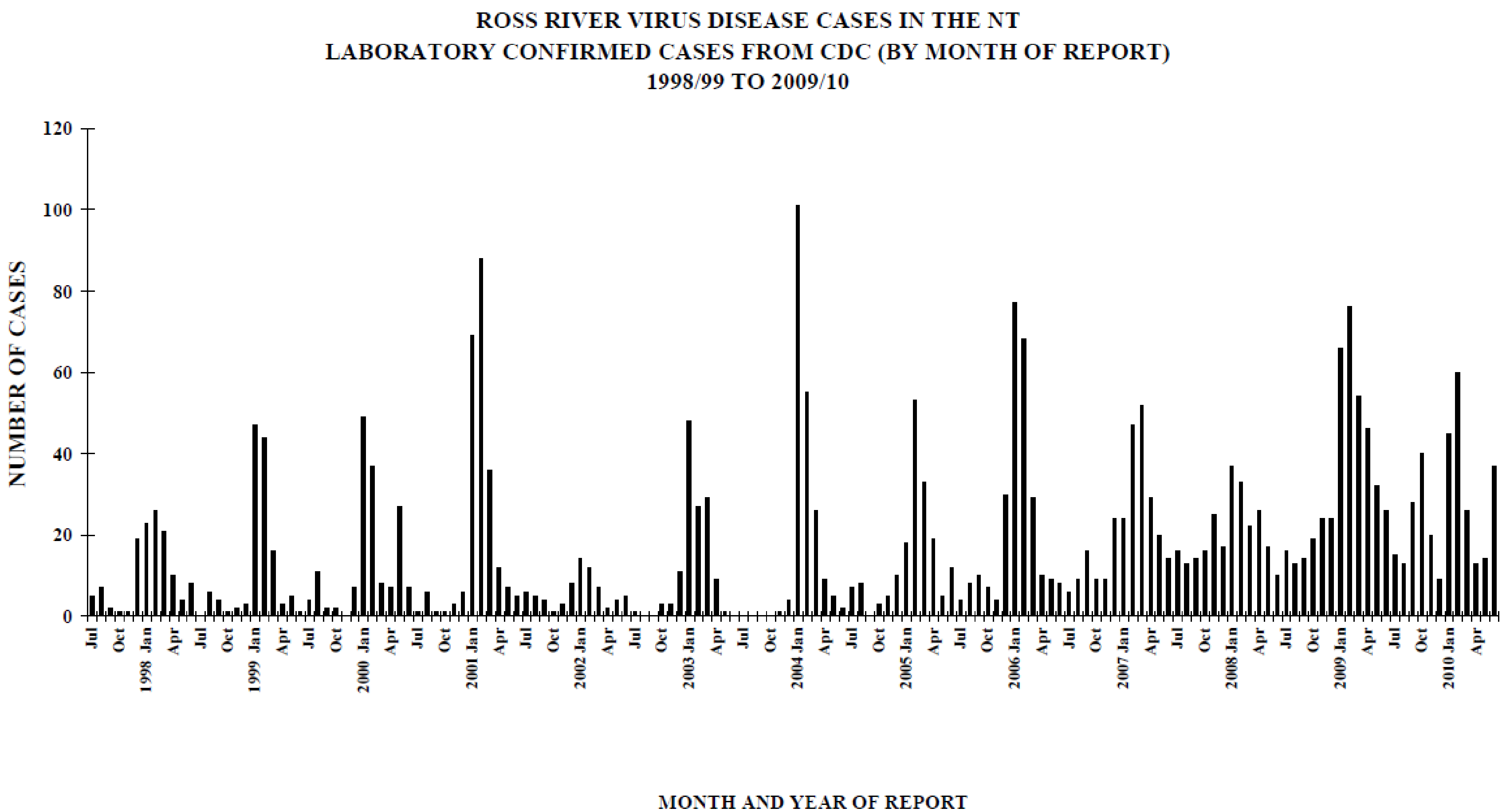
Virus	Description	Symptoms	Risk of transmission	Principal arboviral carriers	Peak risk period	Probable main risk period
Murray Valley encephalitis (MVEV)	Most serious arbovirus in the NT (CDC, 2010a); rare; outbreaks occur sporadically towards the end of the wet early dry season; usually 1 or 2 cases a year in the NT (CDC 2012b)	Severe headache, high fever, drowsiness, tremor, seizures (especially in young children); potentially leading to delirium, coma, permanent brain damage or death (CDC 2010a)	The disease develops in ~1 in 1000 people bitten	*Cx. annulirostris*	Feb–May	Jan–Jul with peak in Mar–May (Whelan 1997)
Kunjin virus (KUNV)	Arbovirus present in the NT; rare but generally milder than MVEV (CDC 2012b)	Swollen and aching joints, fever, headache and rash; and potentially neck stiffness and delirium; potentially leading to encephalitis (NSW Health 2011)	Risk is considered similar to that of MVEV	*Cx. annulirostris*	Feb–May	Jan–Jul
Ross River virus (RRV)	Most common arbovirus in Australia and the NT (Whelan et al., 2008); usually 250–450 cases a year in the NT (CDC 2012b)	Painful or swollen joints (particularly in the hands, ankles and knees), sore muscles, aching tendons, skin rash, fatigue, fever, headache and swollen lymph nodes (CDC 2012a)	Risk is high, due to the wide distribution and abundances of the arboviral carriers in coastal NT	*Ae. vigilax* and *Cx. annulirostris*	Jan–Mar	Dec–Jun
Barmah Forest virus (BMV)	Second most common arbovirus after RRV (CDC, 2009); similar to RRV but less common; usually 50–130 cases a year in the NT (CDC 2012b)	Symptoms are similar to that of RRV (CDC 2012b)	Risk is considered similar to that of RRV	*Ae. vigilax* and *Culex. annulirostris*	Jan–Mar	Oct–Jul with peak in Jan–Mar (Whelan 1997)

Malaria	Endemic malaria has been eradicated in the mainland NT, but the possibility remains of it entering via travellers and imports or vessels transporting exotic arbovirus carrier species, e.g. *Aedes aegypti* (CDC 2010b)	Fever, headache, chills and vomiting; potentially leading to severe anaemia, respiratory distress in relation to metabolic acidosis, or cerebral malaria, multi-organ damage and death (CDC 2010b; WHO 2005)	Risk is low in the NT, as the virus is not known to be present	*A. farauti; A. annulipes s.1.; An. hilli; An. bancroftii; and An. amictus*	Low risk at all times	Low risk at all times

Adapted from CDC, 2010, 2011 and 2012; DLP 2011; NSW Health 2011; Warchot and Whelan 2004; and WHO 2005

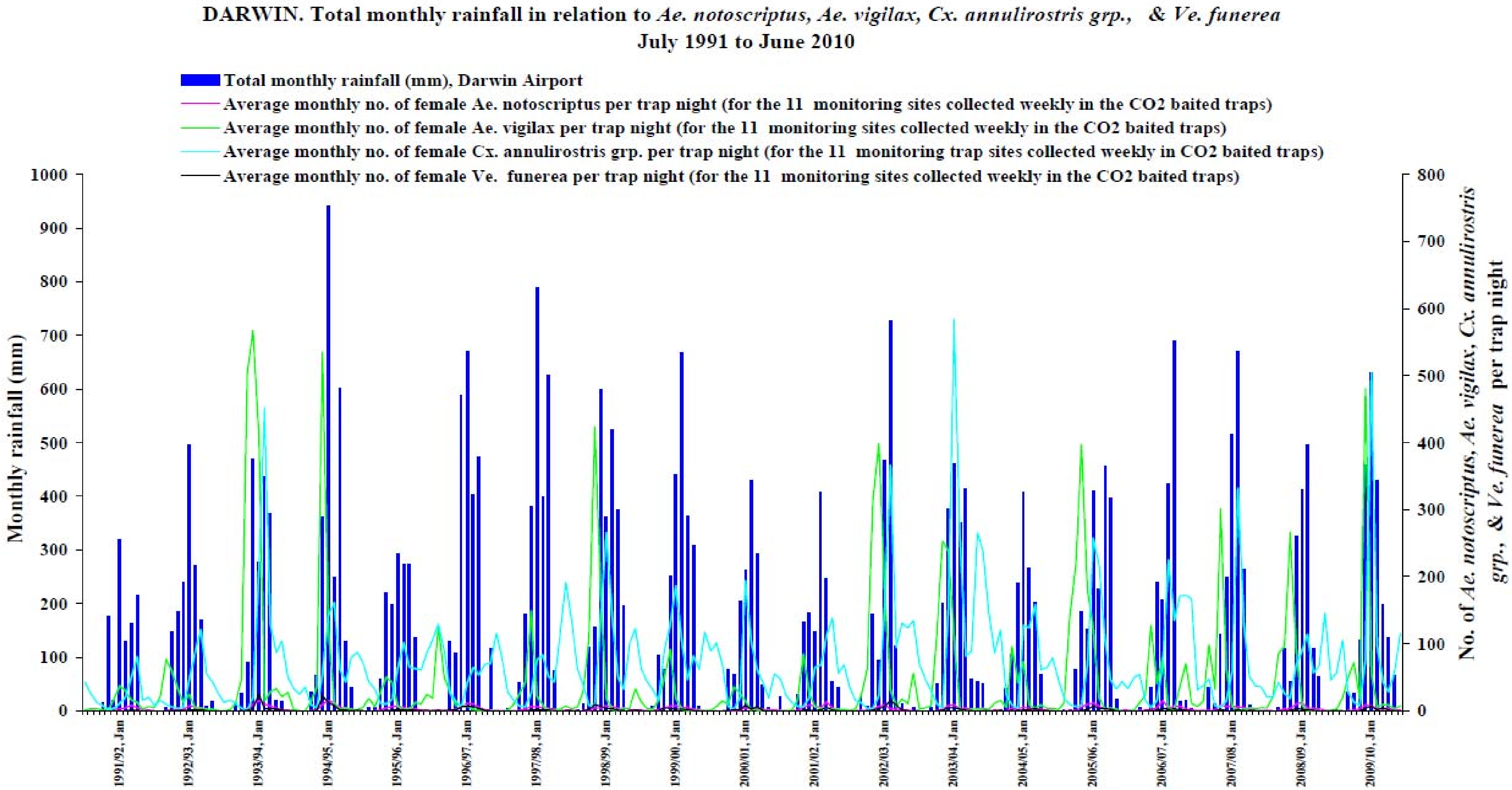
APPENDIX G: MONTHLY ROSS RIVER VIRUS OCCURRENCE AND BITING INSECT ABUNDANCES

Plate 1: Ross River Virus Disease Cases in the Northern Territory



Source: Medical Entomology, 2010

Plate 2: Total Monthly Rainfall and Relationship with Numbers of Mosquitoes



Source: Medical Entomology, 2010

APPENDIX H: CALENDER OF HIGH-RISK PERIODS

Northern Territory Government

DEPARTMENT OF **HEALTH**

Biting Midge Pest Calendar for the Coastal Top End NT 2012

Culicoides ornatus

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

See www.health.nt.gov.au/Medical_Entomology/index.aspx

Department of **Health** is a Smoke Free Workplace

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

Biting midges

There are a number of marine biting midge pest species around the coast of the NT, and they can be appreciable pests in or close to their particular breeding sites. The mangrove biting midge, *Culicoides ornatus,* causes the greatest pest problems around the coast of northern Australia. Areas mostly affected are extensive coastal and tidal river mangrove areas and adjacent areas up to 2km inland from the landward margin of mangrove areas.

Breeding sites of the mangrove biting midge

Primary breeding sites are in the upper neap tide level on the mud banks of the upper reaches of small tidal creeks, from downstream and up to the creek line where the canopy closes over. The prime breeding sites are associated with mud and *Rhizophora* and *Avicennia* mangrove pneumatophores. The more of these small mangrove creeks in an area (eg dendrite patterns of creeks), the more area of prime biting midge breeding, and the greater potential for severe pest problems. Minor wet season breeding sites exist in the back of the creek bank in the *Bruguiera/Ceriops* mangrove zone. Less productive breeding sites include the muddy foreshore areas with wide and extensive areas of the woodland mangrove species *Sonneratia alba* present. Sandy foreshore areas with fringing mangroves are not appreciable breeding sites of the mangrove biting midge but can be sources of other biting midge species.

Local problem sites in Darwin

The mangrove biting midge may be a nuisance all around the NT coast within 2 kilometres of extensive areas of coastal mangroves containing numerous small feeder creeks. Mangrove creeks and areas in Darwin and Palmerston that have midge activity include:

- Mangrove areas within 1 km of Sadgrove Creek including the Winnellie industrial area and Bayview Haven locality, Reichardt Creek, Hudson Creek, around the lower areas of Berrimah including the Railway terminal and east Arm wharf, Elizabeth River from Wickham Point to Virginia including near Palmerston, the mouth of Buffalo Creek, the Lee Point and Muirhead lower fringe areas (high midge activity) and Middle Arm from Channel Island to Berry Springs.
- Palmerston rural residential areas within 1 km of harbour–fronting mangroves (high midge activity), including the Marlow Lagoon area and near the Archer ovals.
- Within 500 m of the lowest reaches of Rapid Creek and Ludmilla Creek (moderate midge activity).
- Suburban border areas of the Palmerston suburbs of Durack, Driver, Moulden, Archer, and Bellamack (moderate midge activity).

Seasonal occurrence

Mangrove biting midge abundance varies greatly during the month, with highest numbers occurring 3 days either side of the full moon and to a lesser extent 3 days either side of the new moon.

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

Biting midge numbers

Biting midge numbers exceeding 1,000 *C. ornatus* in one CO2 baited EVS trap per night is considered a high pest problem, with numbers exceeding 5,000 per trap night indicating a severe pest problem. High primary peaks of biting midges can be expected between August and December around the full moon, with average numbers within 2km of extensive areas of mangroves with primary breeding sites of 15,000 to 25,000 per trap night, and high secondary peaks of 5,000 to 15,000 around the new moon. Moderate primary peaks of 1,000 to 5,000 can be expected between January and July around the full moon, and moderate secondary peaks of 300 to 1,000 around the new moon. Areas of mangroves with less prime breeding sites will experience lower pest levels.

Biting midge bites

Biting midges do not transmit diseases to humans in Australia but scratching of the bites may lead to secondary bacterial infection. *Culicoides ornatus* bite in the highest numbers in the 2 hour period before and after sunrise, and the 2 hour period before and after sunset. However, bites can also occur at other times and during the day in or adjacent to their primary breeding sites.

Self protection

Personal protection, such as full-length trousers, long sleeved shirts, socks and shoes, and the use of insect repellents containing DEET or Picaridin will generally be required within 2 km of their prime breeding sites. The precaution and application advice on product labels should be followed, as some repellents are not recommended for young children. Protection can also be obtained with the use of insecticide pad products such as mosquito lanterns or electric plug in devices, which are heated and create a relatively narrow protective zone. Barrier sprays near outdoor recreation or relaxation areas, such as bifenthrin sprayed on screening shrubs and external walls and fences up to 2m high can offer very good premise and yard protection for periods up to 6 weeks (Standfast et al. 2003).

Pest calendar

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

References

Standfast H., Fanning I., Maloney L,. Purdie D. and Brown M (2003). 'Field evaluation of Bistar 80SC as an effective insecticide harbourage treatment for biting midges (*Culicoides*) and mosquitoes infesting peridomestic situations in an urban environment'. *Bull. Mosq. Control Assoc. Aust. Vol. 15 (2).*

Whelan PI (2010). 'Personal protection from mosquitoes and biting midges in the NT'. DHF. Available at:

http://digitallibrary.health.nt.gov.au/dspace/handle/10137/264

High pest period (August to December)

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

(Pest rank 1)

Days highlighted in red indicate expected highest primary peaks of the pest biting midge *Culicoides ornatus* within 2km of extensive prime breeding sites. These extremely high biting midge pest levels can occur in the late dry season (August to December) in the days around the full moon and present a very high to severe pest problem.

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

(Pest rank 2)

Days highlighted in orange indicate expected high secondary peaks of the pest biting midge *Culicoides ornatus* within 2km of extensive areas of prime breeding sites. These high biting midge levels can occur in the late dry season (August to December) in the days around the new moon. *Culicoides ornatus* numbers are slightly lower compared to the numbers during the primary peaks in those months but still present a high to very high pest problem.

Moderate pest period (January to July)

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

(Pest rank 3)

Days highlighted in yellow indicate expected moderate primary peaks of the pest biting midge *Culicoides ornatus* within 2km of prime breeding sites. These moderate biting midge pest levels can occur in January to July around the full moon, with highest levels in January.

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

(Pest rank 4)

Days highlighted in blue indicate expected moderate secondary peaks of the pest biting midge *Culicoides ornatus* within 2km of prime breeding sites. These moderate to low biting midge pest levels can occur in January to July around the new moon, with highest levels in January.

For more information on biting midges or personal protection, please contact:

Medical Entomology, CDC, DoH Darwin on (08) 89228901

DEPARTMENT OF **HEALTH**

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

AUSTRALIA, NORTH COAST – DARWIN 2012

LAT 12° 28' S LONG 130° 51' E

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

JANUARY

Date	Day	Moon	Time	m	Time	m	Time	m	Time	m
1	SU	◑	0518	2.62	1057	5.39	1624	3.14	2251	6.08
2	MO		0605	2.75	1158	5.09	1720	3.67	2327	5.67
3	TU		0702	2.81	1321	4.95	1845	4.07		
4	WE		0021	5.28	0813	2.74	1518	5.18	2022	4.20
5	TH		0148	5.06	0927	2.52	1630	5.65	2204	4.04
6	FR		0319	5.14	1027	2.19	1715	6.12	2305	3.74
7	SA		0415	5.41	1113	1.82	1753	6.53	2345	3.43
8	SU		0458	5.74	1153	1.48	1829	6.90		
9	MO	○	0019	3.12	0538	6.07	1229	1.20	1904	7.21
10	TU		0052	2.82	0617	6.36	1304	1.01	1937	7.43
11	WE		0128	2.53	0655	6.59	1335	0.94	2009	7.56
12	TH		0205	2.27	0735	6.71	1407	1.02	2039	7.58
13	FR		0243	2.07	0816	6.73	1438	1.24	2107	7.50
14	SA		0323	1.93	0900	6.62	1511	1.63	2135	7.30
15	SU		0405	1.89	0948	6.39	1545	2.15	2205	6.99
16	MO	◐	0451	1.94	1042	6.07	1624	2.77	2239	6.59
17	TU		0541	2.06	1146	5.71	1717	3.42	2319	6.12
18	WE		0644	2.19	1311	5.47	1844	3.96		
19	TH		0019	5.66	0808	2.20	1505	5.62	2044	4.11
20	FR		0201	5.40	0936	1.98	1633	6.13	2223	3.82
21	SA		0337	5.56	1046	1.61	1733	6.68	2332	3.36
22	SU		0442	5.92	1141	1.25	1821	7.15		
23	MO	●	0022	2.88	0536	6.30	1226	0.99	1902	7.48
24	TU		0104	2.47	0624	6.61	1304	0.88	1937	7.66
25	WE		0142	2.15	0709	6.81	1339	0.93	2008	7.69
26	TH		0217	1.94	0750	6.86	1410	1.15	2035	7.58
27	FR		0251	1.85	0828	6.78	1436	1.50	2058	7.37
28	SA		0323	1.88	0903	6.57	1458	1.94	2117	7.08
29	SU		0354	2.00	0938	6.28	1514	2.41	2136	6.73
30	MO		0425	2.19	1016	5.92	1534	2.91	2157	6.32
31	TU	◑	0501	2.43	1100	5.53	1605	3.45	2220	5.86

FEBRUARY

Date	Day	Moon	Time	m	Time	m	Time	m	Time	m
1	WE		0547	2.68	1157	5.17	1708	3.99	2250	5.37
2	TH		0649	2.89	1325	4.97	1902	4.36	2355	4.93
3	FR		0816	2.92	1559	5.26	2111	4.33		
4	SA		0229	4.79	0952	2.64	1654	5.79	2254	3.96
5	SU		0356	5.13	1054	2.21	1732	6.30	2333	3.53
6	MO		0447	5.60	1138	1.78	1807	6.79		
7	TU		0007	3.07	0530	6.09	1217	1.36	1843	7.22
8	WE	○	0043	2.59	0612	6.54	1252	1.08	1916	7.56
9	TH		0118	2.12	0654	6.92	1324	0.95	1946	7.76
10	FR		0153	1.70	0735	7.17	1354	0.99	2013	7.82
11	SA		0228	1.38	0815	7.28	1424	1.22	2038	7.74
12	SU		0305	1.20	0856	7.20	1455	1.63	2105	7.51
13	MO		0343	1.22	0940	6.94	1527	2.18	2132	7.14
14	TU		0423	1.43	1027	6.50	1602	2.84	2203	6.63
15	WE	◐	0509	1.79	1122	5.97	1646	3.53	2239	6.02
16	TH		0606	2.21	1238	5.50	1814	4.12	2338	5.39
17	FR		0734	2.53	1446	5.45	2047	4.22		
18	SA		0202	5.05	0924	2.45	1625	5.94	2239	3.73
19	SU		0351	5.37	1044	2.09	1722	6.49	2336	3.13
20	MO		0456	5.88	1137	1.71	1805	6.95		
21	TU		0018	2.61	0546	6.36	1218	1.43	1841	7.28
22	WE	●	0052	2.17	0629	6.74	1252	1.29	1911	7.47
23	TH		0124	1.83	0707	7.00	1322	1.29	1937	7.53
24	FR		0154	1.60	0742	7.11	1348	1.42	1959	7.47
25	SA		0221	1.49	0814	7.08	1411	1.68	2017	7.32
26	SU		0248	1.49	0844	6.94	1431	2.00	2036	7.09
27	MO		0315	1.61	0914	6.71	1449	2.39	2055	6.78
28	TU		0345	1.83	0946	6.39	1509	2.82	2114	6.38
29	WE		0417	2.15	1022	5.99	1534	3.30	2134	5.92

MARCH

Date	Day	Moon	Time	m	Time	m	Time	m	Time	m
1	TH	◑	0456	2.52	1108	5.56	1611	3.82	2154	5.43
2	FR		0548	2.88	1213	5.18	1754	4.28	2225	4.95
3	SA		0706	3.12	1413	5.09	2015	4.36		
4	SU		0123	4.61	0900	3.02	1611	5.55	2225	3.94
5	MO		0338	5.00	1023	2.58	1656	6.11	2306	3.39
6	TU		0433	5.60	1113	2.08	1732	6.66	2342	2.79
7	WE		0520	6.22	1155	1.64	1808	7.15		
8	TH	○	0019	2.16	0605	6.80	1232	1.32	1841	7.52
9	FR		0054	1.57	0648	7.28	1305	1.17	1911	7.75
10	SA		0130	1.07	0730	7.60	1337	1.21	1937	7.82
11	SU		0206	0.73	0809	7.71	1408	1.44	2005	7.73
12	MO		0242	0.62	0848	7.60	1440	1.83	2033	7.47
13	TU		0320	0.77	0929	7.27	1514	2.36	2105	7.04
14	WE		0401	1.16	1014	6.76	1552	2.98	2138	6.44
15	TH	◐	0446	1.72	1106	6.15	1640	3.60	2220	5.75
16	FR		0543	2.34	1217	5.61	1826	4.08	2338	5.08
17	SA		0710	2.81	1413	5.44	2100	3.93		
18	SU		0227	4.96	0906	2.85	1557	5.80	2230	3.35
19	MO		0357	5.44	1029	2.54	1653	6.26	2319	2.77
20	TU		0455	5.98	1120	2.21	1734	6.65	2356	2.28
21	WE		0541	6.46	1159	1.96	1807	6.92		
22	TH		0028	1.89	0620	6.84	1231	1.81	1834	7.09
23	FR	●	0056	1.59	0656	7.09	1259	1.77	1857	7.16
24	SA		0123	1.37	0728	7.22	1323	1.83	1917	7.16
25	SU		0148	1.25	0757	7.23	1346	1.98	1937	7.07
26	MO		0215	1.25	0824	7.14	1408	2.20	1958	6.90
27	TU		0242	1.37	0853	6.95	1432	2.48	2022	6.63
28	WE		0312	1.61	0923	6.67	1457	2.82	2044	6.27
29	TH		0345	1.96	0957	6.32	1525	3.22	2107	5.85
30	FR		0422	2.37	1037	5.91	1606	3.65	2133	5.40
31	SA	◑	0509	2.78	1132	5.53	1724	4.03	2221	4.94

APRIL

Date	Day	Moon	Time	m	Time	m	Time	m	Time	m
1	SU		0614	3.10	1254	5.30	1928	4.10		
2	MO		0042	4.64	0751	3.18	1447	5.47	2125	3.70
3	TU		0305	5.01	0933	2.90	1557	5.94	2222	3.08
4	WE		0410	5.66	1036	2.46	1643	6.45	2306	2.39
5	TH		0502	6.35	1123	2.05	1722	6.91	2346	1.69
6	FR		0550	6.98	1204	1.76	1757	7.27		
7	SA	○	0025	1.07	0636	7.49	1241	1.61	1829	7.50
8	SU		0102	0.58	0718	7.81	1316	1.62	1900	7.58
9	MO		0140	0.32	0759	7.89	1350	1.79	1932	7.50
10	TU		0219	0.32	0839	7.74	1427	2.09	2008	7.23
11	WE		0259	0.60	0921	7.38	1507	2.52	2045	6.77
12	TH		0342	1.11	1005	6.88	1552	3.01	2128	6.16
13	FR	◐	0430	1.77	1055	6.31	1656	3.47	2223	5.50
14	SA		0527	2.44	1158	5.81	1839	3.70		
15	SU		0005	4.98	0646	2.95	1324	5.55	2032	3.46
16	MO		0217	5.04	0824	3.13	1458	5.65	2152	2.98
17	TU		0338	5.48	0951	3.00	1603	5.92	2243	2.50
18	WE		0435	5.96	1049	2.76	1647	6.19	2322	2.09
19	TH		0521	6.39	1130	2.55	1721	6.40	2353	1.76
20	FR		0601	6.75	1204	2.38	1749	6.56		
21	SA	●	0022	1.49	0637	7.00	1233	2.29	1813	6.67
22	SU		0049	1.29	0709	7.15	1258	2.26	1837	6.72
23	MO		0116	1.17	0739	7.18	1323	2.30	1902	6.71
24	TU		0144	1.17	0807	7.13	1348	2.40	1929	6.61
25	WE		0214	1.28	0836	6.99	1416	2.56	1956	6.41
26	TH		0246	1.50	0905	6.78	1446	2.79	2024	6.13
27	FR		0320	1.82	0939	6.51	1521	3.07	2056	5.78
28	SA		0357	2.19	1018	6.19	1607	3.37	2136	5.40
29	SU	◑	0442	2.58	1106	5.88	1715	3.60	2238	5.02
30	MO		0539	2.92	1208	5.64	1849	3.60		

 Bureau of Meteorology National Tidal Centre

Datum of Predictions is Lowest Astronomical Tide

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

High Pest Periods	Moderate Pest Periods
Highest primary peaks of *C. ornatus* (Full moon) (Pest rank 1)	Moderate primary peaks of *C. ornatus* (Full moon) (Pest rank 3)
High secondary peaks of *C.ornatus* (New moon) (Pest rank 2)	Moderate to low secondary peaks of *C. ornatus* (New moon) (Pest rank 4)

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

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

AUSTRALIA, NORTH COAST – DARWIN 2012

LAT 12° 28' S LONG 130° 51' E

TIMES AND HEIGHTS OF HIGH AND LOW WATERS

TIME ZONE –0930

MAY

Date	Day	Time	m	Time	m	Time	m	Time	m
1	TU	0023	4.85	0657	3.12	1327	5.60	2022	3.25
2	WE	0217	5.13	0829	3.08	1445	5.81	2130	2.66
3	TH	0336	5.72	0947	2.84	1544	6.16	2223	2.00
4	FR	0436	6.38	1045	2.53	1630	6.53	2309	1.34
5	SA	0530	6.98	1133	2.27	1712	6.86	2353	0.78
6	SU	0620	7.45	1216	2.10	1750	7.09		
7	MO	0036	0.38	0706	7.73	1256	2.04	1828	7.20
8	TU	0118	0.22	0749	7.80	1336	2.08	1909	7.14
9	WE	0200	0.30	0832	7.66	1418	2.24	1951	6.91
10	TH	0243	0.63	0913	7.36	1504	2.48	2036	6.52
11	FR	0328	1.15	0956	6.95	1557	2.77	2127	6.02
12	SA	0416	1.78	1042	6.49	1703	3.03	2232	5.49
13	SU	0510	2.42	1132	6.05	1821	3.13	2359	5.13
14	MO	0614	2.95	1232	5.70	1942	3.02		
15	TU	0135	5.11	0728	3.28	1342	5.52	2056	2.74
16	WE	0258	5.36	0849	3.36	1454	5.53	2154	2.41
17	TH	0402	5.74	1002	3.26	1550	5.66	2238	2.09
18	FR	0454	6.13	1055	3.07	1631	5.82	2315	1.80
19	SA	0537	6.48	1135	2.87	1705	5.99	2347	1.55
20	SU	0615	6.74	1207	2.71	1735	6.15		
21	MO	0018	1.35	0650	6.91	1236	2.60	1805	6.27
22	TU	0049	1.22	0722	6.99	1302	2.53	1836	6.35
23	WE	0120	1.18	0751	7.00	1331	2.50	1907	6.35
24	TH	0152	1.24	0822	6.94	1402	2.53	1939	6.26
25	FR	0226	1.40	0853	6.82	1437	2.63	2013	6.09
26	SA	0300	1.64	0925	6.66	1517	2.76	2052	5.85
27	SU	0337	1.94	1001	6.45	1605	2.90	2139	5.58
28	MO	0418	2.29	1042	6.21	1704	2.99	2241	5.32
29	TU	0509	2.66	1130	5.97	1813	2.94		
30	WE	0002	5.20	0613	2.98	1228	5.79	1928	2.69
31	TH	0131	5.33	0732	3.17	1336	5.73	2039	2.27

JUNE

Date	Day	Time	m	Time	m	Time	m	Time	m
1	FR	0257	5.72	0856	3.16	1445	5.85	2141	1.74
2	SA	0409	6.25	1008	2.98	1545	6.09	2237	1.22
3	SU	0511	6.77	1106	2.73	1636	6.37	2327	0.77
4	MO	0606	7.20	1156	2.50	1722	6.62		
5	TU	0015	0.46	0656	7.48	1243	2.30	1809	6.79
6	WE	0102	0.34	0742	7.59	1328	2.18	1855	6.82
7	TH	0147	0.43	0824	7.54	1414	2.15	1942	6.71
8	FR	0231	0.71	0903	7.34	1502	2.19	2032	6.45
9	SA	0315	1.16	0942	7.04	1553	2.31	2126	6.10
10	SU	0359	1.72	1020	6.66	1647	2.46	2223	5.71
11	MO	0443	2.32	1057	6.25	1745	2.59	2327	5.37
12	TU	0531	2.87	1136	5.83	1845	2.65		
13	WE	0039	5.17	0628	3.31	1225	5.46	1948	2.62
14	TH	0159	5.17	0738	3.58	1330	5.21	2052	2.47
15	FR	0319	5.39	0858	3.62	1445	5.15	2149	2.25
16	SA	0423	5.75	1016	3.47	1545	5.26	2236	1.99
17	SU	0513	6.10	1108	3.23	1630	5.47	2317	1.73
18	MO	0554	6.40	1146	3.00	1708	5.70	2354	1.50
19	TU	0631	6.63	1218	2.80	1743	5.93		
20	WE	0029	1.31	0706	6.80	1247	2.62	1817	6.12
21	TH	0103	1.20	0738	6.91	1319	2.46	1852	6.24
22	FR	0137	1.17	0809	6.96	1353	2.35	1928	6.28
23	SA	0210	1.24	0840	6.95	1431	2.29	2007	6.24
24	SU	0243	1.40	0909	6.87	1512	2.26	2048	6.13
25	MO	0318	1.66	0940	6.72	1556	2.27	2136	5.95
26	TU	0356	2.01	1014	6.50	1645	2.28	2232	5.75
27	WE	0440	2.44	1052	6.22	1739	2.27	2338	5.57
28	TH	0535	2.89	1137	5.91	1841	2.20		
29	FR	0054	5.50	0645	3.27	1235	5.63	1952	2.03
30	SA	0222	5.63	0815	3.45	1351	5.50	2107	1.73

JULY

Date	Day	Time	m	Time	m	Time	m	Time	m
1	SU	0349	6.01	0941	3.34	1512	5.62	2214	1.35
2	MO	0458	6.48	1051	3.04	1617	5.91	2313	0.98
3	TU	0557	6.91	1148	2.68	1711	6.24		
4	WE	0005	0.69	0647	7.24	1238	2.33	1802	6.51
5	TH	0052	0.55	0732	7.43	1325	2.04	1851	6.68
6	FR	0136	0.58	0810	7.47	1409	1.84	1940	6.70
7	SA	0217	0.80	0846	7.37	1453	1.76	2028	6.59
8	SU	0256	1.17	0918	7.14	1535	1.79	2114	6.34
9	MO	0332	1.67	0947	6.80	1617	1.93	2201	6.02
10	TU	0405	2.22	1013	6.39	1658	2.13	2248	5.65
11	WE	0437	2.77	1039	5.95	1743	2.34	2341	5.32
12	TH	0522	3.27	1110	5.49	1835	2.52		
13	FR	0047	5.08	0628	3.67	1159	5.05	1938	2.59
14	SA	0217	5.07	0752	3.86	1324	4.75	2051	2.50
15	SU	0351	5.35	0935	3.76	1507	4.79	2159	2.27
16	MO	0449	5.74	1051	3.47	1607	5.08	2253	1.96
17	TU	0533	6.11	1133	3.16	1651	5.42	2336	1.65
18	WE	0612	6.44	1206	2.85	1729	5.77		
19	TH	0014	1.38	0647	6.73	1238	2.54	1807	6.09
20	FR	0050	1.18	0721	6.96	1311	2.24	1844	6.34
21	SA	0123	1.06	0751	7.11	1345	1.98	1923	6.52
22	SU	0155	1.07	0820	7.17	1422	1.76	2002	6.59
23	MO	0226	1.20	0846	7.13	1459	1.62	2043	6.56
24	TU	0258	1.47	0914	6.99	1539	1.57	2128	6.42
25	WE	0333	1.87	0942	6.74	1621	1.61	2218	6.18
26	TH	0413	2.37	1014	6.38	1708	1.75	2315	5.87
27	FR	0501	2.93	1051	5.94	1803	1.92		
28	SA	0024	5.58	0609	3.45	1144	5.47	1916	2.03
29	SU	0157	5.48	0751	3.71	1314	5.13	2046	1.95
30	MO	0330	5.77	0937	3.54	1506	5.23	2206	1.65
31	TU	0452	6.26	1055	3.09	1618	5.64	2308	1.29

AUGUST

Date	Day	Time	m	Time	m	Time	m	Time	m
1	WE	0548	6.73	1151	2.58	1715	6.10		
2	TH	0000	0.98	0636	7.11	1237	2.11	1805	6.49
3	FR	0044	0.81	0714	7.35	1318	1.73	1852	6.75
4	SA	0123	0.80	0748	7.43	1355	1.48	1937	6.86
5	SU	0158	0.96	0817	7.36	1432	1.34	2017	6.82
6	MO	0230	1.29	0843	7.16	1506	1.37	2055	6.63
7	TU	0258	1.72	0905	6.85	1538	1.53	2133	6.33
8	WE	0321	2.20	0925	6.48	1611	1.78	2210	5.97
9	TH	0344	2.69	0945	6.04	1647	2.09	2253	5.58
10	FR	0418	3.19	1010	5.56	1731	2.41	2346	5.21
11	SA	0520	3.67	1042	5.04	1831	2.67		
12	SU	0059	4.97	0653	3.98	1151	4.57	1951	2.77
13	MO	0304	5.06	0855	3.95	1434	4.47	2124	2.60
14	TU	0424	5.48	1044	3.57	1555	4.86	2230	2.24
15	WE	0508	5.93	1120	3.16	1640	5.33	2317	1.84
16	TH	0545	6.36	1151	2.73	1720	5.81	2358	1.48
17	FR	0619	6.76	1223	2.28	1800	6.26		
18	SA	0033	1.21	0652	7.08	1255	1.84	1838	6.64
19	SU	0106	1.05	0723	7.29	1330	1.45	1917	6.91
20	MO	0137	1.04	0750	7.38	1404	1.14	1956	7.06
21	TU	0206	1.19	0815	7.34	1439	0.96	2036	7.05
22	WE	0238	1.48	0841	7.17	1517	0.96	2117	6.87
23	TH	0312	1.93	0909	6.86	1557	1.13	2203	6.53
24	FR	0350	2.48	0940	6.40	1641	1.47	2256	6.08
25	SA	0437	3.10	1017	5.84	1735	1.89		
26	SU	0002	5.62	0550	3.65	1111	5.23	1852	2.25
27	MO	0139	5.40	0756	3.83	1317	4.81	2034	2.30
28	TU	0331	5.66	0954	3.44	1523	5.12	2202	2.02
29	WE	0440	6.17	1101	2.83	1630	5.68	2303	1.65
30	TH	0530	6.65	1147	2.26	1722	6.22	2351	1.36
31	FR	0612	6.99	1226	1.77	1808	6.65		

Bureau of Meteorology National Tidal Centre

Datum of Predictions is Lowest Astronomical Tide

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

High Pest Periods

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

Moderate Pest Periods

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

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

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

AUSTRALIA, NORTH COAST – DARWIN 2012

LAT 12° 28' S LONG 130° 51' E

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

SEPTEMBER

Date	Day	Time	m	Time	m	Time	m	Time	m	Moon
1	SA	0029	1.20	0646	7.21	1300	1.40	1850	6.94	
2	SU	0103	1.18	0715	7.28	1332	1.16	1927	7.07	
3	MO	0133	1.31	0739	7.23	1401	1.05	2001	7.04	
4	TU	0200	1.55	0801	7.07	1431	1.10	2034	6.89	
5	WE	0224	1.89	0820	6.82	1459	1.27	2105	6.63	
6	TH	0246	2.27	0841	6.49	1528	1.54	2138	6.30	
7	FR	0308	2.69	0902	6.08	1601	1.91	2214	5.91	
8	SA	0338	3.15	0924	5.59	1642	2.33	2300	5.49	Last Quarter
9	SU	0428	3.62	0947	5.07	1737	2.74			
10	MO	0002	5.14	0602	3.99	1022	4.57	1854	2.99	
11	TU	0137	5.01	0813	3.99	1349	4.31	2037	2.93	
12	WE	0337	5.34	1016	3.56	1542	4.79	2159	2.57	
13	TH	0428	5.82	1051	3.04	1627	5.38	2251	2.14	
14	FR	0506	6.31	1123	2.49	1708	5.98	2332	1.75	
15	SA	0541	6.75	1157	1.92	1748	6.54			
16	SU	0009	1.44	0615	7.11	1231	1.36	1829	7.01	New Moon
17	MO	0043	1.28	0645	7.35	1305	0.89	1909	7.35	
18	TU	0115	1.27	0713	7.45	1339	0.57	1947	7.50	
19	WE	0147	1.41	0739	7.41	1415	0.44	2026	7.46	
20	TH	0220	1.71	0809	7.21	1453	0.55	2107	7.21	
21	FR	0256	2.14	0841	6.84	1533	0.89	2151	6.79	
22	SA	0337	2.68	0917	6.30	1618	1.42	2242	6.26	
23	SU	0429	3.25	0959	5.64	1714	2.04	2347	5.75	First Quarter
24	MO	0558	3.70	1109	4.97	1835	2.55			
25	TU	0120	5.48	0810	3.65	1349	4.75	2021	2.68	
26	WE	0304	5.67	0951	3.09	1531	5.26	2149	2.46	
27	TH	0412	6.08	1047	2.47	1630	5.86	2248	2.16	
28	FR	0500	6.45	1128	1.93	1718	6.39	2332	1.92	
29	SA	0537	6.74	1203	1.51	1800	6.80			
30	SU	0008	1.77	0608	6.91	1234	1.20	1838	7.08	

OCTOBER

Date	Day	Time	m	Time	m	Time	m	Time	m	Moon
1	MO	0039	1.73	0634	6.98	1302	1.00	1911	7.21	
2	TU	0106	1.79	0657	6.97	1329	0.92	1943	7.20	
3	WE	0132	1.94	0719	6.87	1356	0.96	2013	7.09	
4	TH	0156	2.15	0742	6.69	1423	1.13	2041	6.88	
5	FR	0221	2.43	0806	6.42	1452	1.42	2112	6.60	
6	SA	0248	2.75	0831	6.05	1524	1.81	2146	6.25	
7	SU	0321	3.12	0855	5.61	1602	2.27	2226	5.86	
8	MO	0406	3.51	0923	5.13	1651	2.73	2320	5.50	Last Quarter
9	TU	0526	3.83	1009	4.65	1801	3.09			
10	WE	0033	5.27	0722	3.86	1240	4.35	1935	3.20	
11	TH	0210	5.35	0914	3.45	1508	4.78	2109	2.98	
12	FR	0327	5.73	1006	2.86	1603	5.44	2212	2.60	
13	SA	0415	6.18	1047	2.22	1647	6.13	2259	2.22	
14	SU	0455	6.60	1124	1.57	1732	6.77	2341	1.92	
15	MO	0530	6.96	1201	0.97	1814	7.29			New Moon
16	TU	0018	1.74	0604	7.21	1238	0.49	1856	7.65	
17	WE	0053	1.70	0636	7.34	1314	0.21	1937	7.79	
18	TH	0128	1.80	0708	7.31	1351	0.16	2017	7.71	
19	FR	0206	2.02	0743	7.11	1432	0.38	2058	7.44	
20	SA	0246	2.37	0822	6.72	1514	0.85	2143	7.01	
21	SU	0334	2.79	0904	6.17	1601	1.49	2232	6.50	
22	MO	0436	3.20	0957	5.52	1657	2.19	2332	6.02	First Quarter
23	TU	0607	3.43	1127	4.94	1814	2.78			
24	WE	0047	5.71	0752	3.26	1342	4.89	1948	3.05	
25	TH	0213	5.69	0919	2.78	1513	5.36	2116	3.00	
26	FR	0324	5.89	1016	2.25	1614	5.90	2220	2.81	
27	SA	0418	6.12	1059	1.80	1702	6.39	2306	2.61	
28	SU	0454	6.33	1134	1.46	1744	6.78	2344	2.45	
29	MO	0528	6.47	1205	1.20	1821	7.06			
30	TU	0015	2.36	0553	6.57	1232	1.02	1855	7.21	
31	WE	0043	2.32	0619	6.62	1259	0.94	1926	7.25	

NOVEMBER

Date	Day	Time	m	Time	m	Time	m	Time	m	Moon
1	TH	0110	2.35	0645	6.60	1326	0.98	1955	7.18	
2	FR	0137	2.44	0713	6.51	1354	1.10	2023	7.04	
3	SA	0204	2.58	0742	6.32	1424	1.36	2053	6.83	
4	SU	0236	2.78	0811	6.04	1456	1.71	2126	6.57	
5	MO	0312	3.03	0842	5.69	1530	2.13	2202	6.27	
6	TU	0359	3.30	0919	5.28	1612	2.58	2247	5.96	
7	WE	0504	3.50	1014	4.88	1710	2.99	2343	5.71	Last Quarter
8	TH	0630	3.51	1155	4.63	1828	3.28			
9	FR	0053	5.60	0801	3.21	1400	4.84	2001	3.32	
10	SA	0208	5.71	0911	2.67	1524	5.45	2121	3.12	
11	SU	0313	5.99	1004	2.03	1621	6.14	2221	2.83	
12	MO	0404	6.33	1049	1.38	1712	6.81	2310	2.55	
13	TU	0447	6.66	1132	0.80	1759	7.35	2354	2.33	
14	WE	0526	6.92	1213	0.36	1845	7.71			New Moon
15	TH	0035	2.21	0605	7.09	1253	0.12	1928	7.87	
16	FR	0116	2.18	0645	7.11	1334	0.13	2010	7.83	
17	SA	0158	2.25	0728	6.97	1416	0.39	2052	7.61	
18	SU	0244	2.41	0813	6.65	1500	0.87	2135	7.27	
19	MO	0337	2.63	0902	6.18	1546	1.52	2220	6.85	
20	TU	0439	2.85	1002	5.64	1638	2.23	2308	6.40	
21	WE	0552	2.96	1122	5.19	1740	2.87			First Quarter
22	TH	0003	6.02	0710	2.89	1300	5.04	1856	3.34	
23	FR	0107	5.74	0827	2.64	1434	5.26	2019	3.53	
24	SA	0217	5.64	0933	2.30	1547	5.69	2137	3.48	
25	SU	0320	5.70	1023	1.95	1642	6.15	2237	3.30	
26	MO	0409	5.83	1103	1.66	1726	6.55	2322	3.10	
27	TU	0447	5.98	1137	1.41	1805	6.86	2357	2.93	
28	WE	0520	6.13	1207	1.22	1840	7.07			
29	TH	0027	2.79	0551	6.26	1236	1.10	1912	7.18	Full Moon
30	FR	0054	2.70	0622	6.35	1306	1.06	1942	7.20	

DECEMBER

Date	Day	Time	m	Time	m	Time	m	Time	m	Moon
1	SA	0123	2.65	0654	6.37	1335	1.13	2010	7.15	
2	SU	0153	2.65	0726	6.30	1406	1.29	2040	7.05	
3	MO	0227	2.70	0800	6.15	1436	1.55	2110	6.90	
4	TU	0306	2.80	0836	5.92	1507	1.90	2143	6.70	
5	WE	0351	2.91	0917	5.63	1541	2.30	2218	6.46	
6	TH	0444	3.00	1009	5.32	1625	2.73	2301	6.20	
7	FR	0546	3.00	1122	5.09	1727	3.16	2352	5.97	Last Quarter
8	SA	0656	2.84	1253	5.08	1847	3.48			
9	SU	0054	5.81	0810	2.50	1432	5.41	2020	3.57	
10	MO	0204	5.81	0919	2.00	1552	6.00	2140	3.43	
11	TU	0312	5.98	1017	1.44	1654	6.63	2243	3.16	
12	WE	0410	6.27	1108	0.92	1747	7.19	2336	2.86	
13	TH	0500	6.57	1155	0.51	1836	7.60			New Moon
14	FR	0024	2.60	0547	6.81	1240	0.27	1921	7.83	
15	SA	0110	2.38	0634	6.95	1323	0.26	2004	7.89	
16	SU	0156	2.24	0721	6.93	1406	0.47	2044	7.79	
17	MO	0243	2.19	0810	6.75	1448	0.89	2122	7.55	
18	TU	0333	2.22	0902	6.43	1530	1.48	2159	7.20	
19	WE	0425	2.32	0956	6.02	1611	2.15	2236	6.77	
20	TH	0520	2.47	1056	5.59	1654	2.83	2313	6.31	First Quarter
21	FR	0618	2.59	1205	5.24	1748	3.43	2355	5.87	
22	SA	0722	2.64	1328	5.11	1903	3.85			
23	SU	0052	5.49	0832	2.55	1505	5.31	2032	4.01	
24	MO	0210	5.29	0940	2.34	1619	5.74	2205	3.88	
25	TU	0324	5.33	1032	2.07	1710	6.18	2307	3.61	
26	WE	0417	5.51	1115	1.78	1751	6.56	2348	3.35	
27	TH	0458	5.74	1150	1.53	1826	6.85			
28	FR	0019	3.11	0534	5.99	1223	1.32	1859	7.08	Full Moon
29	SA	0047	2.90	0608	6.20	1254	1.19	1930	7.20	
30	SU	0116	2.71	0643	6.36	1324	1.15	1959	7.28	
31	MO	0147	2.58	0718	6.43	1353	1.21	2027	7.29	

 Bureau of Meteorology National Tidal Centre

Datum of Predictions is Lowest Astronomical Tide

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

High Pest Periods

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

Moderate Pest Periods

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

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Northern Territory Government

DEPARTMENT OF **HEALTH**

Salt Marsh Mosquito Pest Calendar for the Coastal Top End NT

2012

Aedes vigilax – northern salt marsh mosquito

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Medical Entomology
Centre for Disease Control
Department of Health
Northern Territory Government

See www.health.nt.gov.au/Medical_Entomology/index.aspx

Salt Marsh Mosquito Pest Periods in the Coastal Top End of the NT

The northern salt marsh mosquito, *Aedes vigilax,* can pose appreciable seasonal pest problems around the northern Australian coast near the most productive breeding sites of the upper tidal section of extensive mangrove areas, brackish swamps with extensive reed growth, or flood plains associated with tidal rivers.

Aedes vigilax is likely to cause moderate to high pest problems around the northern coast following the highest monthly tides in the late dry season and early wet season. In Darwin the critical tide of 7.4m in May to July indicates the start of the salt marsh mosquito breeding season but numbers are usually relatively low in this period and maybe restricted to within 1km of prime breeding sites. In other areas of the NT this is generally the highest spring tide in this period. *Aedes vigilax* mosquitoes can be very numerous from the late dry season to the early wet season (August to January). Generally the numbers increase after each succeeding spring tide from August to December and reach their highest numbers in December after the highest spring tide or after a combination of high tides and the early heavy rains. The pattern and levels of abundance can vary from one year to another, due to the variable height of the spring tides each year and the amount and timing of rain in relation to the tides. In Darwin tide episodes for above 7.8m in October to December usually indicates an appreciable rise in salt marsh mosquitoes will follow.

Aedes vigilax is likely to pose an appreciable pest problem for 7 to 10 days per month over the late dry season to early wet season, within 2km of appreciable areas of breeding sites. The pest problems start around 9 days after the first initiating tide of the month, and generally persist up to 7 days after hatching after the highest tide of the month in the mid dry season to November. Pest problems may last 7-14 days in humid conditions in the December to January period. The larvae are usually absent in the major habitats from the mid wet to the mid dry season, as the prime habitats are either flooded and have high numbers of aquatic predators such as fish in the former period, or are dry in the latter period.

Aedes vigilax is regarded as the most important pest mosquito in the Top End of the NT because of its aggressive biting habits, its ability to bite during the day as well as the night, and its sudden emergence in plague proportions. They can disperse over long distances of up to 50km but are generally more common within 5km of extensive breeding sites and particularly in dense forest areas within 1 to 2km of extensive breeding sites. There can be a sudden appearance of salt marsh mosquitoes seeking blood 9 days after the flooding of the prime breeding sites. Salt marsh mosquito numbers exceeding 50 in a CO_2 baited EVS trap per night is considered a minor pest problem in the vicinity of the trap, with numbers over 500 indicating a severe pest problem.

The highest numbers of *Aedes vigilax* can be expected between October and December, with average numbers per CO2 trap per night of 500 to 1,000 experienced within 2km of extensive areas of prime breeding sites. High numbers can also be expected between August and September with average numbers of 50 to 500 per trap night. Moderate numbers occur in early to late January after the first heavy rain, with average *Ae. vigilax* numbers of 50 to 300 per trap night. Low numbers generally occur in June and July with average numbers of 5 to 50 per trap night. Negligible numbers usually occur from late January to May.

Aedes vigilax is a vector of Ross River virus and Barmah Forest virus disease in the Top End of the NT. The greatest potential transmission period for these viruses in the Top End is in December and January, when *Ae. vigilax* occurs in relatively high numbers and humid conditions extend the longevity of the mosquito population. Older mosquitoes present at the tail ends of the highest pest periods when *Ae. vigilax* numbers are low, can pose a higher potential risk for Ross River virus transmission, as they have had more time to acquire the virus from animal reservoirs. Personal protection, such as full-length trousers, long sleeved shirts, socks and shoes, and the use of insect repellents containing DEET or Picaridin is needed to provide protection from salt marsh mosquitoes particularly during these predicted pest periods, and also during periods outside these higher pest periods in locations when salt marsh mosquitoes are observed to be present.

This calendar shows periods when pest numbers of *Aedes vigilax* are expected in the Darwin area in 2011 in relation to Darwin Harbour tides. Other coastal areas of the NT near extensive breeding sites will generally have pest problems around these same periods each month.

High pest period (August to December)

Highest numbers of *Aedes vigilax* October to December (Pest rank 1)

Days highlighted in red indicate expected highest numbers of the salt marsh mosquito *Aedes vigilax*. These extremely high *Ae. vigilax* numbers can occur for up to 10 days in the late dry season (October to December) starting 9 days after the first initiating tide of the monthly highest tide cluster, and can present a severe pest problem.

Moderate to high numbers of *Aedes vigilax* August to September (Pest rank 2)

Days highlighted in orange indicate expected moderate to high numbers of the salt marsh mosquito *Aedes vigilax*. Moderate to high numbers can occur for 7 days starting 9 days after the first initiating tide of the monthly highest tide cluster in the mid to late dry season between August and September, and present a high pest problem.

Moderate pest period (January to July)

Moderate numbers of *Aedes vigilax* January (rain dependant) (Pest rank 3)

Days highlighted in yellow indicate expected moderate numbers of the salt marsh mosquito *Aedes vigilax.* Moderate numbers can occur in early to late January for 7 to 14 days starting 9 days after heavy rainfall, and present a moderate pest problem.

Low numbers of *Aedes vigilax* June and July (Pest rank 4)

Days highlighted in blue indicate expected low numbers of the salt marsh mosquito *Aedes vigilax.* Low numbers can occur in June and July, following any high spring tides, and can present a minor pest problem. Negligible numbers generally occur from late January to May.

For more information on salt marsh mosquitoes or personal protection, please contact:

Medical Entomology, CDC, DoH Darwin on (08) 89228901

Salt Marsh Mosquito Pest Calendar for the Coastal Top End of the NT

AUSTRALIA, NORTH COAST – DARWIN 2012

LAT 12° 28' S LONG 130° 51' E

TIMES AND HEIGHTS OF HIGH AND LOW WATERS

TIME ZONE –0930

JANUARY

Date	Day	Time m
1	SU	0518 2.62; 1057 5.39; 1624 3.14; 2251 6.08
2	MO	0605 2.75; 1158 5.09; 1720 3.67; 2327 5.67
3	TU	0702 2.81; 1321 4.95; 1845 4.07
4	WE	0021 5.28; 0813 2.74; 1518 5.18; 2022 4.20
5	TH	0148 5.06; 0927 2.52; 1630 5.65; 2204 4.04
6	FR	0319 5.14; 1027 2.19; 1715 6.12; 2305 3.74
7	SA	0415 5.41; 1113 1.82; 1753 6.53; 2345 3.43
8	SU	0458 5.74; 1153 1.48; 1829 6.90
9	MO	0019 3.12; 0538 6.07; 1229 1.20; 1904 7.21
10	TU	0052 2.82; 0617 6.36; 1304 1.01; 1937 7.43
11	WE	0128 2.53; 0655 6.59; 1335 0.94; 2009 7.56
12	TH	0205 2.27; 0735 6.71; 1407 1.02; 2039 7.58
13	FR	0243 2.07; 0816 6.73; 1438 1.24; 2107 7.50
14	SA	0323 1.93; 0900 6.62; 1511 1.63; 2135 7.30
15	SU	0405 1.89; 0948 6.39; 1545 2.15; 2205 6.99
16	MO	0451 1.94; 1042 6.07; 1624 2.77; 2239 6.59
17	TU	0541 2.06; 1146 5.71; 1717 3.42; 2319 6.12
18	WE	0644 2.19; 1311 5.47; 1844 3.96
19	TH	0019 5.66; 0808 2.20; 1505 5.62; 2044 4.11
20	FR	0201 5.40; 0936 1.98; 1633 6.13; 2223 3.82
21	SA	0337 5.56; 1046 1.61; 1733 6.68; 2332 3.36
22	SU	0442 5.92; 1141 1.25; 1821 7.15
23	MO	0022 2.88; 0536 6.30; 1226 0.99; 1902 7.48
24	TU	0104 2.47; 0624 6.61; 1304 0.88; 1937 7.66
25	WE	0142 2.15; 0709 6.81; 1339 0.93; 2008 7.69
26	TH	0217 1.94; 0750 6.86; 1410 1.15; 2035 7.58
27	FR	0251 1.85; 0828 6.78; 1436 1.50; 2058 7.37
28	SA	0323 1.88; 0903 6.57; 1458 1.94; 2117 7.08
29	SU	0354 2.00; 0938 6.28; 1514 2.41; 2136 6.73
30	MO	0425 2.19; 1016 5.92; 1534 2.91; 2157 6.32
31	TU	0501 2.43; 1100 5.53; 1605 3.45; 2220 5.86

FEBRUARY

Date	Day	Time m
1	WE	0547 2.68; 1157 5.17; 1708 3.99; 2250 5.37
2	TH	0649 2.89; 1325 4.97; 1902 4.36; 2355 4.93
3	FR	0816 2.92; 1559 5.26; 2111 4.33
4	SA	0229 4.79; 0952 2.64; 1654 5.79; 2254 3.96
5	SU	0356 5.13; 1054 2.21; 1732 6.30; 2333 3.53
6	MO	0447 5.60; 1138 1.76; 1807 6.79
7	TU	0007 3.07; 0530 6.09; 1217 1.36; 1843 7.22
8	WE	0043 2.59; 0612 6.54; 1252 1.08; 1916 7.56
9	TH	0118 2.12; 0654 6.92; 1324 0.95; 1946 7.76
10	FR	0153 1.70; 0735 7.17; 1354 0.99; 2013 7.82
11	SA	0228 1.38; 0815 7.28; 1424 1.22; 2038 7.74
12	SU	0305 1.20; 0856 7.20; 1455 1.63; 2105 7.51
13	MO	0343 1.22; 0940 6.94; 1527 2.18; 2132 7.14
14	TU	0423 1.43; 1027 6.50; 1602 2.84; 2203 6.63
15	WE	0509 1.79; 1122 5.97; 1646 3.53; 2239 6.02
16	TH	0606 2.21; 1238 5.50; 1814 4.12; 2338 5.39
17	FR	0734 2.53; 1446 5.45; 2047 4.22
18	SA	0202 5.05; 0924 2.45; 1625 5.94; 2239 3.73
19	SU	0351 5.37; 1044 2.09; 1722 6.49; 2336 3.13
20	MO	0456 5.88; 1137 1.71; 1805 6.95
21	TU	0018 2.61; 0546 6.36; 1218 1.43; 1841 7.28
22	WE	0052 2.17; 0629 6.74; 1252 1.29; 1911 7.47
23	TH	0124 1.83; 0707 7.00; 1322 1.29; 1937 7.53
24	FR	0154 1.60; 0742 7.11; 1348 1.42; 1959 7.47
25	SA	0221 1.49; 0814 7.08; 1411 1.68; 2017 7.32
26	SU	0248 1.49; 0844 6.94; 1431 2.00; 2036 7.09
27	MO	0315 1.61; 0914 6.71; 1449 2.39; 2055 6.78
28	TU	0345 1.83; 0946 6.39; 1509 2.82; 2114 6.38
29	WE	0417 2.15; 1022 5.99; 1534 3.30; 2134 5.92

MARCH

Date	Day	Time m
1	TH	0456 2.52; 1108 5.56; 1611 3.82; 2154 5.43
2	FR	0548 2.88; 1213 5.18; 1754 4.28; 2225 4.95
3	SA	0706 3.12; 1413 5.09; 2015 4.36
4	SU	0123 4.61; 0900 3.02; 1611 5.55; 2225 3.94
5	MO	0338 5.00; 1023 2.58; 1656 6.11; 2306 3.39
6	TU	0433 5.60; 1113 2.08; 1732 6.66; 2342 2.79
7	WE	0520 6.22; 1155 1.64; 1808 7.15
8	TH	0019 2.16; 0605 6.80; 1232 1.32; 1841 7.52
9	FR	0054 1.57; 0648 7.28; 1305 1.17; 1911 7.75
10	SA	0130 1.07; 0730 7.60; 1337 1.21; 1937 7.82
11	SU	0206 0.73; 0809 7.71; 1408 1.44; 2005 7.73
12	MO	0242 0.62; 0848 7.60; 1440 1.83; 2033 7.47
13	TU	0320 0.77; 0929 7.27; 1514 2.36; 2105 7.04
14	WE	0401 1.16; 1014 6.76; 1552 2.98; 2138 6.44
15	TH	0446 1.72; 1106 6.15; 1640 3.60; 2220 5.75
16	FR	0543 2.34; 1217 5.61; 1826 4.08; 2338 5.08
17	SA	0710 2.81; 1413 5.44; 2100 3.93
18	SU	0227 4.96; 0906 2.85; 1557 5.80; 2230 3.35
19	MO	0357 5.44; 1029 2.54; 1653 6.26; 2319 2.77
20	TU	0455 5.98; 1120 2.21; 1734 6.65; 2356 2.28
21	WE	0541 6.46; 1159 1.96; 1807 6.92
22	TH	0028 1.89; 0620 6.84; 1231 1.81; 1834 7.09
23	FR	0056 1.59; 0656 7.09; 1259 1.77; 1857 7.16
24	SA	0123 1.37; 0728 7.22; 1323 1.83; 1917 7.16
25	SU	0148 1.25; 0757 7.23; 1346 1.98; 1937 7.07
26	MO	0215 1.25; 0824 7.14; 1408 2.20; 1958 6.90
27	TU	0242 1.37; 0853 6.95; 1432 2.48; 2022 6.63
28	WE	0312 1.61; 0923 6.67; 1457 2.82; 2044 6.27
29	TH	0345 1.96; 0957 6.32; 1525 3.22; 2107 5.85
30	FR	0422 2.37; 1037 5.91; 1606 3.65; 2133 5.40
31	SA	0509 2.78; 1132 5.53; 1724 4.03; 2221 4.94

APRIL

Date	Day	Time m
1	SU	0614 3.10; 1254 5.30; 1928 4.10
2	MO	0042 4.64; 0751 3.18; 1447 5.47; 2125 3.70
3	TU	0305 5.01; 0933 2.90; 1557 5.94; 2222 3.08
4	WE	0410 5.66; 1036 2.46; 1643 6.45; 2306 2.39
5	TH	0502 6.35; 1123 2.05; 1722 6.91; 2346 1.69
6	FR	0550 6.98; 1204 1.76; 1757 7.27
7	SA	0025 1.07; 0636 7.49; 1241 1.61; 1829 7.50
8	SU	0102 0.58; 0718 7.81; 1316 1.62; 1900 7.58
9	MO	0140 0.32; 0759 7.89; 1350 1.79; 1932 7.50
10	TU	0219 0.32; 0839 7.74; 1427 2.09; 2008 7.23
11	WE	0259 0.60; 0921 7.38; 1507 2.52; 2045 6.77
12	TH	0342 1.11; 1005 6.88; 1552 3.01; 2128 6.16
13	FR	0430 1.77; 1055 6.31; 1656 3.47; 2223 5.50
14	SA	0527 2.44; 1158 5.81; 1839 3.70
15	SU	0005 4.98; 0646 2.95; 1324 5.55; 2032 3.46
16	MO	0217 5.04; 0824 3.13; 1458 5.65; 2152 2.98
17	TU	0338 5.48; 0951 3.00; 1603 5.92; 2243 2.50
18	WE	0435 5.96; 1049 2.76; 1647 6.19; 2322 2.09
19	TH	0521 6.39; 1130 2.55; 1721 6.40; 2353 1.76
20	FR	0601 6.75; 1204 2.38; 1749 6.56
21	SA	0022 1.49; 0637 7.00; 1233 2.29; 1813 6.67
22	SU	0049 1.29; 0709 7.15; 1258 2.26; 1837 6.72
23	MO	0116 1.17; 0739 7.18; 1323 2.30; 1902 6.71
24	TU	0144 1.17; 0807 7.13; 1348 2.40; 1929 6.61
25	WE	0214 1.28; 0836 6.99; 1416 2.56; 1956 6.41
26	TH	0246 1.50; 0905 6.78; 1446 2.79; 2024 6.13
27	FR	0320 1.82; 0939 6.51; 1521 3.07; 2056 5.78
28	SA	0357 2.19; 1018 6.19; 1607 3.37; 2136 5.40
29	SU	0442 2.58; 1106 5.88; 1715 3.60; 2238 5.02
30	MO	0539 2.92; 1208 5.64; 1849 3.60

 Bureau of Meteorology National Tidal Centre

Datum of Predictions is Lowest Astronomical Tide

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

High Pest Period

- Highest number of *Ae. vigilax* (Pest rank1)
- Moderate to high numbers of *Ae. vigilax* (Pest rank 2)

Moderate Pest Period

- Moderate Numbers of *Ae. vigilax* (Pest rank 3)
- Low numbers of *Ae. vigilax* (Pest rank 4)

*This Calendar has been produced by Medical Entomology Northern Territory, using the Tidal Tables template with the authorisation of the Bureau of Meteorology. All highlights pertaining to the Salt-marsh mosquito, *Aedes vigilax* are additions made by Medical Entomology.

DEPARTMENT OF **HEALTH**

Salt Marsh Mosquito Pest Calendar for the Coastal Top End of the NT

AUSTRALIA, NORTH COAST – DARWIN 2012

LAT 12° 28' S LONG 130° 51' E

TIMES AND HEIGHTS OF HIGH AND LOW WATERS

TIME ZONE –0930

MAY

		Time	m	Time	m	Time	m	Time	m	
1	TU	0023	4.85	0657	3.12	1327	5.60	2022	3.25	
2	WE	0217	5.13	0829	3.08	1445	5.81	2130	2.66	
3	TH	0336	5.72	0947	2.84	1544	6.16	2223	2.00	
4	FR	0436	6.38	1045	2.53	1630	6.53	2309	1.34	
5	SA	0530	6.98	1133	2.27	1712	6.86	2353	0.78	
6	SU	0620	7.45	1216	2.10	1750	7.09			○
7	MO	0036	0.38	0706	7.73	1256	2.04	1828	7.20	
8	TU	0118	0.22	0749	7.80	1336	2.08	1909	7.14	
9	WE	0200	0.30	0832	7.66	1418	2.24	1951	6.91	
10	TH	0243	0.63	0913	7.36	1504	2.48	2036	6.52	
11	FR	0328	1.15	0956	6.95	1557	2.77	2127	6.02	
12	SA	0416	1.78	1042	6.49	1703	3.03	2232	5.49	
13	SU	0510	2.42	1132	6.05	1821	3.13	2359	5.13	◐
14	MO	0614	2.95	1232	5.70	1942	3.02			
15	TU	0135	5.11	0728	3.28	1342	5.52	2056	2.74	
16	WE	0258	5.36	0849	3.36	1454	5.53	2154	2.41	
17	TH	0402	5.74	1002	3.26	1550	5.66	2238	2.09	
18	FR	0454	6.13	1055	3.07	1631	5.82	2315	1.80	
19	SA	0537	6.48	1135	2.87	1705	5.99	2347	1.55	
20	SU	0615	6.74	1207	2.71	1735	6.15			
21	MO	0018	1.35	0650	6.91	1236	2.60	1805	6.27	●
22	TU	0049	1.22	0722	6.99	1302	2.53	1836	6.35	
23	WE	0120	1.18	0751	7.00	1331	2.50	1907	6.35	
24	TH	0152	1.24	0822	6.94	1402	2.53	1939	6.26	
25	FR	0226	1.40	0853	6.82	1437	2.63	2013	6.09	
26	SA	0300	1.64	0925	6.66	1517	2.76	2052	5.85	
27	SU	0337	1.94	1001	6.45	1605	2.90	2139	5.58	
28	MO	0418	2.29	1042	6.21	1704	2.99	2241	5.32	
29	TU	0509	2.66	1130	5.97	1813	2.94			◑
30	WE	0002	5.20	0613	2.98	1228	5.79	1928	2.69	
31	TH	0131	5.33	0732	3.17	1336	5.73	2039	2.27	

JUNE

		Time	m	Time	m	Time	m	Time	m	
1	FR	0257	5.72	0856	3.16	1445	5.85	2141	1.74	
2	SA	0409	6.25	1008	2.98	1545	6.09	2237	1.22	
3	SU	0511	6.77	1106	2.73	1636	6.37	2327	0.77	
4	MO	0606	7.20	1156	2.50	1722	6.62			○
5	TU	0015	0.46	0656	7.48	1243	2.30	1809	6.79	
6	WE	0102	0.34	0742	7.59	1328	2.18	1855	6.82	
7	TH	0147	0.43	0824	7.54	1414	2.15	1942	6.71	
8	FR	0231	0.71	0903	7.34	1502	2.19	2032	6.45	
9	SA	0315	1.16	0942	7.04	1553	2.31	2126	6.10	
10	SU	0359	1.72	1020	6.66	1647	2.46	2223	5.71	
11	MO	0443	2.32	1057	6.25	1745	2.59	2327	5.37	◐
12	TU	0531	2.87	1136	5.83	1845	2.65			
13	WE	0039	5.17	0628	3.31	1225	5.46	1948	2.62	
14	TH	0159	5.17	0738	3.58	1330	5.21	2052	2.47	
15	FR	0319	5.39	0858	3.62	1445	5.15	2149	2.25	
16	SA	0423	5.75	1016	3.47	1545	5.26	2236	1.99	
17	SU	0513	6.10	1108	3.23	1630	5.47	2317	1.73	
18	MO	0554	6.40	1146	3.00	1708	5.70	2354	1.50	
19	TU	0631	6.63	1218	2.80	1743	5.93			
20	WE	0029	1.31	0706	6.80	1247	2.62	1817	6.12	●
21	TH	0103	1.20	0738	6.91	1319	2.46	1852	6.24	
22	FR	0137	1.17	0809	6.96	1353	2.35	1928	6.28	
23	SA	0210	1.24	0840	6.95	1431	2.29	2007	6.24	
24	SU	0243	1.40	0909	6.87	1512	2.26	2048	6.13	
25	MO	0318	1.66	0940	6.72	1556	2.27	2136	5.95	
26	TU	0356	2.01	1014	6.50	1645	2.28	2232	5.75	
27	WE	0440	2.44	1052	6.22	1739	2.27	2338	5.57	◑
28	TH	0535	2.89	1137	5.91	1841	2.20			
29	FR	0054	5.50	0645	3.27	1235	5.63	1952	2.03	
30	SA	0222	5.63	0815	3.45	1351	5.50	2107	1.73	

JULY

		Time	m	Time	m	Time	m	Time	m	
1	SU	0349	6.01	0941	3.34	1512	5.62	2214	1.35	
2	MO	0458	6.48	1051	3.04	1617	5.91	2313	0.98	
3	TU	0557	6.91	1148	2.68	1711	6.24			
4	WE	0005	0.69	0647	7.24	1238	2.33	1802	6.51	○
5	TH	0052	0.55	0732	7.43	1325	2.04	1851	6.68	
6	FR	0136	0.58	0810	7.47	1409	1.84	1940	6.70	
7	SA	0217	0.80	0846	7.37	1453	1.76	2028	6.59	
8	SU	0256	1.17	0918	7.14	1535	1.79	2114	6.34	
9	MO	0332	1.67	0947	6.80	1617	1.93	2201	6.02	
10	TU	0405	2.22	1013	6.39	1658	2.13	2248	5.65	
11	WE	0437	2.77	1039	5.95	1743	2.34	2341	5.32	◐
12	TH	0522	3.27	1110	5.49	1835	2.52			
13	FR	0047	5.08	0628	3.67	1159	5.05	1938	2.59	
14	SA	0217	5.07	0752	3.86	1324	4.75	2051	2.50	
15	SU	0351	5.35	0935	3.76	1507	4.79	2159	2.27	
16	MO	0449	5.74	1051	3.47	1607	5.08	2253	1.96	
17	TU	0533	6.11	1133	3.16	1651	5.42	2336	1.65	
18	WE	0612	6.44	1206	2.85	1729	5.77			
19	TH	0014	1.38	0647	6.73	1238	2.54	1807	6.09	●
20	FR	0050	1.18	0721	6.96	1311	2.24	1844	6.34	
21	SA	0123	1.06	0751	7.11	1345	1.98	1923	6.52	
22	SU	0155	1.07	0820	7.17	1422	1.76	2002	6.59	
23	MO	0226	1.20	0846	7.13	1459	1.62	2043	6.56	
24	TU	0258	1.47	0914	6.99	1539	1.57	2128	6.42	
25	WE	0333	1.87	0942	6.74	1621	1.61	2218	6.18	
26	TH	0413	2.37	1014	6.38	1708	1.75	2315	5.87	◑
27	FR	0501	2.93	1051	5.94	1803	1.92			
28	SA	0024	5.58	0609	3.45	1144	5.47	1916	2.03	
29	SU	0157	5.48	0751	3.71	1314	5.13	2046	1.95	
30	MO	0339	5.77	0937	3.54	1506	5.23	2205	1.65	
31	TU	0452	6.26	1055	3.09	1618	5.64	2308	1.29	

AUGUST

		Time	m	Time	m	Time	m	Time	m	
1	WE	0548	6.73	1151	2.58	1715	6.10			
2	TH	0000	0.98	0635	7.11	1237	2.11	1805	6.49	○
3	FR	0044	0.81	0714	7.35	1318	1.73	1852	6.75	
4	SA	0123	0.80	0748	7.43	1355	1.46	1937	6.86	
5	SU	0158	0.96	0817	7.36	1432	1.34	2017	6.82	
6	MO	0230	1.29	0843	7.16	1506	1.37	2055	6.63	
7	TU	0258	1.72	0905	6.85	1538	1.53	2133	6.33	
8	WE	0321	2.20	0925	6.48	1611	1.78	2210	5.97	
9	TH	0344	2.69	0945	6.04	1647	2.09	2253	5.58	
10	FR	0418	3.19	1010	5.56	1731	2.41	2346	5.21	◐
11	SA	0520	3.67	1042	5.04	1831	2.67			
12	SU	0059	4.97	0653	3.98	1151	4.57	1951	2.77	
13	MO	0304	5.06	0855	3.95	1434	4.47	2124	2.60	
14	TU	0424	5.48	1044	3.57	1555	4.86	2230	2.24	
15	WE	0508	5.93	1120	3.16	1640	5.33	2317	1.84	
16	TH	0545	6.36	1151	2.73	1720	5.81	2358	1.48	
17	FR	0619	6.76	1223	2.28	1800	6.26			
18	SA	0033	1.21	0652	7.08	1255	1.84	1838	6.64	●
19	SU	0106	1.05	0723	7.29	1330	1.45	1917	6.91	
20	MO	0137	1.04	0750	7.38	1404	1.14	1956	7.06	
21	TU	0206	1.19	0815	7.34	1439	0.96	2036	7.05	
22	WE	0238	1.48	0841	7.17	1517	0.96	2117	6.87	
23	TH	0312	1.93	0909	6.86	1557	1.13	2203	6.53	
24	FR	0350	2.48	0940	6.40	1641	1.47	2256	6.08	◑
25	SA	0437	3.10	1017	5.84	1735	1.89			
26	SU	0002	5.62	0550	3.65	1111	5.23	1852	2.25	
27	MO	0139	5.40	0756	3.83	1317	4.81	2034	2.30	
28	TU	0331	5.68	0954	3.44	1523	5.12	2202	2.02	
29	WE	0440	6.17	1101	2.83	1630	5.68	2303	1.65	
30	TH	0530	6.63	1147	2.26	1722	6.22	2351	1.36	
31	FR	0612	6.99	1226	1.77	1808	6.65			○

 Bureau of Meteorology National Tidal Centre

Datum of Predictions is Lowest Astronomical Tide

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

High Pest Period

- Highest number of *Ae. vigilax* (Pest rank1)
- Moderate to high numbers of *Ae. vigilax* (Pest rank 2)

Moderate Pest Period

- Moderate Numbers of *Ae. vigilax* (Pest rank 3)
- Low numbers of *Ae. vigilax* (Pest rank 4)

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Salt Marsh Mosquito Pest Calendar for the Coastal Top End of the NT

AUSTRALIA, NORTH COAST – DARWIN

2012

LAT 12° 28' S LONG 130° 51' E

TIMES AND HEIGHTS OF HIGH AND LOW WATERS

TIME ZONE –0930

SEPTEMBER

Date	Day	Time	m	Time	m	Time	m	Time	m
1	SA	0029	1.20	0646	7.21	1300	1.40	1850	6.94
2	SU	0103	1.18	0715	7.28	1332	1.16	1927	7.07
3	MO	0133	1.31	0739	7.23	1401	1.05	2001	7.04
4	TU	0200	1.55	0801	7.07	1431	1.10	2034	6.89
5	WE	0224	1.89	0820	6.82	1459	1.27	2105	6.63
6	TH	0246	2.27	0841	6.49	1528	1.54	2138	6.30
7	FR	0308	2.69	0902	6.08	1601	1.91	2214	5.91
8	SA ◐	0338	3.15	0924	5.59	1642	2.33	2300	5.49
9	SU	0428	3.62	0947	5.07	1737	2.74		
10	MO	0002	5.14	0602	3.99	1022	4.57	1854	2.99
11	TU	0137	5.01	0813	3.99	1349	4.31	2037	2.93
12	WE	0337	5.34	1016	3.56	1542	4.79	2159	2.57
13	TH	0428	5.82	1051	3.04	1627	5.38	2251	2.14
14	FR	0506	6.31	1123	2.49	1708	5.98	2332	1.75
15	SA	0541	6.75	1157	1.92	1748	6.54		
16	SU ●	0009	1.44	0615	7.11	1231	1.36	1829	7.01
17	MO	0043	1.28	0645	7.35	1305	0.89	1909	7.35
18	TU	0115	1.27	0713	7.45	1339	0.57	1947	7.50
19	WE	0147	1.41	0739	7.41	1415	0.44	2026	7.46
20	TH	0220	1.71	0809	7.21	1453	0.55	2107	7.21
21	FR	0256	2.14	0841	6.84	1533	0.89	2151	6.79
22	SA	0337	2.68	0917	6.30	1618	1.42	2242	6.26
23	SU ◑	0429	3.25	0959	5.64	1714	2.04	2347	5.75
24	MO	0558	3.70	1109	4.97	1835	2.55		
25	TU	0120	5.48	0810	3.65	1349	4.75	2021	2.68
26	WE	0304	5.67	0951	3.09	1531	5.26	2149	2.46
27	TH	0412	6.08	1047	2.47	1630	5.86	2248	2.16
28	FR	0500	6.45	1128	1.93	1718	6.39	2332	1.92
29	SA	0537	6.74	1203	1.51	1800	6.80		
30	SU ○	0008	1.77	0608	6.91	1234	1.20	1838	7.08

OCTOBER

Date	Day	Time	m	Time	m	Time	m	Time	m
1	MO	0039	1.73	0634	6.98	1302	1.00	1911	7.21
2	TU	0106	1.79	0657	6.97	1329	0.92	1943	7.20
3	WE	0132	1.94	0719	6.87	1356	0.96	2013	7.09
4	TH	0156	2.15	0742	6.69	1423	1.13	2041	6.88
5	FR	0221	2.43	0806	6.42	1452	1.42	2112	6.60
6	SA	0248	2.75	0831	6.05	1524	1.81	2146	6.25
7	SU	0321	3.12	0855	5.61	1602	2.27	2226	5.86
8	MO ◐	0406	3.51	0923	5.13	1651	2.73	2320	5.50
9	TU	0526	3.83	1009	4.65	1801	3.09		
10	WE	0033	5.27	0722	3.86	1240	4.35	1935	3.20
11	TH	0210	5.35	0914	3.45	1508	4.78	2109	2.98
12	FR	0327	5.73	1006	2.86	1603	5.44	2212	2.60
13	SA	0415	6.18	1047	2.22	1647	6.13	2259	2.22
14	SU	0455	6.60	1124	1.57	1732	6.77	2341	1.92
15	MO ●	0530	6.96	1201	0.97	1814	7.29		
16	TU	0018	1.74	0604	7.11	1238	0.49	1856	7.65
17	WE	0053	1.70	0636	7.34	1314	0.21	1937	7.79
18	TH	0128	1.80	0708	7.31	1351	0.16	2017	7.71
19	FR	0206	2.02	0743	7.11	1432	0.38	2058	7.44
20	SA	0246	2.37	0822	6.72	1514	0.85	2143	7.01
21	SU	0334	2.79	0904	6.17	1601	1.49	2232	6.50
22	MO ◑	0436	3.20	0957	5.52	1657	2.19	2332	6.02
23	TU	0607	3.43	1127	4.94	1814	2.78		
24	WE	0047	5.71	0752	3.26	1342	4.89	1948	3.05
25	TH	0213	5.69	0919	2.78	1513	5.36	2118	3.00
26	FR	0324	5.89	1016	2.25	1614	5.90	2220	2.81
27	SA	0416	6.12	1059	1.80	1702	6.39	2306	2.61
28	SU	0454	6.33	1134	1.46	1744	6.78	2344	2.45
29	MO	0526	6.47	1205	1.20	1821	7.06		
30	TU	0015	2.38	0553	6.57	1232	1.02	1855	7.21
31	WE	0043	2.32	0619	6.62	1259	0.94	1926	7.25

NOVEMBER

Date	Day	Time	m	Time	m	Time	m	Time	m
1	TH	0110	2.35	0645	6.60	1326	0.96	1955	7.18
2	FR	0137	2.44	0713	6.51	1354	1.10	2023	7.04
3	SA	0204	2.58	0742	6.32	1424	1.36	2053	6.83
4	SU	0236	2.78	0811	6.04	1456	1.71	2126	6.57
5	MO	0312	3.03	0842	5.66	1530	2.13	2202	6.27
6	TU	0359	3.30	0919	5.28	1612	2.58	2247	5.96
7	WE ◐	0504	3.50	1014	4.88	1710	2.99	2343	5.71
8	TH	0630	3.51	1155	4.63	1828	3.28		
9	FR	0053	5.60	0801	3.21	1400	4.84	2001	3.32
10	SA	0208	5.71	0911	2.67	1524	5.45	2121	3.12
11	SU	0313	5.99	1004	2.03	1621	6.14	2221	2.83
12	MO	0404	6.33	1049	1.38	1712	6.81	2310	2.55
13	TU	0447	6.66	1132	0.80	1759	7.35	2354	2.33
14	WE ●	0526	6.92	1213	0.36	1845	7.71		
15	TH	0035	2.21	0605	7.09	1253	0.12	1928	7.87
16	FR	0116	2.18	0645	7.11	1334	0.13	2010	7.83
17	SA	0158	2.25	0728	6.97	1416	0.39	2052	7.61
18	SU	0244	2.41	0813	6.65	1500	0.87	2135	7.27
19	MO	0337	2.63	0902	6.18	1546	1.52	2220	6.85
20	TU	0439	2.85	1002	5.64	1638	2.23	2308	6.40
21	WE ◑	0552	2.96	1122	5.19	1740	2.87		
22	TH	0003	6.02	0710	2.89	1300	5.04	1856	3.34
23	FR	0107	5.74	0827	2.64	1434	5.26	2019	3.53
24	SA	0217	5.64	0933	2.30	1547	5.69	2137	3.48
25	SU	0320	5.70	1023	1.95	1642	6.15	2237	3.30
26	MO	0409	5.83	1103	1.66	1726	6.55	2322	3.10
27	TU	0447	5.98	1137	1.41	1805	6.86	2357	2.93
28	WE	0520	6.13	1207	1.22	1840	7.07		
29	TH	0027	2.79	0551	6.25	1236	1.10	1912	7.18
30	FR	0054	2.70	0622	6.35	1305	1.06	1942	7.20

DECEMBER

Date	Day	Time	m	Time	m	Time	m	Time	m
1	SA	0123	2.65	0654	6.37	1335	1.13	2010	7.15
2	SU	0153	2.65	0726	6.30	1406	1.29	2040	7.05
3	MO	0227	2.70	0800	6.15	1436	1.55	2110	6.90
4	TU	0306	2.80	0836	5.92	1507	1.90	2143	6.70
5	WE	0351	2.91	0917	5.63	1541	2.30	2218	6.46
6	TH	0444	3.00	1009	5.32	1625	2.73	2301	6.20
7	FR ◐	0546	3.00	1122	5.09	1727	3.16	2352	5.97
8	SA	0656	2.84	1253	5.08	1847	3.48		
9	SU	0054	5.81	0810	2.50	1432	5.41	2020	3.57
10	MO	0204	5.81	0919	2.00	1552	6.00	2140	3.43
11	TU	0312	5.98	1017	1.44	1654	6.63	2243	3.16
12	WE	0410	6.27	1108	0.92	1747	7.19	2336	2.86
13	TH ●	0500	6.57	1155	0.51	1836	7.60		
14	FR	0024	2.60	0547	6.81	1240	0.27	1921	7.83
15	SA	0110	2.38	0634	6.95	1323	0.26	2004	7.89
16	SU	0156	2.24	0721	6.93	1406	0.47	2044	7.79
17	MO	0243	2.19	0810	6.75	1448	0.89	2122	7.55
18	TU	0333	2.22	0902	6.43	1530	1.48	2159	7.20
19	WE	0425	2.32	0956	6.02	1611	2.15	2236	6.77
20	TH ◑	0520	2.47	1056	5.59	1654	2.83	2313	6.31
21	FR	0618	2.59	1205	5.24	1748	3.43	2355	5.87
22	SA	0722	2.64	1328	5.11	1903	3.85		
23	SU	0052	5.49	0832	2.55	1505	5.31	2032	4.01
24	MO	0210	5.29	0940	2.34	1619	5.74	2205	3.88
25	TU	0324	5.33	1032	2.07	1710	6.18	2307	3.61
26	WE	0417	5.51	1115	1.78	1751	6.56	2348	3.35
27	TH	0458	5.74	1150	1.53	1826	6.85		
28	FR	0019	3.11	0534	5.99	1223	1.32	1859	7.06
29	SA	0047	2.90	0608	6.20	1254	1.19	1930	7.20
30	SU	0116	2.71	0643	6.36	1324	1.15	1959	7.28
31	MO	0147	2.56	0718	6.43	1353	1.21	2027	7.29

Bureau of Meteorology National Tidal Centre

Datum of Predictions is Lowest Astronomical Tide

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

Note: October – December:
High or moderate numbers of *Ae. vigilax* might occur outside the indicated high pest periods between October and December 2012 due to rain events causing additional problems 9 days after rain 20mm or over in tidal coastal swamps.

High Pest Period		Moderate Pest Period	
(red)	Highest number of *Ae. vigilax* (Pest rank1)	(yellow)	Moderate Numbers of *Ae. vigilax* (Pest rank 3)
(orange)	Moderate to high numbers of *Ae. vigilax* (Pest rank 2)	(blue)	Low numbers of *Ae. vigilax* (Pest rank 4)

*This Calendar has been produced by Medical Entomology Northern Territory, using the Tidal Tables template with the authorisation of the Bureau of Meteorology. All highlights pertaining to the Salt-marsh mosquito, *Aedes vigilax* are additions made by Medical Entomology