DEPARTMENT OF HEALTH

Mosquito investigation Wagait Beach 18th -19th December 2017

Medical Entomology
Centre for Disease Control
NT Department of Health
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1.0 Introduction

Medical Entomology received an enquiry from Wagait Shire Council in mid-November 2017 regarding mosquito pest problems. The enquiry coincided with elevated salt marsh mosquito (*Aedes* vigilax) numbers in the Darwin Northern Suburbs, and when other areas of the Top End coastline were most likely also experiencing similar mosquito problems. The subsequent mosquito investigation was therefore planned to commence on the 18th of December, which was 13 days after the 7.98m December high tide, to determine if high tides and salt marsh mosquitoes were the cause of mosquito problems at Wagait Beach. A previous mosquito investigation was carried out on the 14th-15th of January 2015 in response to high mosquito numbers after heavy rain, with this previous investigation revealing salt marsh mosquitoes were the cause of the pest problem.

This current investigation involved;

- The setting of four overnight adult mosquito monitoring traps (carbon dioxide baited EVS traps) within and nearby to the community of Wagait Beach, to determine the most abundant endemic mosquito species.
- The setting of two overnight exotic adult mosquito monitoring traps (Bio-gents Sentinel traps – BG traps), to determine if day biting exotic *Aedes* mosquito species were present at Wagait Beach.
- Brief mosquito larval surveys of nearby seasonally flooded areas, to determine the likely sources of mosquitoes.
- An examination of the current and past mosquito trap results, and desktop examination of aerial photography, to determine potential mosquito breeding sites affecting Wagait Beach and mosquito risk periods.
- Providing recommendations on mosquito mitigation measures that could be applied at Wagait Beach to manage the seasonal mosquito problems.

2.0 Methods

Four CO_2 baited EVS trap sites and two CO_2 baited BG trap sites were chosen for this investigation (Figure 1). The sites were selected within close proximity to potential mosquito breeding or harbourage areas.

The EVS traps consisted of a black insulated bucket, a suction fan powered by two ‘D’ cell batteries, a ‘grain of wheat’ light, and a rigid plastic collection container fitted with a muslin sleeve and very fine wire mesh vents. The traps were hung on trees around chest height and baited with approximately 1kg of dry ice. Traps were set in the afternoon on the 18th of December and collected the following morning after 9am.

The BG traps consisted of a white cylindrical container with a black funnel in the top, and a suction fan powered by a small motorcycle battery. The CO_2 was provided by a CO_2 gas bottle, with the flow regulated at 250ml/minute. The BG traps were set before lunch on the 18th, and collected during mid-morning on the 19th, to allow as long as possible in the field to detect any day biting exotic *Aedes* mosquitoes.

Once all the traps had been collected and returned to the laboratory, the mosquitoes were killed in the freezer to enable identification via a light microscope using various taxonomic keys. For catches less than 300 mosquitoes, each individual mosquito was identified. For catches over 300 mosquitoes, a sub sample of around 300 mosquitoes was obtained from the bulk sample, with all mosquitoes in the sub sample identified and the bulk scanned for species not present in the sub sample. A multiplication factor was calculated by dividing the weight of all mosquitoes by the weight of the sub sample, which was then applied to the sub sample results to get an overall count of each species. All species and totals for each individual collection were then entered into a database for evaluation.

Field surveys for mosquito larvae were also conducted at twelve suspected mosquito breeding sites on 18th December, with survey points shown in Figure 1. Surveys were carried out on foot using a 350ml ladle dipper to sample any areas of ponding, with site locations saved on a hand held GPS and photos taken for future reference.

3.0 Results

3.1 Adult mosquito trapping

The results of the adult mosquito trapping are shown in Table 1 (EVS traps) and Table 2 (BG traps). Trap locations are shown in Figure 1. There were a total of 1264 adult female mosquitoes collected from the four EVS traps, representing a total of 12 different mosquito species (Table 1). There were a total of 664 adult female mosquitoes collected from the two BG traps, representing a total of 7 different mosquito species (Table 2).

EVS trapping

The most productive trap site was Trap Site 3 at the east end of De Lissa Rd, with 595 adult female mosquitoes collected, representing 47.07% of all mosquitoes collected in the EVS traps (Table 1). The second most productive trap site was Trap Site 5 on Charles Point Rd opposite Power Pole 35, with 426 adult female mosquitoes collected, representing 33.7% of all mosquitoes collected in the EVS traps. Trap Site 1a, located at the edge of the freshwater swamp at the back of Lot 76 Cox Dve (Country Club), and Trap Site 2 located, in the creekline forest at the end of Vangemann Rd, recorded similar numbers of mosquitoes (119 & 124 adult females respectively).

The most common mosquito collected in the EVS traps was the northern salt marsh mosquito *Aedes vigilax,* with a total of 710 adult females collected in the 4 traps, representing 56.17% of all mosquitoes collected in the EVS traps (Table 1). The most productive trap site for this mosquito was Trap Site 5. A total of 320 adult female *Ae. vigilax* were collected at this site. Trap Site 3 was the second most productive trap site for *Ae. vigilax,* collecting 201 adult females. Trap Sites 1a and 2 recorded 97 and 92 adult female *Ae. vigilax* respectively.

The second most abundant mosquito was the saltwater *Culex* mosquito *Culex sitiens,* with 489 adult females collected at the four sites, representing 38.69% of all mosquitoes collected in the EVS traps (Table 1). Trap Site 3 was by far the most productive trap site, accounting for 363 adult females, followed by Trap Site 5 (88 adult females). Trap Sites 1a and 2 recorded similar but low numbers of this mosquito.

The other mosquito species collected in the EVS traps were only collected in minor to low numbers, which is expected during the early wet season in coastal areas. Important mosquito species collected in low numbers included *Anopheles farauti s.l., Anopheles hilli, Culex annulirostris, Coquillettidia xanthogaster, Aedes notoscriptus* and *Verrallina funerea.*

BG trapping

The most productive BG trap site was BG1, located in Section 64 Forsyth Rd next to a rainwater tank. A total of 603 adult female mosquitoes were collected, accounting for 90.81% of all mosquitoes collected in the two BG traps (Table 2). Trap Site BG2, set under the banyan tree at the country club outdoor area, collected 61 adult female mosquitoes.

The most common mosquito collected in the two BG traps was *Ae. vigilax,* accounting for 83.89% of all mosquitoes (Table 2). Trap Site BG1 was the most productive site for this species, collecting 512 adult females, with 45 adult female *Ae. vigilax* recorded at BG2.

Culex sitiens was the second most abundant mosquito collected in the BG traps, accounting for 9.79% of all mosquitoes (Table 2). Trap Site BG1 recorded the majority of this species, collecting 61 out of the 65 adult female *Cx. sitiens.*

Aedes notoscriptus was recorded in low numbers at BG1 only, *Aedes tremulus* was collected at both sites in the same numbers, while *Cx. quinquefasciatus* was only recorded at BG2. *Anopheles farauti s.l.* was recorded in very low numbers at both sites. There were no exotic *Aedes* mosquitoes detected in the two traps.

3.2 Larval mosquito survey

Photos of potential mosquito breeding sites are shown in Attachment 1, with survey points shown in Figure 1. There were no mosquito larvae found during the survey, primarily due to most sites being dry due to very low rainfall around Wagait Beach in the weeks prior to the survey, and a period of two weeks since the previous high tide. The only inspected site that was ponding water was the tidal swamp on the west edge of Wagait Beach, with no mosquito larvae located. There were numerous small fish in the upper reaches of the swamp closest to residents, which most likely providing effective bio-control in the open areas of the swamp. The swamp appeared fully flooded despite the low rainfall and almost two weeks since the last tide, suggesting seepage into at least the eastern arm of the swamp from Imaluk Spring. This swamp appears to be a potentially major *Ae. vigilax* breeding site during the mid-late dry and early wet season, and is also likely to be a *Cx. sitiens* breeding site during the dry season and early wet season. The brackish water *Anopheles* mosquitoes *An. farauti s.l.* and *An. hilli* are also likely to breed in this swamp during the dry season, particularly in association with the zones of brackish water reeds.

The coastal swamp on the east edge of Wagait Beach was not inspected due to access difficulties, but was most likely also ponding tide and/or groundwater. The high number of *Cx. sitiens* in EVS Trap Site 3 indicated long term saltwater/brackish water ponding occurs in the swamp.

The several drainage lines from Cox and De Lissa Rd to the beachline were dry/damp, but appeared similar to some important *Ae. vigilax* breeding sites in Casuarina Coastal Reserve in Darwin. Sand build up where the drains meet the beach suggested that significant ponding and *Ae. vigilax* breeding could occur in most or all of the drainage lines after tides greater than about 7.8m, and most likely after heavy rainfall events from November until early Januuary. November and December likely to be the main months for breeding. Once the drainage lines begin to flow groundwater after the first significant monsoon, breeding will cease due to fish predation and lack of damp ground for *Ae. vigilax* egg laying.

The coastal dune depressions previously identified as *Ae. vigilax* breeding sites in 2015 were dry, due to a lack of heavy rainfall. Costal sand dune depressions usually require the first or second monsoon to bring the water table up above the surface of the depressions to allow successful mosquito breeding to occur.

The coastal swamps associated with Two Fella Creek, starting about 1.6km west of Wagait Beach, were not inspected.

3.3 Desktop assessment of potential mosquito breeding sites

Potential mosquito breeding sites are indicated in Figure 1. Previous larval mosquito surveys in January 2015 revealed the interdunal depressions between the northern residents and the main beach front are productive breeding sites for *Ae. vigilax.* Interdunal depressions are usually the last habitat type for *Ae. vigilax* to become seasonally flooded, and therefore it is expected that late December to February would be the main months of breeding in the interdunal areas at Wagait Beach.

The main breeding sites for *Ae. vigilax* from September to late December are likely to be the two large tidal swamps immediately to the east and west of Wagait Beach township. Productive breeding is expected to occur when monthly high tides flood the previously dry swamps, causing *Ae. vigilax* eggs to hatch. Numerous generations are expected to occur as the swamps periodically dry and re-flood during this period. Seasonal *Ae. vigilax* breeding in these swamps would cease once the swamps remain flooded with water after consistent heavy rains during the monsoon season. Observations in December 2017, after very little build-up rainfall at Wagait Beach, indicated that after a large and late wet season surface water may still persist well into the following dry season in at least the western swamp, and thus maintain small fish predators and reduce available *Ae. vigilax* breeding habitat. It is possible that this scenario also occurs in the eastern swamp after a large and prolonged wet season.

In Darwin, some tidal drains can be productive sources of *Ae. vigilax* during the late dry season and early wet season. At Wagait Beach, *Aedes vigilax* is also likely to be breeding in the stormwater drains that convey stormwater from the roads to the beachline during the late dry and early wet season. In particular, the drain that runs between Lots 12 & 13 De Lissa Dve and associated depression near the beachline, could be a productive breeding site for *Ae. vigilax* when residual ponding occurs. The drain downstream of the Country Club (in and north of Lot 22 Cox Dve) also appears to be a potentially productive *Ae. vigilax* breeding site. The potential for mosquito breeding appears to be caused by dry season sand build-up at the point where the drains meet the beachline, along with some sediment deposition and tree growth within the drains.

Wagait Beach is also likely to be subject to *Ae. vigilax* dispersal from swamps up to 5-10km away, due to the very long flight range of this mosquito. The numerous large tidal swamps associated with Two Fella Creek, starting about 1.6km to the west of Wagait Beach, are likely to contribute to the *Ae. vigilax* problem in Wagait Beach during September to December/early January. The numerous small tidal swamps associated with small mangrove creeks between Mandorah and Woods Inlet may also contribute to the Wagait Beach *Ae. vigilax* problem from September to early January, but are probably of lower significance compared to the Two Fella Creek swamps.

The numerous paperbark swamps within Wagait Beach township (eg in Lot 132 & 133 Erikson Cres and Lots 2 to 5 Cox Dve) are not expected to be breeding sites for *Ae. vigilax*, as dense paperbark swamps are not typical breeding sites for this mosquito. The paperbark swamps however are likely to be major breeding sites for *Verrallina funerea,* particularly the paperbark swamp in Lots 2 to 4 Cox Dve, which is likely to be brackish and highly suitable for this species, as well as brackish water depressions associated with the two large swamps either side of Wagait Beach. The months of December to March are likely to be the peak months for *Ve. funerea* breeding in brackish swamps. The dense paperbark swamps contained minimal semi-aquatic vegetation, suggesting they are not likely to be major breeding sites for freshwater mosquito species, but could produce low to moderate levels of *Cx. annulirostris* and *Anopheles* species during the early to dry season.

The grassy freshwater depression in Lot 76 upstream of Cox Dve (Country Club) is likely to be a localised breeding site for *Cx. annulirostris,* after isolated ponding during the early wet season before the depression overflows Cox Drive, and during the early dry season when residual shallow ponding occurs as the swamp dries out. Low to moderate levels of *Anopheles* mosquitoes are also likely to breed in this depression.

During the dry season, the two large tidal swamps either side of Wagait Beach are likely to be the most important sources of freshwater/brackish water mosquitoes such as *Cx. annulirostris, Anopheles* species and *Cx. sitiens.* See Section 3.4 below regarding the importance of these swamps for dry season mosquito abundance.

3.4 Cox Peninsular Baseline Mosquito Trapping April 1990 to May 1991

Baseline mosquito trapping was carried out in Cox Peninsular from April 1990 to May 1991, with traps set on a monthly basis during the dry season and early wet season (Medical Entomology unpublished data). Out of the 23 traps set around Cox Peninsular, four traps were relevant to Wagait Beach, with two traps set at the large swamps either side of Wagait Beach (CP16 & CP17), with another trap was set at the large swamp on the eastern arm of Two Fella Creek (CP18), and a trap set south of Charles Point road adjacent to a large seasonal wetland (CP19). Trap sites are shown in Figure 1, with results shown in Tables 3-6.

A total of 3496 adult mosquitoes were collected during 14 trapping episodes at CP16 (Table 3). The most common mosquito collected was *Cx. vishnui grp,* which accounted for 25.06% of all mosquitoes, followed by *Ae. vigilax* (18.94%), *Cx. annulirostris* (16.99%), *Cx. sitiens* (16.56%), *Ve. funerea* (7.87%) and *An. farauti s.l.*. Overall, individual trap catches for all species was generally low to moderate from a pest perspective, with the exception of high *Ae. vigilax* numbers in December 1990. However, there were important catches of *Cx. annulirostris* and *An. farauti s.l.* from a potential disease perspective.

A total of 2583 adult mosquitoes were collected during 13 trapping episodes at CP17 (Table 4). The most common mosquito collected was *An. farauti s.l.,* which accounted for 35.77% of all mosquitoes collected at this site. This was followed by *Cx. annulirostris* (29.89%), *Ae. vigilax* (5.88%) and *An. bancroftii* (4.34%). Overall, individual trap catches for all species was low to moderate from a pest perspective. However, there were important catches of *Cx. annulirostris, Ae. vigilax, An. farauti s.l.* and *An. meraukensis* from a potential disease perspective.

A total of 3468 adult mosquitoes were collected during 14 trapping episodes at CP18 (Table 5). The most common mosquito collected was *Cx. annulirostris,* which accounted for 28.14% of all mosquitoes collected at this site. This was closely followed by *Ae. vigilax* (26.3%), *An. farauti s.l.* (17.94%) and *An. meraukensis* (6.92%). *Aedes vigilax* was recorded in high numbers from a pest perspective in November and December, while other mosquito species were recorded in low to moderate numbers. There were important catches of *Cx. annulirostris, Ae. vigilax, An. farauti s.l.* and *An. meraukensis* from a potential disease perspective.

A total of 991 adult mosquitoes were collected during 13 trapping episodes at CP19 (Table 6). The most common mosquito collected was *Cx. annulirostris,* which accounted for 37.74% of all mosquitoes collected at this site. This was followed by *Cq. xanthogaster* (22.7%) and *Ae. vigilax* (17.56%). *Aedes vigilax* was recorded in moderate numbers from a pest perspective in December, while all other mosquito species were recorded in minor numbers from both a pest and potential disease perspective.

4.0 Discussion

4.1 Northern salt marsh mosquito *Aedes vigilax*

Aedes vigilax is the principal pest mosquito in coastal areas of the NT from September to January, due to its sudden appearance in plagues, aggressive day and night biting, and long flight range (over 60km) from very large breeding sites. Pest problems usually begin 9 days after flooding high tides or rain, and persist for about one week in the hotter drier months, and up to two-three weeks in the humid months. *Aedes vigilax* lays eggs at the edge of vegetation in damp or drying depressions in upper tidal areas (7.3m to 8.1m ACD), with eggs hatching after monthly high tides or heavy rain events. As each female *Ae. vigilax* can lay up to 100 eggs, each successive generation is usually more productive than the previous generation, until the major breeding sites become fully flooded and unavailable for egg laying. November and December are usually the months of maximum abundance for this species in the western Top End.

The trapping in December 2017 revealed relatively high *Ae. vigilax* numbers in the three traps along Charles Point Rd, at the eastern end of De Lissa Dve and at the end of Mungalo Rd. Moderate numbers were recorded at the Country Club and at the end of Vangemann Rd. This suggests all of the Wagait Beach residential area would have been experiencing some pest problems. Trapping in mid-January 2015 (Warchot and Copley 2015) also revealed moderate to high *Ae. vigilax* numbers throughout Wagait Beach, indicating January would also be an important month for this species at Wagait Beach.

The presence of a wide range of potential *Ae. vigilax* habitat at Wagait Beach is most likely causing seasonal pest problems over many months of the year. Upper tidal swamps and drainage lines are likely to provide the main *Ae. vigilax* problems from September to early January, while interdunal breeding sites would prolong the season into February for at least the northern portion Wagait Beach. Overall, the pest problem posed by this mosquito throughout Wagait Beach is likely to range from moderate to very high from September to February.

Aedes vigilax is a vector of Ross River virus and Barmah Forest virus. Macropods such as wallabies are presumed to be the natural host for RRV, and in rural areas such as Wagait Beach, which is surrounded by large areas of undeveloped land, wallaby hosts are likely to occur in greater numbers than in urban cities such as Darwin. Therefore, due to the likely higher numbers of reservoir host animals combined with the high seasonal *Ae. vigilax* numbers, the RRV risk at Wagait Beach is likely to be higher compared to Darwin and Palmerston, and probably similar to mosquito prone areas in Litchfield Shire. The BFV risk is also likely to be similar to mosquito prone areas in Litchfield Shire. Overall, the potential RRV and BFV risk posed by this mosquito at Wagait Beach is considered seasonally high.

4.2 Common banded mosquito *Culex annulirostris*

Culex annulirostris is the main disease carrying mosquito in the NT, capable of transmitting the potentially fatal Murray Valley encephalitis virus, as well as Kunjin virus, RRV and BFV. This mosquito generally breeds in open freshwater and brackish water swamps, floodplains and depressions in the presence of semi-aquatic vegetation such as *eleocharis* and *typha* reeds and dense floodplain grasses. In urban situations, this species can breed in high numbers in polluted drains (dry season), disused swimming pools and poorly maintained sewage ponds. The peak season in the Top End of the NT occurs from January to August, although populations can vary during this period.

The recent trapping in December 2017 only revealed very minor *Cx. annulirostris* numbers due to the absence of significant freshwater ponding. The trapping in January 2015 revealed low numbers. Cox Peninsular baseline trapping in 1990-91 revealed a peak season from January to September adjacent to Wagait Beach residents, with highest numbers in the early dry season (May). There was a gap in the baseline trapping program during February and March, although February is usually a productive month for this mosquito around Darwin, and therefore February is likely to be an important month for this species at Wagait Beach.

The Cox Peninsular baseline trapping program did not reveal high numbers of *Cx. annulirostris* from a pest perspective. *Culex annulirostris* only bites at night and is more timid in the presence of personal repellents and well lit night areas, therefore higher EVS trap counts are usually required compared to *Ae. vigilax* before a pest problem is expected to occur. The indicative pest threshold for this mosquito is about 600/trap night, which was not exceeded in around Wagait Beach in either the Cox Peninsular baseline trapping or recent ad-hoc trapping.

Despite the absence of appreciable pest problems, the *Cx. annulirostris* levels were indicative of a seasonal virus risk. About 70-100 *Cx. annulirostris* in an overnight EVS trap suggests a possible virus risk (Kurucz et al 2005, Whelan 1987). The Cox Peninsular baseline traps at either end of Wagait Beach periodically collected *Cx. annulirostris* in numbers that exceeded this threshold in the mid wet and dry season, indicating the possibility of this species posing a periodically low to moderate Murray Valley encephalitis virus, Kunjin virus, RRV and BFV transmission risk.

4.3 Anopheles species

Anopheles species were recorded in relatively high numbers at the western end of Wagait Beach, and low to moderate numbers at the eastern end of Wagait Beach during the Cox Peninsular baseline trapping. In particular, one of the most important *Anopheles* species, *An. farauti s.l.,* was the predominant *Anopheles* species collected at the western end of Wagait Beach. Other *Anopheles* species recorded in periodically notable numbers during the baseline trapping at either the western or eastern end of Wagait Beach were *Anopheles annulipes s.l., An. meraukensis* and *An. bancroftii.*

Anopheles mosquitoes are important due to their potential to transmit malaria. Local malaria transmission occurred in the NT up until 1962 (Whelan 1991), and Australia was certified free of Malaria by the World Health Organisation in 1983 (WHO 1983). However, due to prevalence of potential malaria carrying mosquitoes in the NT, particularly in the Top End, there is the potential for the re-introduction of malaria. The risk would only arise if a person acquired the parasite from overseas and infects local *Anopheles* mosquitoes. The malaria mosquito risk level is considered to be about 10 various *Anopheles* species in an overnight EVS trap or two *An. farauti s.l.,* which was appreciably exceeded at the western end of Wagait Beach throughout the dry season from April to October, and reached/exceeded during the same months at the eastern end of Wagait Beach. This indicates there is a risk of local malaria transmission. However, due to the current Department of Health, Centre for Disease Control case management and Medical Entomology reactive fogging program, the current malaria risk at Wagait Beach, and indeed the rest of the NT, is considered very low.

The levels of *Anopheles* species mosquitoes recorded during the Cox Peninsular baseline trapping suggest that moderate pest problems could be encountered by residents within about 500m of the western swamp during the dry season, and low pest problems could be encountered by the eastern fringe residents.

4.4 Other mosquito species

The black jungle mosquito *Verrallina funerea* is likely to pose a high seasonal problem to residents living next to brackish water paperbark swamps and depressions, with December to March the likely peak season. This mosquito is considered a potential RRV and BFV vector, but does not venture far from dense vegetation at their breeding sites, and therefore would only be a localised problem to residents living very close to breeding sites.

Freshwater pest mosquitoes such as *Coquillettidia xanthogaster* and *Mansonia uniformis* were only recorded in minor to low numbers during baseline trapping, suggesting an absence of suitable semi-aquatic reed habitat for these mosquitoes Therefore, these species are currently of only minor significance.

There were no exotic *Aedes* mosquitoes collected at Wagait Beach. This indicates that Wagait Beach, like the rest of the NT, is free from mosquitoes that could potentially transmit dengue and Zika viruses. The absence of exotic *Aedes* mosquitoes was not surprising, as the Cox Peninsular area is (currently) not a First Point of Entry for foreign ships or aircraft, nor does it attract heavy visitation from North Qld travellers where the dengue mosquito *Aedes aegypti* is endemic.

4.5 Mosquito mitigation measures

The best form of mosquito control is habitat modification to remove the breeding sites or to shift the ecological balance in favour of mosquito larvae predators (fish, water bugs). However, as the modification of swamps is generally not positively viewed, unless perhaps if the swamps have been degraded by urban development, it is unlikely there would be support for such action at Wagait Beach due to the relatively low density living and pristine swamps. If there is strong support for swamp modification, any proposal would need to be assessed under the Environmental Assessment Act/NT Planning Scheme.

Aerial control of the large tidal swamps within proximity of Wagait Beach is an option that could be utilised to reduce *Ae. vigilax* pest problems affecting residents. When used in combination with localised ground control of drains and dune depressions, the seasonal *Ae. vigilax* populations would be greatly reduced. Tidal swamps and depressions within at least 2-3km of Wagait Beach township, and possibly up to 5km, would need to be targeted for control. The most effective and environmentally safe larvicides to use would be *Bacillus thuringiensis* var. *israelensis* and methoprene, with the larvicides rotated as appropriate to prevent resistance. A mosquito control program could also control other problem mosquito species such as *Cx. annulirostris* and *Anopheles* species when there is a significant disease risk. However, it is likely that an intensive mosquito control program would not be economically feasible at Wagait Beach, due to the low density living.

The annual maintenance of stormwater drains could reduce *Ae. vigilax* numbers at Wagait Beach to some extent during the late dry/early wet season, by ensuring drains are clear of obstructions that could otherwise cause high tide/early wet season ponding and mosquito breeding. Shallow sand filling of the interdunal depressions could also be carried out, to fill the depressions to above the wet season water table, and thus prevent surface ponding and mosquito breeding from January to March. This may be a cost effective solution of reducing the impact of *Ae. vigilax*, particularly during the mid wet season when sand dune breeding sites are the main source of this species. However, it is likely that any proposal to shallow fill existing interdunal depressions would require assessment under the Environmental Assessment Act/NT Planning Scheme.

Culex annulirostris breeding at Wagait Beach could also be reduced by removing early dry season and early wet season ponding from the Country Club depression upstream of Cox Dve, by filling the depression to match the level of the Cox Dve culvert. Alternatively, the depression could be converted to contain a pond that holds water and small fish throughout the dry season.

The use of residual barrier insecticides, such as bifenthrin or alpha-cypermethrin, would reduce adult mosquito problems around residences when applied to mosquito harbourage areas (e.g. shrub vegetation, outdoor shaded areas, under demountables etc.). However, the insecticide should not be used near waterways, and affects non-target insects. Therefore, if barrier spraying is to be considered by individual residents or for use at community areas, qualified pest controllers should be engaged to apply the product. Treatments should only be carried out occasionally to avoid issues with insecticide resistance and cumulative impact on non-target insects.

Adult mosquito fogging would not be a solution to the seasonal mosquito pest problem, due to the impact on non-target insects and short term efficacy of fog treatments, and difficulty in fogging residential areas. However, fogging would be required if a malaria risk occurs, to control adult *Anopheles* mosquitoes that may have acquired the parasite after biting an infected traveller. This fogging would be carried out by Medical Entomology.

Personal protection is likely to be the most effective ongoing measure for residents to reduce exposure to mosquitoes. Personal protection could involve using suitable screening on houses, the use of outdoor mosquito repellent lanterns/gas powered devices, mosquito coils and personal repellents, along with the avoidance of outdoor areas during problem periods. Further information on personal protection can be found in Attachment 2. Medical Entomology also produces annual pest calendars for *Ae. vigilax* based on tide events, and issues media releases when significant pest mosquito problems are expected, or when there is an elevated risk of mosquito borne disease. These would usually also be relevant to Wagait Beach residents, and therefore can be published in the local paper and printed and displayed on community notice boards, and conveyed by any other means such as social media.

5. Conclusions and recommendations

- Wagait Beach residents are likely to periodically experience moderate to very high seasonal pest problems caused by the day and night biting northern salt marsh mosquito *Ae. vigilax.* Pest problems will begin 9 days after monthly high tides or heavy rain events during September to February, and persist for one to two weeks. This mosquito will also pose a potential Ross River virus and Barmah Forest virus risk. The main breeding sites for this species would be the two swamps either side of Wagait Beach, along with dispersal from the Two Fella Creek tidal swamps and localised breeding in tidally influenced drains and interdunal depressions.

- Wagait Beach residents are likely to periodically experience low to moderate populations of the common banded mosquito *Culex annulirostris* during January to September, with peak numbers occurring during the dry season. This species is not expected to cause appreciable pest problems, but will represent a low to moderate virus risk (MVEV, KUNV, RRV and BFV). The two swamps either side of Wagait Beach are likely to be the main breeding sites, with the Country Club depression and localised grassy depressions also potentially important breeding sites.

- *Anopheles* species mosquitoes would pose a potential malaria risk, if a traveller acquires the parasite overseas and infects local *Anopheles* mosquitoes. The main risk will occur during the dry season, with the western side of Wagait Beach incurring the higher risk. However, the current risk is considered very low due to the current Department of Health, Centre for Disease Control and Medical Entomology malaria prevention strategies.

  Anopheles mosquitoes may periodically cause dry season pest problems, mainly in the western portion of Wagait Beach.

- There were no exotic *Aedes* mosquitoes detected at Wagait Beach. This confirms that Wagait Beach residents, along with the rest of the NT, are not at risk of dengue and Zika virus transmission.

- To adequately reduce *Ae. vigilax* problems, aerial control would need to be carried out in the large swamps either side of Wagait Beach, and would possibly need to include large swamps up to 5km away such as those associated with Two Fella Creek.

  The filling of interdunal depressions, and maintaining drains to be completely free draining would also reduce localised *Ae. vigilax* problems in the northern portion of Wagait Beach.

- To reduce *Cx. annulirostris* and *Anopheles* species numbers, aerial control would need to be carried out in the swamps either side of Wagait Beach. Further reductions in *Cx. annulirostris* numbers could be achieved by preventing shallow residual ponding in the Country Club depression to the south of Cox Dve, and shallow filling of interdunal depressions.

- Ground control could be carried out in drains and localised depressions to reduce *Ae. vigilax* and *Cx. annulirostris* numbers. The main larvicide of choice would be a residual methoprene formulation, rotated with *Bacillus thuringiensis* var. *israelensis* to prevent resistance.

- Due to the likelihood of aerial mosquito control and habitat modification being unfeasible due to the low density living, to reduce mosquito problems residents would need to rely on personal protection, appropriate building design and potentially the periodic use of outdoor residual insecticides during peak periods of mosquito/virus activity.

- Anyone suspected of having malaria should be advised to seek immediate medical attention, to allow Medical Entomology to be subsequently notified and assess the local transmission risk.

- Medical Entomology issues mosquito warnings when major pest problems are expected and when there is an elevated mosquito borne disease risk. These warnings can be reproduced by local council for local media purposes.

6. References

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May 2018

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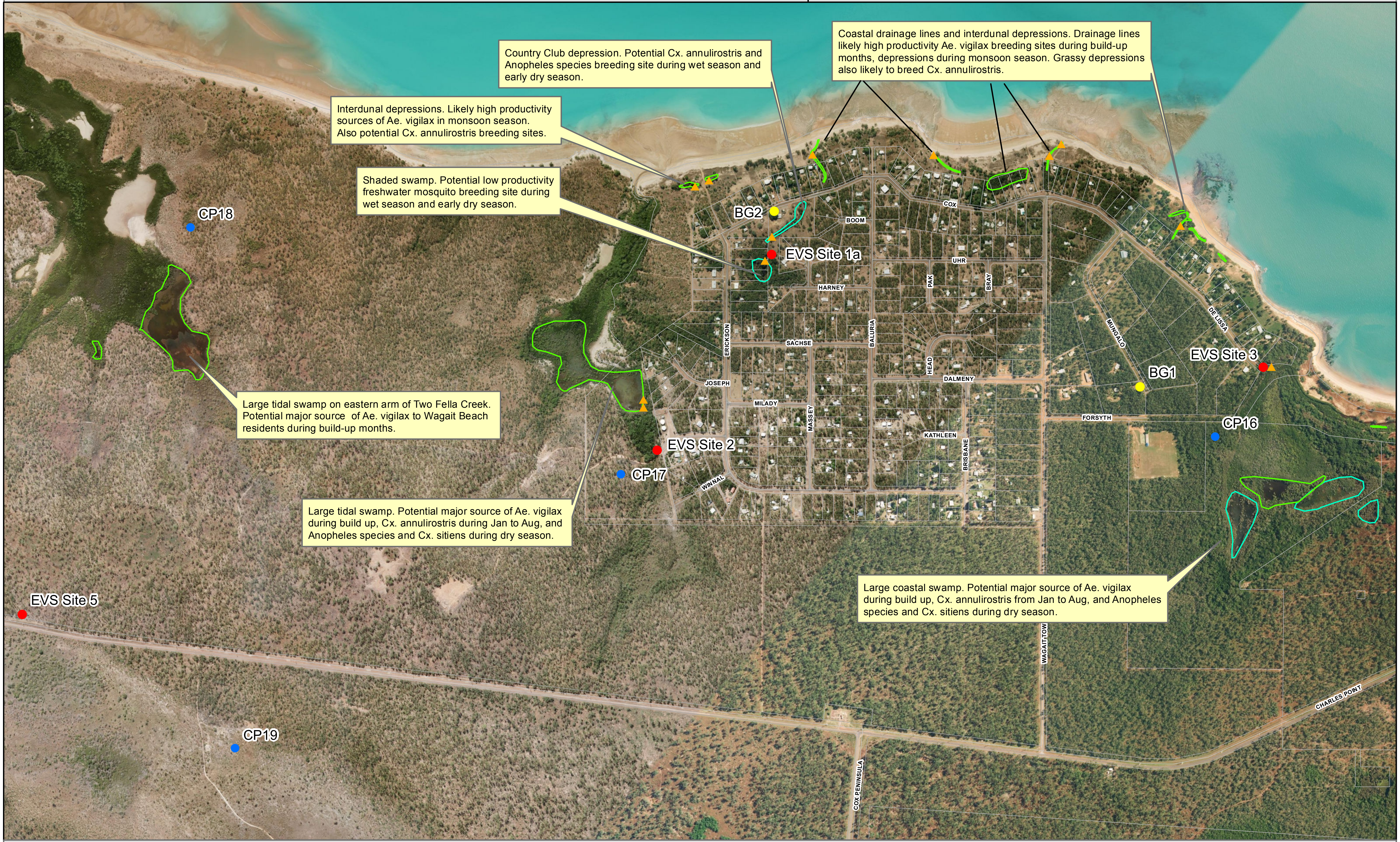
Figures

Figure 1 : Wagait Beach Mosquito Investigation 18-19 December 2017.

Datum: GCS GDA 94   Absolute scale 1:12,996

0 200 400 600 800 1,000 1,200 Meters



Legend

- Adult biting insect trap locations (CO2 baited BG traps) 18-19 Dec 2017
- Adult biting insect trap locations (CO2 baited EVS traps) 18-19 Dec 2017
- Larval mosquito survey sites 18 Dec 2017.
- Cox Peninsular Baseline adult biting insect trap locations (CO2 baited EVS traps) 1990-1991
- Potential salt marsh/brackish water mosquito breeding site.
- Potential freshwater mosquito breeding site.

Prepared and produced by Medical Entomology, Department of Health, Darwin, Northern Territory of Australia
May 2018

Aerial Imagery : NTLIS Google Earth WMS Server

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Tables

Table 1. Wagait Beach mosquito investigation December 2017. Total number of all adult female mosquitoes collected in CO_2 baited EVS traps 18th-19th December 2017.

Trap location	*Ae. (Cha) elchoensis*	*Ae. (Fin) notoscriptus*	*Ae. (Mac) tremulus*	*Ae. (Muc) alternans*	*Ae. (Och) vigilax*	*An. (Cel) farauti s.l.*	*An. (Cel) hilli*	*Cq. (Coq) xanthogaster*	*Cx. (Cux) annulirostris*	*Cx. (Cux) sitiens*	*Cx. (Cux) Vishnui group*	*Ve. (Ver) funerea*	Totals	%
Wagait Beach Site 1a- Lot 76 Cox Drive, edge of paperbark swamp at back of Country Club	0	2	0	0	97	0	0	0	2	18	0	0	119	9.41
Wagait Beach Site 2 - Lot 227 in creekline vegetation at end of Vangemann Rd	0	6	0	0	92	5	0	0	0	20	0	1	124	9.81
Wagait Beach Site 3 - east end of De Lissa Rd in monsoon vegetation adjacent to mangrove swamp	0	0	2	1	201	0	0	0	2	363	8	18	595	47.07
Wagait Beach Site 5 - Charles Point Rd in bush opposite Power Pole 35	5	0	0	0	320	4	4	1	4	88	0	0	426	33.70
Totals	5	8	2	1	710	9	4	1	8	489	8	19	1264	100.00
%	0.40	0.63	0.16	0.08	56.17	0.71	0.32	0.08	0.63	38.69	0.63	1.50	100.00	

Table 2. Wagait Beach mosquito investigation December 2017. Total number of all adult female mosquitoes collected in CO_2 baited EVS traps 18th-19th December 2017.

Trap location	*Ae. (Fin) notoscriptus*	*Ae. (Mac) tremulus*	*Ae. (Och) vigilax*	*An. (Cel) farauti s.l.*	*Cx. (Cux) quinquefasciatus*	*Cx. (Cux) sitiens*	*mosquitoes unidentifiable (damaged)*	*Ve. (Ver) funerea*	Totals	%
Wagait Beach BG1- Sec 64 Forsyth Rd, next to water tank	3	10	512	5	0	61	11	1	603	90.81
Wagait Beach BG2- Lot 76 Cox Drive, garden bed of Country Club	0	10	45	1	1	4	0	0	61	9.19
Totals	3	20	557	6	1	65	11	1	664	100.00
%	0.45	3.01	83.89	0.90	0.15	9.79	1.66	0.15	100.00	

Table 3 - Cox Peninsular Baseline Adult Mosquito Trapping April 1990 to May 1991. Total numbers of all adult female mosquitoes collected in CO2 baited EVS traps at Trap Site CP16 - Swamp on eastern edge of Wagait Beach township.

Date collected	*Ad. (Ady) catasticta*	*Ae. (Adm) alboscutellatus*	*Ae. (Fin) kochi*	*Ae. (Fin) notoscriptus*	*Ae. (Mac) species*	*Ae. (Mac) tremulus*	*Ae. (Och) phaecasiatus*	*Ae. (Och) vigilax*	*Ae. daliensis*	*An. (Ano) bancroftii*	*An. (Ano) powelli*	*An. (Cel) annulipes s.l.*	*An. (Cel) farauti s.l.*	*An. (Cel) meraukensis*	*An. (Cel) novaguinensis*	*Cq. (Coq) xanthogaster*	*Cx. (Cux) annulirostris*	*Cx. (Cux) quinquefasciatus*	*Cx. (Cux) sitiens*	*Cx. (Cux) species 32*	*Cx. (Cux) Vishnui group*	*Cx. (Lop) cubiculi*	*Cx. (Ocu) squamosus*	*Ma. (Mnd) uniformis*	Not collected mosquitoes	*Tp. (Pol) punctolateralis*	*Ur. (Ura) lateralis*	*Ve. (Ver) funerea*	Totals	%
24-Apr-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0		
27-Apr-90	0	0	0	0	0	1	0	2	0	0	0	0	6	0	0	0	5	0	1	1	0	0	0	17	0	0	0	0	33	0.94
17-May-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0		
14-Jun-90	2	0	0	2	0	0	0	4	0	22	22	0	66	0	0	2	2	0	148	0	158	0	0	2	0	0	12	0	442	12.64
15-Jun-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0		
31-Jul-90	2	0	0	1	0	0	0	1	0	2	0	0	45	1	0	3	8	1	1	0	145	0	0	0	0	0	1	0	211	6.04
01-Aug-90	4	0	0	0	0	0	0	0	1	4	0	1	19	0	0	14	31	0	0	0	58	0	0	0	0	1	0	0	133	3.80
28-Aug-90	0	0	0	0	0	0	0	2	3	0	0	0	10	1	0	0	26	1	13	0	115	0	0	0	0	0	0	0	171	4.89
29-Aug-90	4	0	0	1	0	0	0	6	3	0	0	0	25	0	0	2	19	0	0	0	77	1	0	0	0	0	0	0	138	3.95
25-Sep-90	0	0	0	0	0	1	0	2	0	0	0	0	2	1	0	0	3	0	0	0	14	0	0	0	0	0	0	0	23	0.66
26-Sep-90	0	0	0	0	0	0	0	28	2	0	0	1	5	0	0	3	10	2	1	0	49	0	0	0	0	0	0	0	101	2.89
23-Oct-90	0	0	0	0	0	0	0	89	1	0	0	0	2	0	0	1	20	0	12	0	2	0	0	0	0	0	0	0	127	3.63
24-Oct-90	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	3	6	1	4	0	0	0	0	0	0	0	0	0	44	1.26
28-Nov-90	0	0	0	1	0	3	0	89	1	0	0	0	7	0	0	0	19	0	287	0	4	0	0	0	0	0	0	2	413	11.81
20-Dec-90	0	0	4	8	0	0	0	344	0	0	0	0	0	0	0	0	20	0	90	0	133	0	0	0	0	0	0	104	703	20.11
17-Jan-91	0	54	2	24	0	0	8	65	0	0	0	0	10	0	0	0	125	0	14	0	17	0	1	0	0	0	0	169	489	13.99
15-Feb-91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0		
16-Mar-91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0		
15-Apr-91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0		
14-May-91	0	0	0	0	0	0	0	0	2	4	0	10	22	6	4	6	300	0	8	0	104	0	0	0	0	0	2	0	468	13.39
Totals	12	54	6	37	0	5	8	662	13	32	22	12	219	9	4	34	594	5	579	1	876	1	1	19		1	15	275	3496	100.00
%	0.34	1.54	0.17	1.06	0.00	0.14	0.23	18.94	0.37	0.92	0.63	0.34	6.26	0.26	0.11	0.97	16.99	0.14	16.56	0.03	25.06	0.03	0.03	0.54		0.03	0.43	7.87	100.00	

Table 4 - Cox Peninsular Baseline Adult Mosquito Trapping April 1990 to May 1991. Total numbers of all adult female mosquitoes collected in CO2 baited EVS traps at Trap Site CP17 - Tidal swamp on western edge of Wagait Beach township.

Date collected	*Ad. (Ady) catasticta*	*Ae. (Adm) alboscutellatus*	*Ae. (Cha) elchoensis*	*Ae. (Fin) britteni*	*Ae. (Fin) kochi*	*Ae. (Fin) notoscriptus*	*Ae. (Mac) tremulus*	*Ae. (Mol) pecuniosus*	*Ae. (Och) vigilax*	*An. (Ano) bancroftii*	*An. (Ano) powelli*	*An. (Cel) annulipes s.l.*	*An. (Cel) farauti s.l.*	*An. (Cel) hilli*	*An. (Cel) meraukensis*	*An. (Cel) novaguinensis*	*Cq. (Coq) xanthogaster*	*Cx. (Cui) pullus*	*Cx. (Cux) annulirostris*	*Cx. (Cux) sitiens*	*Cx. (Cux) species 32*	*Cx. (Cux) Vishnui group*	*Cx. (Ocu) bitaeniorhynchus*	*Ma. (Mnd) uniformis*	Not collected mosquitoes	Trap failure mosquitoes	*Ur. (Ura) nivipes*	**Totals**	**%**
24-Apr-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
27-Apr-90	0	0	1	2	15	2	1	1	1	3	1	0	54	3	15	1	3	6	46	0	20	0	4	40	0	0	0	219	8.48
17-May-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
14-Jun-90	8	0	0	0	0	0	0	0	0	77	4	0	52	5	13	0	4	0	11	30	0	35	0	5	0	0	0	244	9.45
15-Jun-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
31-Jul-90	2	0	0	0	0	0	0	0	1	17	2	3	60	0	5	0	11	0	30	0	0	13	0	0	0	0	0	144	5.57
01-Aug-90	0	0	0	0	0	0	0	0	0	2	0	1	50	7	1	0	13	0	10	0	0	0	0	0	0	0	0	84	3.25
28-Aug-90	1	0	0	0	0	0	0	0	5	0	0	3	144	0	4	0	2	0	62	0	0	2	0	0	0	0	0	223	8.63
29-Aug-90	9	0	1	0	0	0	0	0	12	0	0	0	149	0	2	0	10	1	139	21	0	16	0	2	0	0	0	362	14.01
25-Sep-90	2	0	0	0	0	0	0	0	1	3	0	1	172	7	1	0	4	0	63	0	0	5	0	0	0	0	0	259	10.03
26-Sep-90	0	0	0	0	0	0	0	0	10	1	0	0	127	5	0	0	8	0	130	0	0	0	0	0	0	0	0	281	10.88
23-Oct-90	0	0	0	0	0	0	0	0	20	0	0	0	28	4	0	0	4	0	51	8	0	10	0	0	0	0	0	125	4.84
24-Oct-90	0	0	0	0	0	0	0	0	41	0	0	0	22	2	0	0	7	0	20	0	0	0	0	0	0	0	0	92	3.56
28-Nov-90	0	0	0	0	0	1	1	0	28	0	0	0	1	1	0	0	0	0	3	1	0	0	0	0	0	0	0	36	1.39
20-Dec-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		
17-Jan-91	0	1	1	1	6	4	0	0	33	0	0	0	4	0	0	0	2	0	51	0	2	0	0	0	0	0	0	105	4.07
15-Feb-91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
16-Mar-91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
15-Apr-91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
14-May-91	0	0	2	0	1	0	0	0	0	9	7	18	61	0	128	14	2	0	156	0	0	11	0	0	0	0	0	409	15.83
Totals	22	1	5	3	22	7	2	1	152	112	14	26	924	34	169	15	70	7	772	60	22	92	4	47			0	2583	100.00
%	0.85	0.04	0.19	0.12	0.85	0.27	0.08	0.04	5.88	4.34	0.54	1.01	35.77	1.32	6.54	0.58	2.71	0.27	29.89	2.32	0.85	3.56	0.15	1.82			0.00	100.00	

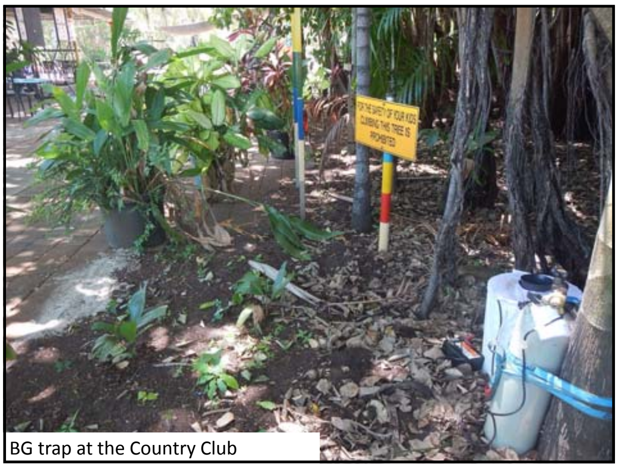
Table 5 - Cox Peninsular Baseline Adult Mosquito Trapping April 1990 to May 1991. Total numbers of all adult female mosquitoes collected in CO_2 baited EVS traps at Trap Site CP18 - Tidal swamp on eastern arm of Two Fella Creek.

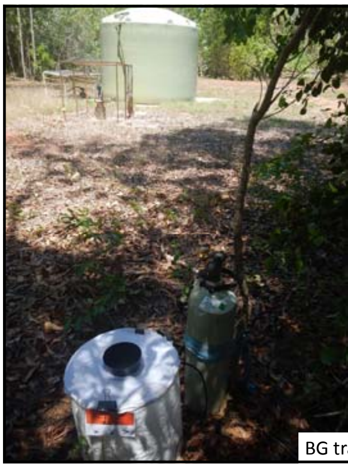
Date collected	*Ad. (Ady) catasticta*	*Ae. (Cha) elchoensis*	*Ae. (Fin) kochi*	*Ae. (Fin) notoscriptus*	*Ae. (Mac) species*	*Ae. (Mac) tremulus*	*Ae. (Mol) pecuniosus*	*Ae. (Och) vigilax*	*An. (Ano) bancroftii*	*An. (Cel) annulipes s.l.*	*An. (Cel) farauti s.l.*	*An. (Cel) hilli*	*An. (Cel) meraukensis*	*An. (Cel) novaguinensis*	*Cq. (Coq) xanthogaster*	*Cx. (Cux) annulirostris*	*Cx. (Cux) sitiens*	*Cx. (Cux) Vishnui group*	*Ma. (Mnd) uniformis*	Not collected mosquitoes	*Ur. (Ura) nivipes*	Totals	%
24-Apr-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		
27-Apr-90	1	1	0	1	0	1	1	1	10	0	158	0	24	3	20	43	6	0	24	0	0	294	8.48
17-May-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		
14-Jun-90	13	0	0	0	0	1	0	2	56	4	107	4	9	1	26	47	35	28	2	0	1	336	9.69
15-Jun-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		
31-Jul-90	13	0	0	0	0	0	0	1	2	0	12	4	0	0	20	5	1	15	0	0	0	73	2.10
01-Aug-90	29	0	0	0	0	0	0	0	1	5	15	4	2	0	15	26	0	6	0	0	0	103	2.97
28-Aug-90	2	0	0	0	0	0	0	2	1	2	74	0	2	0	7	23	0	10	0	0	0	123	3.55
29-Aug-90	3	1	0	0	0	0	0	8	0	0	18	0	1	0	0	34	3	17	0	0	0	85	2.45
25-Sep-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	58	0	0	0	0	0	85	2.45
26-Sep-90	0	0	0	0	0	0	0	6	0	0	5	0	0	0	1	13	0	4	0	0	0	29	0.84
23-Oct-90	0	0	0	0	0	0	0	43	0	0	1	0	0	0	4	45	3	3	0	0	0	99	2.85
24-Oct-90	0	0	0	0	0	0	0	76	0	0	0	2	0	0	3	34	0	0	0	0	0	115	3.32
28-Nov-90	0	2	0	0	0	2	0	422	0	0	1	0	0	0	0	10	3	0	0	0	0	440	12.69
20-Dec-90	0	1	0	1	0	10	0	261	0	0	0	1	0	0	2	47	6	5	0	0	0	334	9.63
17-Jan-91	0	2	1	4	0	9	0	87	0	0	6	0	1	0	2	75	3	0	1	0	0	191	5.51
15-Feb-91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		
16-Mar-91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		
15-Apr-91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		
14-May-91	0	0	0	0	0	0	6	3	0	60	225	0	201	90	57	516	0	3	0	0	0	1161	33.48
Totals	61	7	1	6	0	23	7	912	70	71	622	15	240	94	184	976	60	91	27		1	3468	100.00
%	1.76	0.20	0.03	0.17	0.00	0.66	0.20	26.30	2.02	2.05	17.94	0.43	6.92	2.71	5.31	28.14	1.73	2.62	0.78		0.03	100.00	

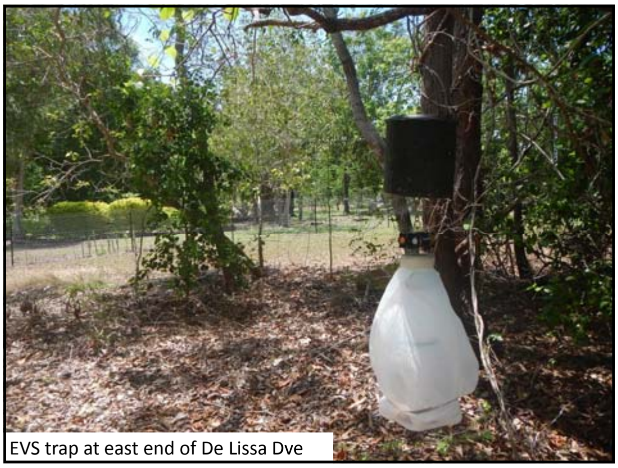
Table 6 - Cox Peninsular Baseline Adult Mosquito Trapping April 1990 to May 1991. Total numbers of all adult female mosquitoes collected in CO2 baited EVS traps at Trap Site CP19 - Large freshwater swamp/floodplain on southern side of Charles Point Rd.

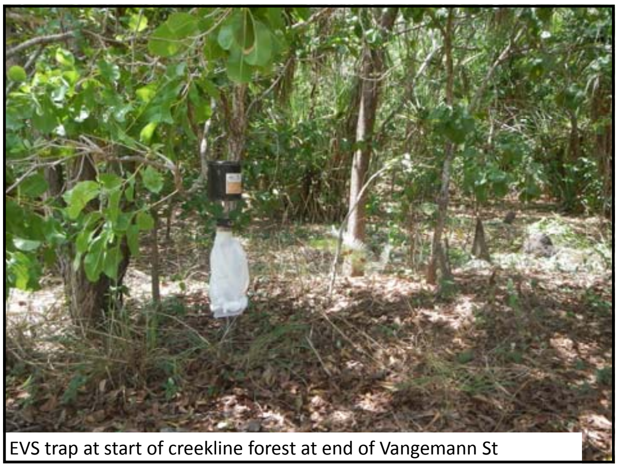
Date collected	*Ad. (Ady) catasticta*	*Ae. (Cha) elchoensis*	*Ae. (Mac) tremulus*	*Ae. (Och) normanensis*	*Ae. (Och) vigilax*	*An. (Ano) bancroftii*	*An. (Cel) annulipes s.l.*	*An. (Cel) farauti s.l.*	*An. (Cel) hilli*	*An. (Cel) meraukensis*	*Cq. (Coq) xanthogaster*	*Cx. (Cux) annulirostris*	*Cx. (Cux) sitiens*	*Cx. (Cux) species 32*	*Cx. (Cux) Vishnui group*	*Cx. (Ocu) bitaeniorhynchus*	Not collected mosquitoes	Trap failure mosquitoes	*Ve. (Ver) reesi*	Totals	%
24-Apr-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
27-Apr-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		
17-May-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
14-Jun-90	11	1	0	2	0	4	1	8	0	4	41	41	0	1	0	0	0	0	0	114	11.50
15-Jun-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
31-Jul-90	33	0	0	0	0	0	0	0	0	0	18	6	0	0	7	0	0	0	0	64	6.46
01-Aug-90	17	0	0	0	0	0	0	3	0	1	31	18	0	0	0	0	0	0	0	70	7.06
28-Aug-90	3	0	0	0	1	0	1	2	0	0	43	54	0	0	0	0	0	0	0	104	10.49
29-Aug-90	17	0	0	0	0	0	1	6	1	0	25	39	0	0	0	0	0	0	0	89	8.98
25-Sep-90	0	0	0	0	1	0	2	0	0	0	22	32	0	0	0	0	0	0	0	57	5.75
26-Sep-90	0	0	0	0	0	0	1	1	0	0	2	18	0	0	0	0	0	0	0	22	2.22
23-Oct-90	0	2	0	0	0	0	0	0	0	0	19	36	0	0	0	0	0	0	0	57	5.75
24-Oct-90	0	0	0	0	2	0	0	0	0	0	1	3	0	0	0	0	0	0	0	6	0.61
28-Nov-90	0	0	2	0	10	0	0	0	0	0	3	7	3	0	0	0	0	0	0	25	2.52
20-Dec-90	0	1	9	2	143	0	0	0	0	0	0	33	12	0	5	0	0	0	0	205	20.69
17-Jan-91	0	0	2	1	17	0	0	0	0	3	7	35	2	0	0	2	0	0	2	71	7.16
15-Feb-91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
16-Mar-91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
15-Apr-91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		
14-May-91	0	0	0	0	0	0	0	0	0	42	13	52	0	0	0	0	0	0	0	107	10.80
Totals	81	4	13	5	174	4	6	20	1	50	225	374	17	1	12	2			2	991	100.00
%	8.17	0.40	1.31	0.50	17.56	0.40	0.61	2.02	0.10	5.05	22.70	37.74	1.72	0.10	1.21	0.20			0.20	100.00	

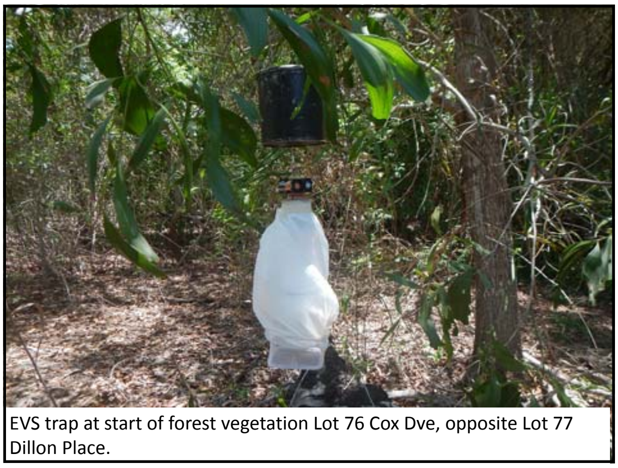
Attachment 1 – Site photos 18 December 2017

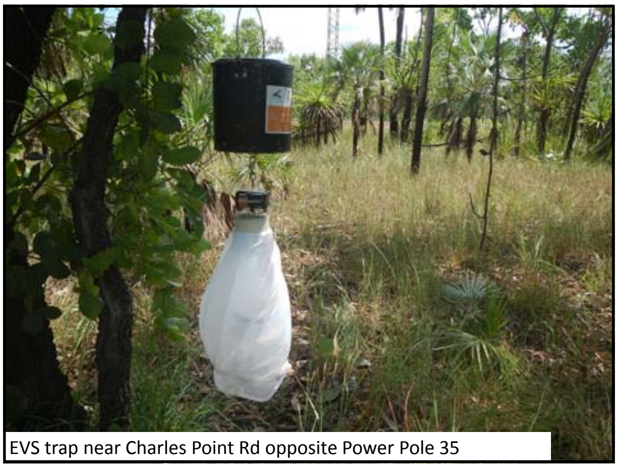

BG trap at the Country Club

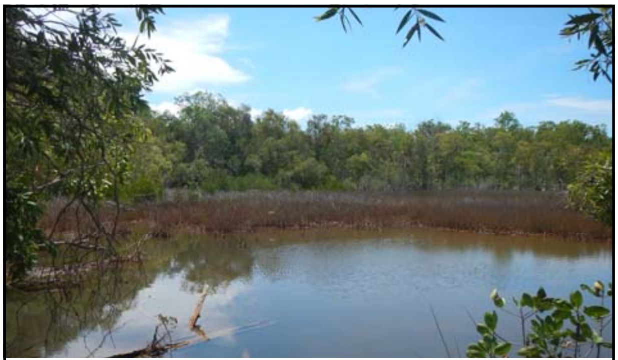

BG trap at Section 64 Forsyth Rd


EVS trap at east end of De Lissa Dve

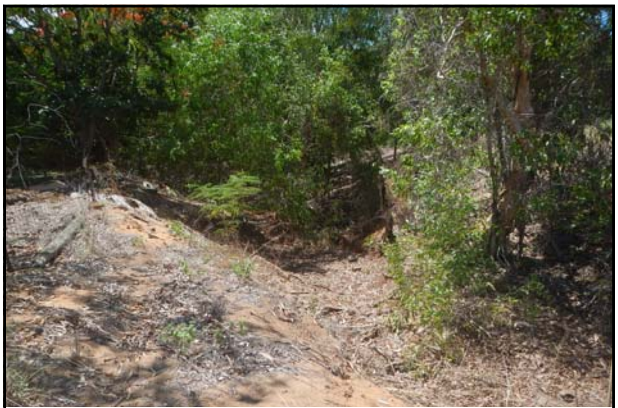

EVS trap at start of creekline forest at end of Vangemann St

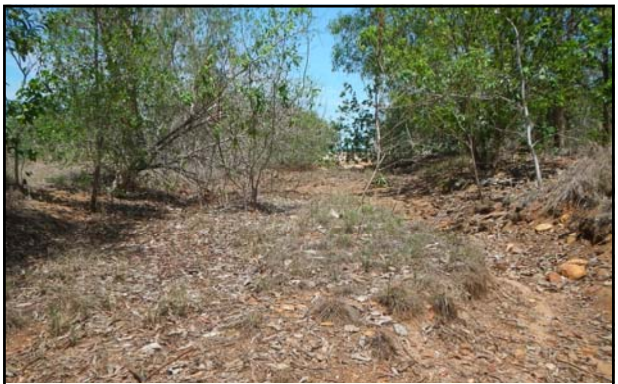

EVS trap at start of forest vegetation Lot 76 Cox Dve, opposite Lot 77 Dillon Place.


EVS trap near Charles Point Rd opposite Power Pole 35


Tidal swamp at west side of Wagait Beach, eastern reaches opposite town water supply tanks. Fish present in open water. Shallow reed areas likely to be important breeding habitat for saltwater and brackish water mosquitoes.


Drain from Cox Dve Country Club depression through Lot 22 to beach. Potential salt marsh mosquito breeding site.


Wagait Trower Rd drain to beach. Potential salt marsh mosquito breeding site.


Drain from De Lissa Dve between Lots 12 & 13 to beach. Potential salt marsh mosquito breeding site. Sediment build-up in lower reaches, similar to other drains at Wagait Beach.

Attachment 2 – Personal protection from mosquitoes and biting midges in the NT

NORTHERN TERRITORY GOVERNMENT

DEPARTMENT OF HEALTH

Personal protection from mosquitoes & biting midges in the NT

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

October 2011

Personal protection from mosquitoes & biting midges in the NT

Department of Health

October 2011

(Revised February 2016)

Adapted from paper by P. Whelan in "Australian Mosquito Control Manual" by a panel of authors, Editors C. Morris and P. Dale. Australian Mosquito Control Association, 1998, ISBN 0-646-35310-1.

1.0 MOSQUITOES AND BITING MIDGE BITES

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

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

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

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

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

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

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

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

2.0 MOSQUITO & BITING MIDGE AVOIDANCE

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

The upper high tide areas near creeks or low-lying areas, particularly near salt marsh habitats, can be significant sources of northern salt marsh mosquitoes *Aedes vigilax* and various other pest mosquitoes. The period of high salt marsh mosquito activity is usually during the late dry season and early wet season in tropical latitudes. Generally they are prevalent for one to two weeks after the highest tides of the month or appreciable rain. Salt marsh mosquito and midge pest calendars are available from the health website
http://www.health.nt.gov.au/Medical_Entomology/index.aspx

Dense vegetation near the breeding sites should be avoided during the day over this period. Pest problems during the evening and night can occur within 3 km of productive breeding sites (Whelan et al., 1997).

Other areas of high mosquito activity are the large seasonally flooded areas associated with rivers or drainage lines, flooded coastal swamps, extensive reed swamps and lagoons, ill defined or poorly draining creeks, extensive irrigation areas, and wastewater disposal facilities. Densely shaded areas near these habitats should be avoided during the day, and accommodation areas should be at least 3 km from extensive areas of these habitats.

Extensive areas of mangroves with small dendritic creeks or estuarine areas with muddy banks are potential sources of mangrove biting midges. These midges have seasonal and monthly population peaks with the monthly peaks usually associated with the tidal regime. When camping or choosing a permanent living site, a separation distance of at least 2 km from these areas is recommended unless specific biting insect investigations indicate there are no seasonal pest problems (Whelan 1990, Whelan, Hayes et al. 1997).

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

In residential areas, a local source of mosquitoes may be the cause of the problem. Check nearby potential artificial sources of mosquitoes such as disused swimming pools, receptacles such as tyres, drums, fallen palm fronds, pot plant drip trays, plant striking buckets, animal water, garden equipment, plastic sheeting, blocked roof gutters, old fishponds, or localised ponding of drains. Sites with mosquitoes breeding can be rectified by physically removing the source or through the use of insecticides. Fish ponds or ponds used for frogs can be rectified by the addition of a few fish.

3.0 SCREENING

The best method of avoiding attack at night is to stay inside insect-screened houses. Screens can be made of galvanised iron, copper, bronze, aluminium or plastic. Near the coast, iron or copper screens are not recommended because of the corrosive action of salt sprays. Homes near biting midge breeding sites require either fine mesh screens or lightproof curtains.

Screens should be of the correct mesh, fit tightly and be in good repair. Biting insects frequently follow people into buildings and for this reason, screen doors should open outward and have automatic closing devices. Insecticides such as permethrin, deltamethrin, bifenthrin, or alpha-cypermethrin sprayed on or around screens may give added protection against mosquitoes or biting midges, but care is needed as some insecticides affect screens.

It is advisable to use an insect proof tent when camping near potential biting insect areas. Coastal areas subject to attack by biting midges require tents to be fitted with a finer mesh screening. Tents can be made more mosquito effective by spraying them inside and out with bifenthrin or alpha-cypermethrin.

4.0 MOSQUITO NETS

Mosquito nets are useful in temporary camps or in unscreened houses near biting insect breeding areas. Generally standard mosquito nets are not sufficient to prevent biting midge attack. White netting is best as mosquitoes accidentally admitted into the net are easily seen and killed. The net is suspended over the bed and tucked under the mattress. An aerosol pyrethrin spray can be used to kill mosquitoes that enter the net. Care is needed not to leave exposed parts of the body in contact with the net, as mosquitoes will bite through the net. Nets can be made more effective by dipping impregnation with permethrin (Lines et al. 1985) or by spraying them inside and out with bifenthrin, lambda-cyhalothrin or alpha-cypermethrin..

5.0 INSECT PROOF CLOTHING

Head nets, gloves and boots can protect parts of the body, which are not covered by other clothing. Head nets with 1-1.5 meshes to the centimetre are recommended for good visibility and comfort, and additional treatment of the net with a repellent will discourage insect attack. Thick clothing or tightly woven material offers protection against bites. Light coloured, loose fitting long sleeved shirts and full-length trousers are recommended. Dark clothing such as dark blue denim or black clothing is much more attractive to salt marsh mosquitoes than white clothing. Many mosquitoes including salt marsh mosquitoes or *Anopheles bancroftii* will bite through tight fitting shirts or pants. For particular risk areas or occupations, protective clothing can be impregnated with permethrin or other synthetic pyrethroid insecticides such as bifenthrin to give added protection (Burgess et al. 1988). Sleeves and collars should be kept buttoned and trousers tucked in socks during biting insect risk periods. Protection is very necessary near areas of salt marsh, mangroves, or large fresh water swamps where the various species of mosquitoes may be very abundant during the day in shaded situations, as well as at night.

6.0 REPELLENTS

Relief from biting insect attack may be obtained by applying repellents to the skin and clothing (Schreck et al. 1984). Many repellents affect plastics and care is needed when applying them near mucous membranes such as the eyes and lips.

Repellents with the chemical diethyl-toluamide (DEET) or picaridin give good protection, with DEET based repellents the best. Some specific repellent products, such as standard Aerogard, which are formulated to repel flies, are generally not efficient against mosquitoes or biting midges. Brands with DEET such as Rid, Tropical Strength Aerogard, Bushman's, and Muskol, or products with picaridin such as Repel include specific products that are effective. Those products with higher amounts of DEET or picaridin are usually the most efficient. Many botanical based products do not offer sufficient protection. However, p-methane 3,8diol or PMD (extract of lemon eucalyptus) at a minimum concentration of 30% provides longer lasting protection compared to other botanicals and has a similar efficacy compared to the low DEET concentration products.

Application of repellents over large areas of the body or on extensive areas of children is not recommended particularly those repellents with concentrations of DEET greater than 20%. Protection from mosquito penetration through open weave or close fitting clothes can be obtained by applying a light application of aerosol repellent to the exterior of clothing. Repellents should be supplementary to protective clothing and should not be regarded as substitutes.

Personal repellents are available as sprays, creams or gels. The gels are best and creams usually last longer than the aerosol formulations. Repellents can prevent bites from 1 to 4 hours, depending on the repellents, the species of biting insect, or the physical activity of the wearer. In general aerosol alcohol based repellents will only give one hour protection in the tropics so reapplication is necessary. Products labelled low irritant generally mean less active ingredient.

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

Insecticide impregnated mosquito coils offer good protection in relatively wind protected areas, while the allethrin pad candle heated mosquito lanterns or gas operated allethrin mosquito protection devices offer excellent protection in patio or veranda or other outdoor situations. Mosquito lanterns or gas powered pad dispensers are cost effective for events such as barbeques or congregations of people, with two or more dispersed around the group to cater for breeze direction. Candle devices need care with the candles, while the gas powered models are safe and effective in situation on boats and vessels. They work best in still or very light breeze conditions.

Electronic insect repellers that emit ultrasonic or audible sounds do not offer any protection against mosquitoes or biting midges. They are based on a false premise and have been found to have no repellent effect under scientific testing (Curtis 1986). Electronic ultrasonic repellers do not repel mosquitoes or biting midges and should not be relied upon for personal protection (Mitchell 1992).

Plants with reported insecticidal properties such as neem trees and the citrosa plant have not been shown to act as mosquito repellents just by growing in the vicinity of people (Mitchell 1992, Matsuda et al. 1996). Growing or positioning these plants near evening activity areas will not prevent mosquito attack. However some plants have some repellency effects as smoke or liniments (see section 12, emergency biting insect protection)

7.0 ANIMAL DIVERSION

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

8.0 LIGHTING DIVERSION

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

9.0 ADULT INSECT CONTROL

If mosquitoes or biting midges have entered a screened area or house or premises they can be knocked down with hand held pyrethrin aerosols. Care should be taken by reading the label to ensure only knockdown aerosols suitable for spraying in the air are used in proximity to people or food.

There are automatic wall mounted dispensers of aerosol for killing adult mosquitoes or flies that dispense mainly pyrethrins. These are registered for use either indoors or outdoors so care is needed in reading the labels. Generally these dispense aerosol in short bursts every 20 to 40 seconds and can last up to 40 hours before refilling. Outdoors devices need to be in wind protected areas such as verandas and patios.

Other devices that can be effective at killing and/or repelling biting insects include mosquito coils (Charlwood & Jolley 1984) and electric plug in insecticide pads. The plug in pad devices are every effective inside buildings but care is needed in reading the labels These devices are only effective in relatively protected or closed areas such as patios, inside buildings or where there are only slight breezes. Use of coils in outdoor or unscreened areas should be backed up with other measures such as suitable protective clothing or repellents.

Large scale adult biting insect control can be achieved for short terms (hours) by using portable or industrial fog generators, backpack misters, or heavy duty ultra-low-volume aerosol generators to knock down active adult insects. The insecticides of choice in these machines are maldison, bioresmethrin or pyrethrum. Control relies on good access, open vegetation, and light breezes in the direction of the breeding or harbouring sites. Application should only be during the peak biting insect activity period of those insects actually causing the problem, which is usually the late evening and early night.

There are some synthetic pyrethroid aerosol products available as outdoor yard or patio repellents. Control may only be temporary (hours) and re-invasion will usually occur within hours or from one to a few days, depending on the species, nearby vegetation, proximity to breeding sites, environmental conditions and times of activity of the pest species.

Application of the older residual insecticides such as maldison, or permethrin sprayed as a mist spray to point of run off on building surfaces or nearby vegetation can sometimes give short term (a few days to a few weeks) relief. This method is useful as a barrier protection when large numbers of mosquitoes or biting midges are present near accommodation or outdoor use areas (Helson & Surgeoner 1985).

There are some longer term residual synthetic pyrethroids such as bifenthrin, lambda-cyhalothrin and alpha-cypermethrin that can be used as barrier sprays and provide excellent (up to 6 weeks) protection (Standfast et al 2003, Li et al 2010). These residual insecticides can be applied according to label recommendations with the aid of a garden sprayer for dark coloured walls, fences and solid surfaces on the outside of houses or back pack mechanical misters in a band 1-2 m high on low thick vegetation and shrubbery areas around houses. If there is no vegetation screen, black weed matting or shade cloth 1-2 m high all around fence lines in urban settings can substitute for vegetation as the application surface. Application should be at label rates and made to the point of just before runoff. For vegetation care is needed to apply under leaves as well as on leaves and surfaces. Use of these insecticides can give immediate relief from salt marsh mosquito plagues on a house block scale and the effect should last up to 4 weeks.

Application can be done by householders with appropriate equipment and familiarization with the chemical and provisions and safeguards for use, although generally it is advisable for applications to be done by a licensed pesticide company.

Care must be taken with all synthetic pyrethroids around fishponds, fish tanks and other nearby fish habitats to avoid spray drift or run off, as these insecticides are efficient fish poisons.

10.0 INSECTOCUTORS AND INSECT TRAPS

Electric insect insectocutors and other trap or killing devices utilising an attracting light or carbon dioxide have been claimed to clear areas of biting insects and thus protect people. These claims have not been substantiated in outdoor situations with people nearby. While trap devices can attract biting insects, as well as a range of other insects, these devices can not be relied on for protection from biting insect attack (Mitchell 1992). When used in outdoor situations it is possible that they can increase local problems by attracting insects to the vicinity of people. Attractive odours and carbon dioxide emitted by humans then divert the insects from the trap device to the people.

11.0 TREATMENT OF BITES

Relief from bites and prevention of secondary infection can be obtained by the application of various products, either to the skin or internally. The effectiveness of various products is variable, depending on individual reaction. Skin application products include proprietary products such as Eurax, Stingose, Medicreme, Katers lotion, Dermocaine and Paraderm crème and topical antihistamine products, and non-proprietary products such as paw paw ointment, tea tree oil, eucalyptus oil, aloevera gel, ice, or methylated spirits.

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

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

12.0 EMERGENCY BITING INSECT PROTECTION

There are a number of emergency measures that can be taken when exposed to biting insects with no protection. Sheltering downwind next to smoky fires can offer considerable protection. Burning dung or aromatic and oil producing foliage from plants such as *Hyptis* (horehound), *Vitex* (black plum), *Calytrix* (Turkey bush), *Melaleuca* species (Paper bark) and *Eucalyptus* species (gum trees) can make the smoke more effective. A small native plant *Pterocaulon serrulatum* (warnulpu) has sticky strongly aromatic leaves, and branches are burnt or the moist leaves are rubbed on the skin by Aborigines in the Katherine district to repel mosquitoes (Aborigines of the NT 1988). Climbing relatively high trees or choosing locations exposed to the wind can also offer protection from some species.

Some protection can be obtained by rubbing exposed skin areas with the leaves of certain plants such as eucalypts, turkey bush, warnulpu, paperbarks or tea-trees that contain volatile oils. However these are not as efficient as proprietary repellents containing DEET or picaridin. Other emergency protection measures include coating the skin with mud, or burying yourself in shallow sand with some form of head protection. If all else fails, keep running. The best form of protection and the most comfortable require an awareness of the potential problems and adequate preparation.

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