Ballina Shire Council Development Control Plan 2012 Chapter 2 Part 3.6 Mosquito Management

BACKGROUND INFORMATION

ballina
shire council

November 2020

Prepared by Associate Professor Cameron E. Webb PhD. BSc (Hons)

Department of Medical Entomology
NSW Health Pathology
Westmead Hospital
Westmead NSW 2145
Australia

Phone: 02 8890 7548
Email: Cameron.Webb@health.nsw.gov.au
Web: www.medent.usyd.edu.au

DISCLAIMER

This document has been prepared in accordance with the brief provided by Ballina Shire Council. Department of Medical Entomology, NSW Health Pathology, accepts no responsibility for its use by other parties. The use of brand names and any mention or listing of commercial products or services in this document does not imply endorsement by the Department of Medical Entomology, NSW Health Pathology, or discrimination against similar products or services not mentioned. NSW Health Pathology have been engaged by a wide range of insect repellent and insecticide manufacturers to provide testing of products and provide expert advice on mosquito biology as well as receiving funding from local, state, federal, and international agencies to undertake research into mosquito and mosquito-borne disease management.

TABLE OF CONTENTS

1. INTRODUCTION

Mosquito-borne disease is a concern for health authorities across Australia. Mosquito-borne Ross River (RRV) and Barmah Forest (BFV) viruses cause thousands of cases of illness each year and, in recent years, substantial outbreaks of RRV have been reported having substantial impact on human health. Imported cases of exotic mosquito-borne diseases caused by dengue (DENV), chikungunya (CHIKV) and Zika (ZIKV) viruses also occur annually.

There is annual activity of mosquito-borne disease in northern NSW. Notwithstanding the impact of mosquito-borne disease, the potentially significant impacts of nuisance biting by abundant and widely dispersing populations of pest mosquitoes may have substantial social and economic impacts on the local community.

The pest and public health risks associated with mosquitoes have been known from the Ballina and northern NSW region for many years. While there are dozens of different types of mosquito found in the local area, the majority are a natural part of local ecosystems and relatively few pose a substantial pest or public health risk. The greatest risks are typically associated with mosquitoes found in coastal estuarine and brackish water habitats but a suite of other freshwater species, commonly found in urban stormwater and wastewater infrastructure, as well as water-holding containers in and around residential and industrial settings, may also cause some impacts.

The local region contains extensive saline and brackish-water coastal wetland areas, freshwater environments, as well as opportunities for mosquitoes within peri-urban and urban areas. Rapidly expanding urban developments in the region bring new challenges for pest and public health threats. New residential and recreational developments bring people closer to wetlands while water conservation initiatives across the region bring new opportunities for mosquitoes associated with urban environments.

Ballina Shire Council has been a leader in mosquito-borne disease management in NSW. A long time participant in the NSW Arbovirus Surveillance and Mosquito Monitoring Program, mosquitoes have remained a focus for local authorities for more than two decades. Ballina Shire Council was one of the first local government sin NSW to acknowledge the potential impact of mosquitoes on new residential developments. In an effort to encourage developers to turn their mind to the issues of mosquitoes, the Development Control Plan developed in 2003 provided guidelines for the assessment of actual and potential mosquito risk associated with proposed new urban developments, including those with proposals to constructed water bodies as part of that development. The experiences of council has informed the way mosquitoes are considered in the approval processes of local governments around Australia.

With continued pressure to expand urban developments, conserve local wetland environments, and build capacity to respond to the threats of a changing climate, a review of the current development control plan, Development Control Plan 2012 - Chapter 2 Part 3.6 Mosquito Management, was undertaken to ensure it reflects the current understandings of mosquito risk and its mitigation.

2. AIMS AND SCOPE

The aim of this document is to provide background information on mosquitoes and the management of their pest and public health risks as relevant to the revised "Ballina Shire Council Development Control Plan 2012 - Chapter 2 Part 3.6 Mosquito Management" (now titled "Ballina Shire Council Development Control Plan 2020 - Chapter 2 Part 3.6 Mosquito Management").

This review was undertaken with a view to ensuring that this component of the Development Control Plan reflects the current understandings of mosquito risk and its mitigation in the local region. In undertaking the review, consideration was given to current strategies employed to inform urban development in coastal regions of Australia and determine best practice with regard to managing the pest and public health risks posed by mosquitoes and other biting insects.

It is not intended that this document contains a comprehensive plan of management for all aspects of control and monitoring of mosquitoes of pest and public health concern. There is a focus on the aspects of mosquito management pertinent to urban planning decisions. It is beyond the scope of this document to provide a proposal for active mosquito population management in the local wetlands, nor detailed public health education program to encourage personal protection measures.

3. MOSQUITO BIOLOGY AND THEIR ECOLOGICAL ROLE

Critical to understanding the importance of local public health risks associated with mosquitoes and how best to manage those risks is an appreciation of their biology and role in local ecosystem. Without an understanding of their biology, especially their propensity to bite, disperse from local wetlands, and links to the climatic/environmental factors that drive population abundance it is difficult to design strategic control and surveillance strategies.

Mosquitoes are small blood sucking insects and, within Australia, there are more than 300 different species. These insects are closely related to flies with each species is associated with particular environments due to their reliance on aquatic habitats to complete development. Their relatively short but complex life cycle consisting of eggs, four aquatic larval stages (instars), an aquatic pupal stage and a terrestrial adult stage. Immature stages are totally aquatic, without access to free-standing water of some kind the larvae cannot complete their development to the adult phase. Larvae cannot develop out of water or in damp mud, soil or vegetation. However, adult mosquitoes do take refuge in dense vegetation in bushland or in long grass, and the abundance of mosquitoes encountered in these refuge habitats often leads to the misconception that these areas are producing the mosquitoes.

The nuisance and public health risks vary markedly between species but are generally caused by the biological requirement for blood. Only the female mosquito bites, the blood meal provides nutrients to assist with egg development. While many mosquitoes are generalist feeders, some specialise in feeding on humans, mammals, birds or amphibians. The ‘host seeking’ behaviour of female mosquitoes is driven by a combination of different stimuli including carbon dioxide, body odours, and body heat/humidity. Upon locating a suitable host, the female will probe the skin for a blood capillary then inject a small amount of saliva containing chemicals that prevent the blood from clotting. This is often the pathway for potential pathogens such as viruses to enter a host.

Once mosquitoes have taken a blood meal, gravid adult mosquitoes will find a resting place to digest her meal and develop eggs before flying off to deposit them in a suitable habitat. Typically lay eggs either on the water surface (usually in the form of a floating raft) or on a frequently inundated substrate (usually singularly or in small groups). These oviposition sites may include soil or vegetation at the edge of a wetland, soil or leaf litter where temporary pools form after rainfall, or the inside of water holding containers (e.g. bird baths, pot plant saucers, discarded tyres etc). On average, most mosquitoes will lay up to 2-3 batches of eggs in their lifetime.

While some mosquito eggs (usually those laid by *Aedes* species) can be desiccation resistant and remain unhatched in the environment for many years, most eggs (particularly those laid by *Culex* and *Anopheles* species) will hatch within 2-3 days. On hatching, the young larvae (commonly called wrigglers) feed continuously on aquatic particulate matter and grow through four different instars or moults. The larvae of some mosquito species have developed specialised mouthparts and are predatory, feeding on other mosquito larvae and aquatic invertebrates. The final larval stage (4^{th} instar) develops into a pupa (commonly called a tumbler) from which the adult mosquito emerges approximately 2 days later. The length of larval development is dependent on water temperature (and thus is usually shorter during the warmer months of the year) and the availability of food, but can be as little as a week from the hatching of eggs to the emergence of adults.

On average, a female mosquito may live approximately 2-3 weeks but the male's lifespan is much shorter. Adult mosquitoes are most active from dusk until dawn, seeking refuge during the day in cool and humid habitats such as well-vegetated areas or under houses. Some mosquitoes are active during the day or, if abundant populations are present, they will also bite during the day.

For those mosquitoes mostly active during the night, some species can display distinct patterns of behaviour throughout the evening. While generally biting outdoors, some mosquitoes will come into dwellings.

Many mosquitoes do not travel far from breeding habitats. However, there are some species that can fly up to and beyond five kilometres, and a few species will disperse over 20 kilometres from the larval habitats. The dispersal ranges of mosquitoes are generally species specific with those species associated with wetland habitats dispersing far greater distances than those associated with water-holding containers.

While mosquitoes are often associated with human health impacts, they may also play a potentially important role in local ecosystems. Abundant adult and immature mosquito populations provide food for predatory vertebrates (e.g. birds, bats, fish, amphibians, reptiles) and invertebrates (e.g. insects and spiders). The ecological role of mosquitoes as prey for these animals has not been well studied. However, some extensive studies have been conducted in coastal wetlands of NSW and have identified that mosquitoes are a common prey item of insectivorous bats. While these bats weren't completely reliant on mosquitoes as food, there was a stronger preference for feeding on moths, mosquitoes were certainly consumed and there was strong evidence that bats changed their foraging behaviour in response to changes in mosquito abundance.

As the direct non-target impact of modern mosquito control agents are demonstrated to be minimal, there is often concern about the direct non-target impact on the animals that prey on mosquitoes. These concerns are most commonly raised regarding the impact on insectivorous birds, including shorebirds that are often observed "feeding" on insects in and around wetlands. As has been observed with bats, there is little doubt that many insectivorous birds are feeding on mosquitoes but they are also feeding on a wide range of other insects. With a paucity of information on specific associations between mosquitoes as prey and their avian predators, it is difficult to confidently assess any potential adverse impact resulting from mosquito control and subsequent significant reductions in mosquito abundance.

Given that both adult male and female mosquitoes will feed on nectars and other plant sugars, to provide an energy resource, these insects may also play a role in pollinating plants. There have been documented cases where mosquitoes have been positively identified as assisting pollination of orchids, including Australian native species, but there is no evidence indicating mosquitoes are the sole pollinators. As is the case with the mosquitoes as a food item for local animals, there are significant gaps in our understanding of the role of mosquitoes as pollinators.

Notwithstanding any potential role in local ecosystems, the majority of mosquitoes found in northern NSW pose little risk to human health as they're rarely abundant or prefer not to bite people. Many of the local mosquitoes will occur at naturally low population abundance, are associated with relatively unique, "out of the way" habitats or simply won't bite humans. For this reason, and those alluded to above, complete eradication of mosquitoes from a local region is not ever likely to be the objective of mosquito control. The only exception to such a strategy would be where an invasive exotic mosquito was detected that posed significant threat to public health. These mosquitoes, however, are far more likely to be associated with urban water-holding containers and not local wetlands.

4. MOSQUITOES AND PUBLIC HEALTH CONCERNS IN THE LOCAL REGION

4.1 Mosquitoes of the local region

Based on this knowledge and existing information within the published scientific literature, an assessment of local mosquito populations can be made. Much of this assessment can be based on both extant mosquito populations together with known mosquito associations with the types of habitats identified within the local region. Broadly speaking, these habitats are categorised as coastal estuarine and brackish-water wetlands, freshwater wetlands and urban environments (including water-holding containers and stormwater infrastructure).

There are dozens of mosquitoes found on the far north coast of NSW with many key species of pest and public health concern. These mosquitoes, along with their association with habitats and pest risk, within the region are shown in Table 1. A summary of the pest and public health risks associated with mosquitoes is provided in Table 2.

The most common mosquitoes are *Aedes alternans, Aedes multiplex*, *Aedes notoscriptus*, *Aedes vigilax*, *Anopheles annulipes*, *Coquillettidia linealis*, *Mansonia uniformis*, *Culex annulirostris* and *Culex quinquefasciatus*. In addition to these key mosquitoes, a range of species belonging to the *Aedes*, *Anopheles*, *Coquillettida* and *Culex* genera may cause occasional and/or highly localised nuisance risks. There is also likely to be a small number of mosquito species that are present in the region but rarely collected. Our understanding of the local mosquito fauna is generally based on traditional mosquito surveillance approaches (i.e. carbon dioxide baited light traps) and some mosquitoes are less likely to be collected by these approaches and, subsequently, are less likely to be reported. However, these additional mosquito species are not likely to pose any significant pest or public health risk, nor be the focus of any strategic mosquito control program.

Without doubt, one of the mosquito of greatest concern is *Aedes vigilax*. This mosquito is the major nuisance-biting pest and vector of RRV and BFV across southern coastal regions of Australia (as well as some inland riverine regions impacted by soil salinity) and it is considered such an important pest due to the propensity to be highly abundant and disperse widely (readily over 3km) from coastal habitats. The productivity of estuarine saline and brackish-water wetlands for *Aedes vigilax* will vary depending on vegetation composition but, more importantly, from the frequency of tidal and rainfall inundation of habitats and their resulting salinities. Mosquito surveillance in the local region has consistently found that this mosquito often dominates collections, a result reflected in other coastal regions of NSW.

A range of other mosquitoes may be found in local freshwater wetlands. However, the relative impact of these mosquitoes will be highly dependent on the size, productivity and proximity of human populations to these habitats. *Culex annulirostris* is potentially a local pest as it is a major nuisance biting pest and vector of RRV and BFV. The local importance of this mosquito will vary, given the relatively low abundance of this species recorded in local surveillance programs, but given it may be closely associated with urban waste-water and stormwater infrastructure (e.g. drains, bioretention swales and ponds, constructed wetlands) and, subsequently, in close contact with both wildlife (e.g. waterbirds) and humans.

Although not considered a significant nuisance-biting pest, *Culex quinquefasciatus* is also often reported from organic rich habitats alongside *Culex annulirostris* and is generally considered a mosquito of urban environments (e.g. drains, sullage pits, septic tanks and other water holding and water storage areas). The propensity of this mosquito to come indoors and cause a nuisance during the evening is a concern and any structure constructed as part of the stormwater or waste-water system (e.g. waste-water treatment, septic tanks, grey water storage) that retains water and is accessible by mosquitoes can provide suitable habitat for this species. Given that this mosquito may disperse over a kilometre from productive wetlands, the potential impact of this mosquito should be considered where urban development begins to encroach on waste-water treatment facilities. A similar species, *Culex molestus*, was introduced into Australia, firstly into Melbourne, during the 1940s and can also be a nuisance in urban areas. It is closely associated with subterranean habitats (e.g. disused septic tanks, stormwater infrastructure) and while it isn't thought to disperse far from these habitats, the mosquito will bite and may cause some concern.

It is not only mosquitoes associated with natural habitats that can represent important pest problems. *Aedes notoscriptus* is one of the most widespread nuisance-biting mosquitoes in Australia. Once only associated with tree-hole habitats, this mosquito is now also adapted to water-holding containers around dwellings. The mosquito will lay eggs in association with small water holding containers such as cans, pot plant saucers, ornamental ponds, roof guttering, water tanks and discarded tyres, as well as water holding plants (e.g. bromeliads) and tree holes. The mosquito is a nuisance-biting pest and potential vector of RRV and BFV as well as dog heartworm parasites (*Dirofilaria immitis*).

The management of *Aedes notoscriptus* is a challenge for local authorities around Australia. While mosquito control programs are effectively established in wetland areas, there are generally no programs targeting mosquitoes associated with backyard habitats. The exception is in Far North Queensland where control of *Aedes aegypti*, a species that shares these water-holding container habitats, is undertaken in response to the threat of local DENV transmission. Studies from QLD, NSW, and WA indicate that *Aedes notoscriptus* can still be an important pest but reducing local mosquito abundance is reliant on increasing awareness among the community and changing behaviours that do not encourage the creation or maintenance of local mosquito habitats. In addition, the nuisance biting of this mosquito can often drive complaints from residents in and around urban wetlands where nuisance-biting by this mosquito is perceived to be due to mosquitoes emerging from local wetlands. For this reason, mosquito monitoring around proposed or newly constructed wetlands can assist in assessing mosquito species-specific and/or habitat specific pest risk and implementation of mitigation strategies. However, disassociation of these pest impacts from the local wetlands is equally important and in these instances, community education programs may hold much greater potential in reducing pest mosquito impacts than mosquito control initiatives.

One of the most common nuisance-biting mosquitoes in the Ballina Shire region is *Aedes vigilax*, a mosquito associated with tidally influenced wetlands such as mangroves, saltmarshes, and sedgelands.

Table 1. Common mosquito species associated with the Ballina and surrounding region. Species list compiled using results of mosquito surveillance by the NSW Arbovirus Surveillance and Mosquito Monitoring Program and known or likely species distributions based on existing scientific literature. Key pest species are highlighted.

Mosquito species	Habitat associations	Public health risks
Aedes alboannulatus	Ephemeral freshwater ground pools in grassland or woodland habitats	Potential nuisance biting pest but only when abundant
Aedes notoscriptus	**Small water holding containers around dwellings such as tins, pots, ornamental ponds, roof guttering bird baths, as well as water holding plants (e.g. bromeliads) and tree holes. Does not travel far (<200m) from larval habitats.**	**Common nuisance-biting pest and vector of RRV and BFV. This is the most important pest mosquito in urban areas across Australia.**
Aedes procax	A range of permanent and ephemeral freshwater, and occasionally brackish-water, habitats	Occasional biting pest and vector of RRV and BFV. One of the most important pest species in local region.
Aedes multiplex	A range of permanent and ephemeral freshwater, and occasionally brackish-water, habitats	Occasional biting pest and vector of RRV and BFV. One of the most important pest species in local region.
Aedes vigilax	**Tidally influenced estuarine wetlands and brackish- water habitats. Disperses widely (>5km) from coastal wetlands.**	**Severe nuisance biting pest and vector of RRV and BFV. One of the most important pest species in local region.**
Anopheles annulipes	A range of permanent and ephemeral freshwater, and occasionally brackish-water, habitats. Disperses moderately (>1km) from larval habitats.	Occasional nuisance-biting pest.
Coquillittidia linealis	Permanent, well vegetated freshwater wetlands, mosquito larvae have close association with submerged structures of aquatic vegetation	Nuisance-biting pest and potential vector of RRV and BFV; may be of increasing concern in association with constructed wetlands.
Culex annulirostris	**Permanently and semi-permanent freshwater habitats ranging from flooded ground pools to the margins of natural and constructed water bodies to drains. Disperses widely (>5km) from freshwater wetlands.**	**Nuisance-biting pest and vector of RRV, BFV, KUNV and MVE. One of the most important pest species in the local region.**
Culex quinquefasciatus	Permanent and semi-permanent freshwater habitats, typically with a high organic content or associated with waste-water.	Nuisance-biting pest, often coming indoors, and potential vector of mosquito-borne pathogens but not considered a significant driver of outbreaks.
Verrallina funerea	**A range of permanent and ephemeral estuarine and brackish-water, habitats. Does not travel far (<100m) from larval habitats.**	**Nuisance-biting pest and potential vector of RRV and BFV**

*Please note that there has been some debate regarding the taxonomy of Australian mosquitoes over recent years, in some publications *Ochlerotatus* has been used in place of *Aedes*. Until these taxonomic issues are resolved, it was the recommendations of the Mosquito Control Association of Australia that *Aedes* is preferred in scientific usage.

4.2 Pest and public health risks associated with local mosquitoes

4.2.1 Nuisance biting problems

Mosquitoes can impact the health and wellbeing of the local community as well as having potentially significant economic impacts. Nuisance biting by abundant mosquitoes can negatively impact the standard of living in the community as well as having economic impacts on residential, recreational and tourist developments.

How many mosquito bites are too many? How often are mosquito bites received too often? Quantifying the impact of nuisance biting is difficult as the tolerance level of individuals varies substantially and is often dependent on the extant of mosquito populations and previous experiences. There is little doubt that when abundant populations of nuisance mosquitoes occur, pest impacts can be substantial. This is especially the case within regions of high tourist visitation where those individuals visiting the region may not have prior exposure to substantial mosquito populations and their potential impacts, nor have experience with the choice of suitable personal protection measures. Similarly, new residents to the region may not be equipped with the knowledge to avoid mosquito bites through personal protection measures.

There is a paucity of research putting a price on the nuisance-biting impacts of mosquitoes in Australia. There is a clear understanding by many local authorities that the biting of mosquitoes can cause disturbance to residents but can also dampen the experiences of visitors to regions where mosquitoes are abundant. Studies from QLD indicate that biting insects (in this instance, biting midges and not mosquitoes) in coastal regions can substantially reduce property prices in suburbs where pest impacts are high compared to neighbouring suburbs that don't experience the same level of nuisance. There are also likely to be additional financial burdens on households in biting insect prone areas. For example, more money is likely spent on structural changes to the property (i.e. screened windows, doors, outdoor areas), and use of mosquito control products (i.e. insect repellents, insecticides, mosquito traps).

The most detailed research into the economic costs of pest mosquitoes has been undertaken in North America where the presence of the severe nuisance-biting pest, *Aedes albopictus* (a mosquito not present in mainland Australia), causes major disruptions to the quality of life of the community. The nuisance-biting impacts of this mosquitoes are considered so severe that residents in communities where this mosquito are active rate the pest problems in line with many forms of vandalism and crime as lowering their standards of living. Some studies of community attitudes to nuisance-biting impacts have concluded that over 3h of outdoor time per week are lost due to the presence of pest mosquitoes. Among these communities there was also a substantial willingness to pay for mosquito control.

There is little scientific data available on the impact of pest mosquitoes to tourism or outdoor recreation in Australia. However, it is likely that abundant nuisance-biting mosquitoes will reduce both the quantity and quality of outdoor activities when mosquitoes are abundant. The amenity of outdoor dining areas of local restaurants and cafes, outdoor sport and recreation facilities (e.g. swimming pools, golf courses), camping grounds, picnic areas, playgrounds, and parklands are all likely to be impacted by mosquitoes. Notwithstanding the potential economic impact this may have on local businesses, there may also be indirect impacts on the local environment if insecticide treatments are routinely conducted to control mosquitoes. In QLD, holiday resorts in some coastal regions rely on the application of residual insecticides around buildings and vegetation to control mosquitoes. These insecticides can be effective in reducing mosquito populations but they will also impact other beneficial, or non-pest, insects.

Coastal wetlands in the Ballina Shire region can provide habitat for a range of mosquitoes including the key nuisance species, *Aedes vigilax*

4.2.2 Mosquito-borne disease

Notwithstanding the impact of nuisance-biting, mosquito-borne disease is a potential concern in the local area.

The greatest public health risk in the local region is due to RRV. Infection with RRV is the most commonly reported mosquito-borne disease across Australia each year with around 5,000 cases occurring. The disease is notifiable diseases with blood tests required to confirm the presence of specific antibodies showing infection. Guidelines on the diagnosis of these mosquito-borne disease are provided by the NSW Ministry of Health.

In NSW more generally, cases of illness resulting from RRV infection range from less than 50 to over 1,500 each year and it is by far the most reported mosquito-borne disease in the state. There are far fewer cases of disease caused by the similar BFV but it is still considered an important mosquito-borne disease in the local region. The number of cases within the region varies between years, highlighting the importance of climatic conditions as drivers of mosquito-borne disease activity. Other factors, especially those associated with local wildlife also play a role but are not well understood.

When assessing the risks of mosquito-borne disease, it is important to consider, not only local wetlands and mosquito populations but also wildlife. The transmission cycles for RRV and BFV generally require the presence of suitable reservoir hosts for sustained public health risks. Serological studies and laboratory investigations have indicated that native mammals (in particular native macropods such as kangaroos and wallabies) are natural hosts for RRV. Less is known about the hosts of BFV and they may include birds as well as mammals (including macropods and bats). The critical mosquito vectors of these pathogens in the local regions are *Aedes vigilax* and *Culex annulirostris* but a suite of other mosquito species are likely to play a role in certain areas or at times of favourable climatic conditions.

The risk of mosquito-borne disease is driven by a combination of factors including mosquito abundance and diversity, populations of wildlife representing reservoirs hosts for the pathogens, and also mosquito management programs. There is no doubt that there are suitable, and suitably abundant, populations of vector mosquitoes. A significant factor in reducing the risk of RRV in the region may be the limited abundance and distribution of suitable reservoir hosts. Populations of macropods are relatively constrained to areas adjoining major wetland systems and natural buffers exist to their higher abundance close to residential areas. It is also important to note that the region has had a sustained mosquito management project in place that is suppressing the abundance of mosquitoes but also providing increased awareness within the community of mosquitoes, their health risks, and personal protection measures.

Mosquito-borne disease risk across the Ballina Shire Council region may vary risk due to prevailing climatic conditions or local landscape characteristics, especially in areas where wildlife populations are abundant. Further investigation of the relative mosquito-borne disease risk within these specific urban centres within the region is provided later in this report but it is important to note that there may be notable differences between the pest and public health risks of these areas and, despite a relatively low risk of RRV, there may still be potentially substantial nuisance-biting pest impacts.

There is a suite of other arboviruses known to, or suspected to, be circulating among local mosquitoes and wildlife. Many of these are not considered a serious threat to human health, either due to a lack of evidence of disease following infection or that infection of humans rarely, or never, occurs. Notwithstanding the "insect-specific viruses" that are known to exist in mosquitoes but not be transmitted to other reservoir hosts or humans, a number of alphaviruses (e.g. Sindbis virus), bunyaviruses (e.g. Trubanaman virus) and flaviviruses (e.g. Stratford virus) may occasionally be detected in local mosquitoes but the threat they pose to humans is either very minor or not well understood.

Exotic mosquitoes and mosquito-borne pathogens are of an increasing threat in Australia. Local, state and federal government authorities are steadily building capacity to respond to the threat posed by these pest and public health risks to ensure a rapid and effective response to exotic mosquito incursion or confirmed local transmission of exotic mosquito-borne pathogens.

Mosquito-borne disease caused by viruses including dengue (DENV), chikungunya (CHIKV) and Zika (ZIKV) in many parts of the world and Australian travellers are increasingly returning home infected with these pathogens. The likelihood of international travellers triggering a local outbreak of disease is extremely low given suitable mosquitoes, *Aedes aegypti* and *Aedes albopictus*, are not currently present in the local region. Australian Government Department of Agriculture and Water Resources (DAWR) undertake monitoring at airports, seaports and facilities handling international freight to detect and respond to these exotic mosquitoes.

Table 2. Mosquito-borne pathogens that may be of concern in the Ballina region.

Pathogen	Comments
Ross River virus	Transmission has been recorded in the local region. Symptoms can vary greatly between individuals and may include fever, rash and a condition known as polyarthritis with arthritic pain in the ankles, fingers, knees and wrists. Generally, the arthritic pain is greater with RRV infection compared to BFV. The primary animal hosts of RRV are macropods (i.e. kangaroos and wallabies).
Barmah Forest virus	Transmission has been recorded in the local region but far less common than RRV. Symptoms can vary greatly between individuals and may include fever, rash and a condition known as polyarthritis with arthritic pain in the ankles, fingers, knees and wrists. Generally, the rash tends to be more florid with BFV infection but the arthritic pain is greater with RRV infection. The primary animal hosts of BFV unconfirmed but are thought to be birds with mammals also potentially playing an important role.
Kunjin virus	No cases of human disease reported in the local area. The primary animal hosts of KUNV are thought to be birds. Significant veterinary impacts (i.e. horse illness) reported in 2011 with some cases identified in the local region.
Other endemic arboviruses	A range of other alphaviruses, bunyaviruses, flaviviruses and orbiviruses are occasionally detected in mosquitoes in northern NSW but the local public health risks are either considered low or have not been well defined.
Japanese encephalitis virus	Not known from local region. Recently, infected individuals returning to northern NSW from travel in SE Asia have been reported. There is currently no risk of local transmission.
Dengue viruses	Not known from local region. Travellers returning from overseas may be diagnosed by local health authorities. There is currently no risk of local transmission due to the absence of mosquitoes capable of spreading the pathogen.
Chikungunya virus	Not known from local region. Travellers returning from overseas may be diagnosed by local health authorities. There is currently no risk of local transmission due to the absence of mosquitoes capable of spreading the pathogen.
Zika virus	Not known from local region. Travellers returning from overseas may be diagnosed by local health authorities. There is currently no risk of local transmission due to the absence of mosquitoes capable of spreading the pathogen.
Malaria	Not known from local region and Australia has been declared malaria free by the World Health Organisation in 1980s. Travellers returning from overseas may be diagnosed by local health authorities. There is currently no risk of local transmission.

5 MANAGING MOSQUITOES AND ROLE OF URBAN PLANNING

Managing mosquitoes and their pest and public health impacts requires an integrated approach that incorporates a range of strategies addressing mosquitoes and their habitats, as well as humans and their behaviour. Urban planning decisions can directly, and indirectly, influence the exposure of the community to mosquitoes. While mosquito and mosquito-borne disease risk should be considered when planning future residential, recreational, and industrial developments, these considerations should be informed by information on existing mosquitoes, mosquito habitats, and the activity of mosquito-borne pathogens.

5.1 Assessing actual and potential mosquito risk

Prior to the initiation of site-specific mosquito management strategies, it is important to understand the relative actual and potential mosquito risk posed to a proposed development site. These risks may come from extant onsite or off site sources of mosquitoes. The subsequent impacts will be determined by the abundance and diversity of mosquitoes determined by the type and extent of habitats. Natural climate variability will also play a role in determining that risk. Future risk must also be considered based on changes to actual and potential mosquito habitat within the footprint of the proposed development as well as the productivity of habitats off site that may be enhanced, or reduced, by the development itself.

In addition to the creation, destruction, or enhancement of water bodies and other water-holding structures that may be a source of mosquitoes, changes to the terrestrial vegetation will also influence the suitability of the area to provide refuge for mosquitoes, increasing their survivorship and subsequent pest impacts. Further detailed information on terrestrial vegetation is provided in section 6.2.6.

A combination of mosquito population surveillance and mosquito habitat surveys should form the basis of local assessment of mosquito risk. The provision of reliable information on mosquito populations, as well as mosquito-borne disease activity, will be crucial in determining mosquito risk and shaping mosquito management strategies. Without data on changes in mosquito abundance and diversity within and between seasons, strategic cost-effective initiatives in mosquito management will not be possible. Longitudinal studies of this nature will rarely be feasible in conjunction with the typical short-term investigation of local mosquito populations undertaken as part of the risk assessment process. However, mosquito population sampling and habitat surveys still have an important role to play.

Ballina Shire Council is actively involved in the NSW Arbovirus Surveillance and Mosquito Monitoring Program on an annual basis. This state-wide program provides monitoring of mosquito abundance and diversity with respect to local environmental conditions, mosquito-borne pathogen activity within local mosquito populations, and notifications of mosquito-borne disease in the human population. Adult mosquitoes are routinely trapped at three locations within Ballina Shire Council. Two sites, Lennox Head and North Creek Road, are among the longest ongoing surveillance sites in NSW and considerable information has been gained over many decades on local mosquito populations and their pest and public health risks.

Mosquitoes are collected using dry-ice baited Encephalitis Virus Surveillance (EVS) traps. These traps use carbon dioxide (supplied as either block or pellet dry ice or via gas cylinder) to attract host seeking mosquitoes. Female mosquitoes are attracted to the carbon dioxide (i.e. simulating exhalation of warm blooded animal), a small light serves as a focus and a battery operated fan blows the incoming mosquitoes into a catch bag. These traps are typically only operated once a week, set in the late afternoon and collected the following morning. Weekly collections are typically made between November and May each season. Mosquito specimens collected each week can be tested to determine if they are carrying any pathogens (e.g. RRV). This information is a solid foundation on local mosquitoes that can inform assessments of mosquito impact on new and existing urban developments as well as the relative impact of wetland construction and rehabilitation projects on local mosquitoes. A summary of recent data is provided in section 10.

Routine programs of this nature can provide valuable information on the temporal variability of relative abundance and diversity of mosquito populations and the pathogens they may be carrying. Identifying relationships between climatic variables and mosquito data can be difficult due to short-term factors influencing overnight mosquito collections (e.g. rainfall, wind, changes in temperature) but the data is valuable in assisting assessment of pest and public health impacts of mosquitoes.

While this body of data on mosquito populations is a useful reference point, climatic and environmental conditions play a critical role in driving mosquito abundance and diversity. These conditions will vary throughout the year and from season to seas. Consequently, an understanding of the relationships between tidal cycles, temperature fluctuations, and rainfall patterns is important for assessing typical mosquito abundance in and around a proposed development. As well as short-term analysis of likely changes in mosquito abundance throughout an individual season, long-term trends may reveal changes in the seasonality of mosquitoes.

There are many resources available to access historical and future climatic conditions in northern NSW. The Bureau of Metrology provided seasonal outlooks of temperature and rainfall forecasts in combination with analysis of el Nino/La Nina trends that will influence climates. Together with short-term changes in mosquito populations driven by seasonal conditions, these long-term climatic conditions must always be considered when interpreting mosquito collections and assessing current and future mosquito risk.

When short-term or localised investigations of mosquitoes are undertaken, careful consideration must be given to how mosquitoes are trapped and when the mosquito collections are made. Mosquitoes are short lived, and their populations fluctuate greatly over the course of a season due to variability in temperature, rainfall, and tides. It is critical that reference be made to the body of data available from Ballina Shire Council when making local assessments of mosquito risk associated with new developments.

5.1.1 Assessing mosquito habitats

Assessing the likely productivity of local mosquito habitats is important in determining current and future mosquito risk. Habitat assessment is critical where it is not possible to undertake adult mosquito sampling during the preferred period between November and April.

For an experienced entomologist specialising in mosquito risk assessment, consideration can be given to various aspects of local wetlands, water bodies, and stormwater infrastructure to determine potential mosquito risk. However, it will remain the preferred process to undertake some form of mosquito population sampling, either adult or immature stages, during the warmer months to confirm likely mosquito production based on habitat assessment.

The suitability of mosquito habitats will be primarily determined by the intrinsically linked characteristics of inundation (rainfall, stormwater flows, and/or tides) and vegetation composition. In the Ballina Shire Council region, the primary habitats of greatest concern are those characterised as saltmarsh, mangroves, she oak forest, or coastal swamp forest. The conditions provided in these environments are suitable for locally significant mosquitoes of pest and public health concern including *Aedes vigilax* and *Aedes funerea*. Highlighting the importance of these habitats is the determination of areas of high mosquito risk, primarily determined by the dispersal range of *Aedes vigilax*, provided in the Ballina Shire Council DCP Mosquito Management Map.

Beyond the tidally influenced saltmarsh and mangrove habitats that represent productive sources for *Aedes vigilax,* brackish-water to freshwater conditions provided in coastal swamp forests are productive sources of *Verrallina funerea* (as well as secondary pests such as *Aedes multiplex* and *Aedes procax*). The productivity of these habitats won't be consistent across the region. It has been demonstrated that the presence of either saltmash or mangrove communities should not immediately be associated with problematic populations of *Aedes vigilax*. The abundance of mosquitoes produced from those habitats will be highly dependent on the hydrology of the site, the frequency and extent of tidal inundation in combination with rainfall and/or stormwater runoff entering the wetlands. When assessing the likely impact of mosquitoes on a new development, consideration must be given to the actual or potential productivity of nearby habitats rather than assuming mosquito production based on vegetation composition alone. Similarly, the production of *Verrallina funerea* from coastal swamp forests and other habitats will be dependent on the persistence of ephemeral pools within these habitats following rain.

The relative impact each of these habitats will have on new developments will be highly dependent on the proximity of the development itself. Given *Aedes vigilax* disperses many kilometres from estuarine wetlands consideration must be given to suitable habitats within 3-5km of the development. While the Ballina Shire Council DCP Mosquito Management Map indicated widespread dispersal of *Aedes vigilax*, it must be noted that as the distance increases from known habitats, the relative abundance of mosquitoes would be expected to decline. This means that at 5km from estuarine wetlands, *Aedes vigilax* would be expected to be present but pest impacts likely to be less severe than in areas closer to sources of mosquitoes.

Verrallina funerea won't travel in great abundance for more than 100m in substantial numbers. For this reason, coastal swamp forests and she-oak woodlands within 200m of any proposed development should be considered a potential source of mosquitoes. In the case of this mosquito, the cover and density of terrestrial vegetation between sources of mosquitoes and development must be considered when assessing the extent to which mosquitoes are likely to travel to and impact development. More on this issue is discussed with regard to the design and maintenance of buffer zones in section 6.2.3.

It is important to note that post-development, there may be a change in the local abundance and diversity of mosquitoes. Where a development is proposed in a greenfield site, there many be permanent and ephemeral mosquito habitats within the footprint of the site that will be removed following development. The potential that a development may reduce overall mosquito populations should not be ignored. Similarly, new habitats may be created by components of stormwater infrastructure to be incorporated within the development. Furthermore, changes may occur in the suitability and productivity of surrounding habitats where discharge from stormwater infrastructure or surface runoff flows into existing mosquito habitats.

Changes in freshwater habitats may influence the relative abundance of pest species such as *Coquillettidia linealis*, *Culex annulirostris*, *Culex quinquefasciatus*, *Mansonia uniformis* or a suite of other species that may be locally important.

The better understand the net change in suitability of local mosquito habitats within a development's footprint, as well as adjacent areas, careful consideration is required of development plans. This is especially the case for stormwater and vegetation plans as well as management plans that may occur for local waterways or habitats adjacent to the development.

5.1.2 Assessing pest and public health risk

It is difficult to assign a threshold level of nuisance caused by mosquitoes. A common complaint to local authorities is that "this season is the worst ever for mosquitoes". In reality, there may not be many more than the usual number of mosquitoes for that time of the year. Individuals vary in their sensitivity to mosquito bites and the level at which nuisance becomes serious. There will also be great variability in the awareness and willingness of the community to contact local authorities to complain. Having access to reliable mosquito population data assists in responding to these enquires from the community and better understanding the local pest and public health risks.

Based on the information provided by the NSW Arbovirus Surveillance and Mosquito Monitoring Program, relative levels of pest impacts associated with adult mosquito trapping data (i.e. mosquitoes per trap night) is as follows: Low <50; Medium 50-100; High 101-1,000; Very High 1,001-10,000; Extreme >10,000. These categories are somewhat arbitrary given the actual level of pest impacts will vary greatly depending on the dominant mosquito species. For example, *Aedes vigilax*, *Culex annulirostris*, and *Verrallina funerea* are likely to be responsible for significant nuisance-biting impact when populations are measured above 1,000 mosquitoes per trap night.

When assessing the nuisance potential of a proposed development, it is important to consider both the abundance and diversity of local mosquitoes. While some assessment can be made based on existing habitat assessments and any existing mosquito abundance data, surveys of local mosquito populations is strongly recommended. However, to best assess the local pest and public health risks, it is important that reference can be made to existing datasets. Difficulties arise when sampling is not undertaken during peak periods of mosquito activity (i.e. November through to April) or adult mosquito sampling in undertaken with traps that differ substantially in design and effectiveness compared to the EVS traps used by local authorities.

There will always be constraints placed on consultants with regard to the extent to which mosquito sampling can be conducted. However, there is great benefit in being able to support assessments on the relative impact of mosquitoes on a proposed development if data can be provided that is cross referenced to existing longitudinal data sets available from Ballina Shire Council.

With regard to mosquito-borne disease threat and new developments, it is important to consider that the most commonly mosquitoes across the Ballina Shire Council region are known vectors of RRV and BFV. However, an abundance of these mosquitoes does not necessarily indicate an elevated risk of disease. Given the presence of wildlife, especially kangaroos and wallabies, will drive increasing risk of pathogen transmission, when considering overall public health risks reference should be made to any existing information on local wildlife (e.g. ecological reports, fauna surveys).

5.2 Urban planning and mosquito risk

5.2.1 Development types and mosquito risk

There is the potential for a wide range of development types to increase exposure of the community to the pest and public health risk of mosquitoes. For each of the land use zones contained with Ballina Local Environmental Plan 2012, there are aspects to be considered that may create opportunities for the community to be exposed to increased levels of mosquitoes, either through the location of development or creation of sources of mosquitoes within the development foot print.

While it may be impractical that all proposed development typess require assessment for mosquito risk, capacity must be included in the revised Development Control Plan to allow for assessment and conditions to be placed on development to mitigate or minimise mosquito risk. While the priority must remain with residential and business zones, especially where residential, seniors housing (aged care facilities), tourist and visitor accommodation, child care centres, and respite day care centres are located, proposed developments within industrial zones may be important together with specific developments such as sporting fields, parklands and playgrounds, nature walks that would all potentially be impacted by mosquitoes, or provide new or enhanced opportunities for mosquitoes. The pest and public health impacts of mosquitoes associated with that infrastructure could be minimised through strategic mosquito management recommendations. Consideration should also be extended to new residents, workers and visitors to these areas may not be aware of the health risks associated with local mosquito populations or the strategies available to protect themselves from mosquito impacts and, as a consequence, may be at a relatively greater risk.

Careful consideration of any proposed development in greenfield areas should be reviewed with respect to its potential for increased pest and public health risk associated with mosquitoes.

5.2.2 Building design and screening

A suite of approaches to building design can reduce the impact of mosquitoes. The most common is the incorporation of screening to prevent entry of mosquitoes into buildings. However, other aspects of building design may assist in minimising the impact of mosquitoes.

Mosquito activity is generally expected in outdoor areas but the entry of mosquitoes into buildings can often have significantly greater nuisance impacts. Insect screens of an appropriate mesh size should be fitted to windows and doors. Insect screens (made of aluminium, bronze or fibreglass) of an appropriate mesh size (mesh size of 1.2mm x 1.2mm is generally recommended) should be fitted to windows and doors where possible and maintained regularly (tears and loose fitting screens will allow mosquitoes entry to buildings). In situations where there is concern regarding obstruction of views or decreased visual amenity, sash windows can be used where only half the screening is required. There is a wide range of options available for screening doors including sliding, spring loaded and pleated screens for doors and windows. Some retractable structures are available for wide openings with pleated and bi-folding options offering potential coverage of openings over 5m wide and up to 3m high. Regular maintenance is necessary to ensure tears or holes in screening are repaired in a timely manner.

Natural breeze or airflow from fans (e.g. ceiling or ground) can occasionally be employed to limit mosquito activity but such as strategy is unlikely to provide protection when mosquito populations are high. A fully enclosed, air conditioned building is less likely to be impacted by mosquitoes but it should also be ensured that there are no entry points via air conditioning ducts, ventilation structures or other connections between indoor and outdoor areas.

Also providing screened outdoor areas that allow for protected outdoor recreation can be a valuable contribution to creating a more pleasant space. This is an increasingly important consideration where developments include aged care and/or child care facilities and the provision of outdoor recreation areas free of nuisance insects is essential.

The challenge in outdoor areas, particularly close to wetlands, is addressing the conflicts between visual amenity and functionality of outdoor areas while minimizing contact with mosquitoes. There is a number of options available with regard to permanent and temporary screening of outdoor areas and with reliable information on local mosquito populations, flexible options can be incorporated into the development's design so that during periods of low mosquito activity, areas can be opened up to maximise visual amenity and air circulation.

The size and structure of these screened outdoor areas will vary greatly. From small shelters containing picnic tables and rest areas through to playgrounds and other facilities. While this may only be a consideration for residential allotments within developments, it may be required for shared community spaces in developments in close proximity to known sources of pest mosquitoes or where other control measures are not sufficient to mitigate those impacts.

For child care centres, seniors housing, or respite day care centres, where the provision of recreational outdoor space is considered critical, it should be a requirement that screened outdoor space is provided. There are flexible options available to provide outdoor recreation areas that minimise contact with mosquitoes and this flexibility allows for them to be modified throughout the season in responses to changes in mosquito activity.

The lighting around dwellings is often identified as a source of potential attraction of mosquitoes. This may be due to the attraction and swarming behaviour often observed in non-mosquito flying insects that are commonly associated with wetlands. This activity around lights may be misinterpreted as lights having similar levels of attraction to mosquitoes. In reality, studies have shown that the spectral composition of light emitted from different sources can modify the attraction of nocturnal arthropods. However, not all lights are similarly attractive to flying insects. While research has been conducted into different spectrums of light sources used in mosquito traps, there is no evidence that lighting around a residential or industrial development will specifically influence the activity of mosquitoes.

5.2.3 Development layout and buffer zones

There are opportunities to reduce the impact of mosquitoes dispersing into residential areas from adjacent wetlands by locating residential allotments as far from pest mosquito habitats as possible. Buffer zones between proposed developments and mosquito habitats are often raised as a possible strategy to assist in minimising the impact of nuisance-biting. However, there are few quantitative studies indicating the appropriate width, shape or vegetation composition of effective buffers. Guidelines provided by local authorities elsewhere in Australia can range from 25m to over 1km. Effective buffer zone distances will be site specific and must be based on the abundance of locally important pest species.

The dispersal range of mosquitoes will vary with species. While some mosquitoes don't fly more than 100m, others have been recorded travelling up to 20kms. Dispersal from larval habitats is also influenced by prevailing climatic conditions (e.g. humidity, wind) and environmental conditions (i.e. vegetation). Connected areas of dense vegetation are more likely to facilitate movement of mosquitoes greater distances away from larval habitats than relatively open, sparsely vegetated areas.

In the Ballina Shire Council area, it is not practical to create buffer zones that provide satisfactory protection from widely dispersing mosquitoes such as *Aedes vigilax*. This mosquito disperses widely with mark-release-recapture experiments demonstrating active dispersal up to 3km. Based on the collection of specimens and distances from known larval habitats, this mosquito commonly disperses up to 5km from saltmarsh and mangrove habitats, bringing pest and public health impacts to a wide area. Anecdotal evidence suggests dispersal could be up to 20km. For this reason, the incorporation of buffer zones between known habitats of unmanaged *Aedes vigilax* populations cannot practically be incorporated into urban planning strategies.

For mosquitoes that do not disperse such distances, buffer zones between sources of mosquitoes and developments can assist in reducing the significance of pest impacts. This is especially the case for mosquitoes such as *Verrallina funerea* (as well as *Aedes multiplex* and *Aedes procax*) that disperse from brackish-water and freshwater habitats within coastal swamp forests and she-oak woodlands. There is information available on the dispersal of other mosquitoes, such as *Anopheles annulipes*, *Culex annulirostris* and *Culex quinquefasciatus*, that have all been documented travelling more than 1km from freshwater wetlands. There is little information on the dispersal of other potential pest mosquitoes associated with freshwater wetlands in the local area such as *Coquillettidia linealis*, *Culex orbostiensis*, or *Mansonia uniformis*. It is likely that what is critical for these mosquitoes is that their activity is generally confined to well shaded areas, especially where vegetation forms contiguous refuges with larval mosquito habitats.

The use of “mosquito hazard reduction” buffer zones, vegetated or non-vegetated areas between mosquito habitats and developments, has been proposed as a potential strategy to reduce the pest and public health risks of mosquitoes. However, due to the paucity of quantitative dispersal studies of local mosquito species, guidelines on the exact distance of buffer zones and their vegetation composition generally relies on anecdotal evidence and the considered expert opinion of suitably qualified entomologists. The effectiveness of buffer zones to protect people within residential, recreational, or industrial developments is going to be highly influenced by the quantity of actual and potential adjacent mosquito habitats as well as the abundance and diversity of local mosquito species.

For a locally significant pest mosquito, *Verrallina funerea*, current understanding is that it does not disperse in abundance across areas of more than 25m where there is an absence of substantial terrestrial vegetation (e.g. shrubs, dense woodlands) to provide refuge. Studies conducted locally suggest that adult mosquito traps operated 50m and beyond such buffers collect approximately 80% of mosquitoes compared to traps located in close proximity to habitats. It is worth noting that this substantial reduction in mosquito abundance does not continue to decline with greater distances so it appears that the buffers primarily around sources of mosquitoes provide the greatest assistance in minimising dispersal.

The incorporation of buffer zones between the habitats for mosquitoes such as *Verrallina funerea* and residential development may assist in reducing the impact of these mosquitoes. However, where productive habitats are nearby and relatively large populations of mosquitoes are generated, it should be expected that enough mosquitoes will disperse across these areas to make the use of buffer zones less effective overall in mitigating nuisance impacts. For example, while substantial reductions in the dispersal of *Verrallina funerea* has been reported, if local mosquito populations are exceptionally high, sufficient mosquitoes are likely to disperse from local habitats during periods of suitable environmental conditions, to still cause significant pest and public health concerns in new developments.

The creation of effective buffer zones can be incorporated into the design of developments in a number of different ways. This can be achieved by placing infrastructure (e.g. roadways, bike paths, footpaths) around the perimeter of new developments. Sporting fields or other passive and active recreation parklands can also be located at the periphery of developments to reduce dispersal of mosquitoes. However, this can also inadvertently increase exposure of the local community to mosquitoes under circumstances where they are spending time in these areas (see section 5.2.4 and 5.2.5 for further discussion).

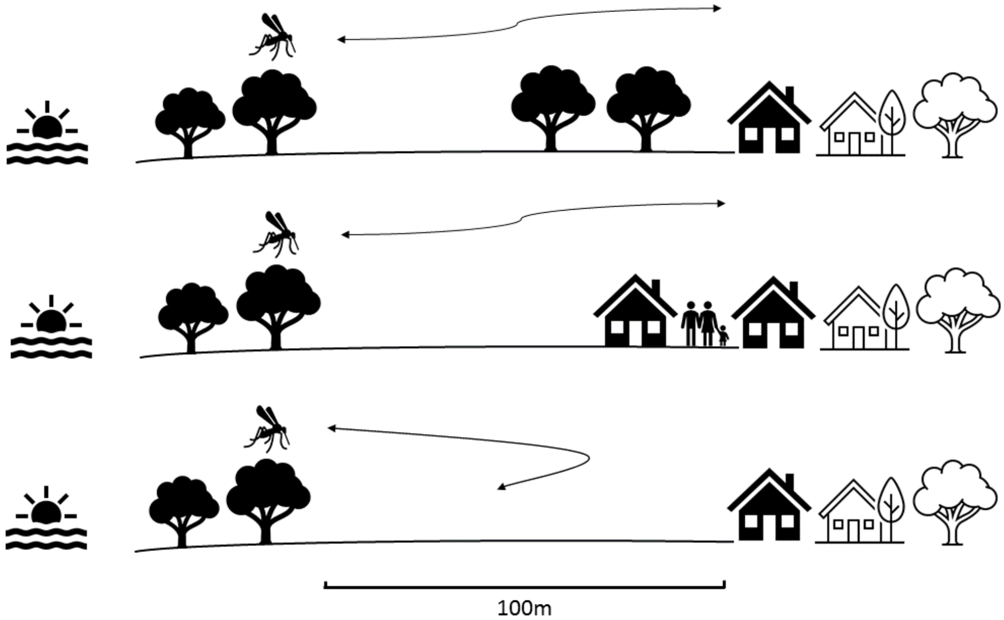
“Mosquito hazard reduction” buffer zones should, ideally, be calculated from the edge of residential allotments. However, in some circumstances, the calculation may be made from the dwelling itself to allow the inclusion of residential allotments in developments facing constraints regarding the effective implementation of a suitable buffer. While this approach may be satisfactory, it is a requirement that the property owner clearly understand that vegetation plantings within their property may substantially degrade the utility of the “mosquito hazard reduction” buffer zones in reducing mosquito impacts directly on their property. In these situations, it is important that the property owner clearly understands the restrictions and such information must therefore be made available on a planning certificate under Section 10.7 of the Environmental Planning and Assessment Act 1979 and restriction placed on affected lots under the Conveyancing Act 1919. Allowing buffers to go on privately owned land may need to be a decision made by Council on a case by case basis.

Asset protection zones can also be used to assist in the creation of these mosquito buffers. In particular, sparsely vegetated open space is a requirement of bushfire hazard reduction and is concomitant with reducing effective dispersal of mosquitoes. There will be circumstances where bushfire hazard reduction zones can be used to create or enhance “mosquito hazard reduction” buffer zones. However, consideration may need to be given to conflicts in the design of these “mosquito hazard reduction” buffer zones and other asset protection and environmental conservation buffer zones (e.g. coastal wetlands protection zone, fish habitat protection zone, etc) that may require maintenance of dense terrestrial vegetation.

The vegetation, and its management, within the “mosquito hazard reduction” will be critical in sustaining the assistance in reducing dispersal of pest mosquitoes. The harbourage sites provided by dense terrestrial vegetation (e.g. shrubs and trees) provides cool humid refuges that assist increased longevity of mosquitoes and dispersal distances. These harbourage sites can also act as “stepping stones” (a number of clumps are close together) or “bridges (a continuous corridor of vegetation) that facilitate the movement of mosquitoes into areas they would not normally disperse due to a naturally short flight range. With regard to the types of vegetation that would be suitable in a “mosquito hazard reduction” buffer zone, there are no scientific studies to call on that could shape prescriptive requirements. However, the more dense the foliage and canopy of a tree or shrub, the greater likelihood is that it will provide suitable refuge for mosquitoes. The preferred vegetation types would be tall growing native trees that cast minimal shade over the ground around it while around the base and lower limbs airflow is maximised. Concomitant with this style of vegetation, the understory vegetation must remain an important consideration as dense and low shrubs, densely planted may also provide refuge for mosquitoes.

There is no quantified evidence as to the role of ground cover vegetation (e.g. garden beds of *Lomandra*) to facilitate movement of mosquitoes. However, these areas of densely planted ground cover are likely to provide some refuge for mosquitoes and, until evidence suggests that environmental conditions in these habitats are unsuitable for mosquitoes (i.e. shading, wind protection, humidity), the extent of plantings should be minimised or allowances should be made for open areas between plantings so that they do not create connections between more substantial adult mosquito refuges and residential developments.

It is important to note that the utility of these "mosquito hazard reduction" buffer zones may also be reduced dependent on recreational buildings (e.g. amenity buildings) and stormwater infrastructure. Where stormwater infrastructure and other water bodies are proposed to be sited within the "mosquito hazard reduction" buffer zones, it should be a requirement that suitably qualified entomologists provide an assessment of whether this will reduce the effectiveness of the zones. Degradation of the effectiveness of the "mosquito hazard reduction" buffer zone may be due to dense planting of macrophytes within constructed wetlands or other drains, bioretention basins, or swales. Notwithstanding the role of these habitats in creating opportunities for mosquito production, the macrophyte zones may provide additional refuge for adult mosquitoes dispersing from habitats adjacent to development.



"Buffer zones" that are free of substantial vegetation can assist in reducing the movement of some mosquitoes (e.g. *Verrallina funerea*) from wetlands into residential areas. The placement of vegetation or built structures within the nominated buffer zones may facilitate the movement of mosquitoes into residential areas.

Notwithstanding the design of "mosquito hazard reduction" buffer zones, maintenance is an important consideration. This includes the maintenance regime of these zones and relates to roles and responsibilities of stakeholders to consider future change in mosquito risk based on activities undertaken within these zones. While initially designed and constructed as "mosquito hazard reduction" buffer zones, the utility of these areas to reduce dispersing mosquitoes may be influenced by future plantings, either for ecological or amenity. It is critical that the intended use of these areas is clearly identified in all management plans so that activities are not undertaken that degrade their effectiveness (e.g. construction of buildings of other structures that may act as "stepping stones" between mosquito habitats and residential areas). Similarly, vegetation in these areas must be the focus of specific actions in vegetation management plans. There must be consistency in maintenance schedules between land managed by Ballina Shire Council and adjoining lands managed privately or by other authorities. Where components of a "mosquito hazard reduction" buffer zones lay within private property, there remains an obligation that vegetation within that zones is adequately managed to ensure integrity is maintained.

While the concept of "buffer zones" does not offer a single effective strategy to reduce all mosquito impacts, the basic principal of reducing harbourage sites close to residential areas is a worthwhile consideration. This will not necessarily be sufficient in mitigating the impact of mosquitoes, the onus should be placed on applicant to demonstrate an appropriate buffer zone, with consideration to source of mosquitoes, width, vegetation composition, and management schedule. It is critical to note that effective buffer distances will be site specific and must be based on the abundance of locally important pest species.

5.2.4 Vegetation planning and management

Terrestrial vegetation within a proposed development can have a substantial influence over the actual and potential impacts of mosquitoes. As well as providing humid refuge sites for mosquitoes dispersing into the development from surrounding habitats, some plant species may provide opportunities for pest mosquitoes such as *Aedes notoscriptus* as they trap water within their structures.

Consideration is required of terrestrial vegetation with regard to both existing vegetation (i.e. vegetation present on development site prior to construction) and future vegetation (i.e. including retained vegetation, revegetation programs, landscaping, and residential allotment planting). Vegetation management plans are required for developments and mosquito risk should be considered as part of those plans. Ideally, a suitably qualified entomologists should be involved in the earliest stages of vegetation plan development but it is essential that they provide an assessment of final plans to determine the potential impact of mosquitoes on future residents, workers, and visitors to development.

The vegetation that will provide the greatest risk of increasing mosquito impacts will be dense tree or shrub stands that provide substantial refuge for adult mosquitoes. Within a development, these areas many be remnant clumps of vegetation designed to be retained within the development for ecological or aesthetic purposes. In some instances, strategies may be proposed that rehabilitate and/or revegetated these areas and those surrounding remnant stands. While there is great benefit for the development to ensure vegetation is retained, it is important that any potential mosquito risk is identified and, where possible, mitigated.

These stands of dense vegetation will provide refuge for mosquitoes dispersing into the site. For developments within the "Coastal Plains and Lowlands", these areas of dense vegetation will provide refuge for *Aedes vigilax* dispersing from nearby coastal wetlands while other pest mosquitoes such as *Verrallina funerea* will similarly use these habitats. Refuge will also be provided for other mosquitoes and facilitate their longevity, increasing the duration of impacts of nuisance biting and, potentially, health risks.

Where remnant clumps of vegetation are designed to be retained within the development, where possible, connections of vegetation between these areas and vegetation in and around dwellings or other inhabitable structures should be minimised. Breaking contiguous vegetation, or at least providing structural differences in vegetation. For example, transition from dense woodland vegetation to grasses or sedges before more heavily vegetated shrub or tree dominated vegetation around/within residential allotments. This approach may assist in minimising the quantity of mosquitoes dispersing from those dense woodland areas.

When selecting plant species within developments, there are no scientific studies to call on that could shape prescriptive requirements in planting guides. However, the denser the foliage and canopy of a tree or shrub, the greater likelihood is that it will provide suitable refuge for mosquitoes. Similarly, high density plantings further contribute to the creation of suitable refuge areas.

The preferred vegetation types would be tall growing native trees that cast minimal shade over the ground around it while around the base and lower limbs airflow is maximised. Concomitant with this style of vegetation, the understory vegetation must remain an important consideration as dense and low shrubs, densely planted may also provide refuge for mosquitoes.

There is no quantified evidence as to the role of ground cover vegetation (e.g. garden beds of *Lomandra*) to facilitate movement of mosquitoes. However, these areas of densely planted ground cover are likely to provide some refuge for mosquitoes and, until evidence suggests that environmental conditions in these habitats are unsuitable for mosquitoes (i.e. shading, wind protection, humidity), the extent of plantings should be minimised or allowances should be made for open areas between plantings so that they do not create connections between more substantial adult mosquito refuges and residential developments. Similarly, playgrounds and other outdoor recreation areas should not be surrounded by dense plantings of ground cover vegetation.

Garden beds within the development featuring water-holding plants can provide opportunities for mosquitoes. Container-inhabiting mosquitoes such as *Aedes notoscriptus*, will take advantage of water retained within the central "urns" of bromeliads. Bromeliads, especially large plants, can be a very productive source of these mosquitoes. Studies in NSW, QLD, and WA have demonstrated that in backyards of residential properties, bromeliads are some of the most common and productive habitats for *Aedes notoscriptus*. These plants, especially the giant bromeliad (*Alcantarea*), are commonly incorporated into landscape plantings given their striking appearance and hardiness. However, they should be avoided where possible due to the potential provision of productive mosquito habitats.

Specific discussion related to aquatic vegetation proposed in planting guides for constructed wetlands and other water bodies is provided in section 5.4

Specific discussion related to vegetation within "mosquito hazard reduction" buffer zones is provided in section 5.2.3

5.2.5 Playgrounds and other outdoor recreational facilities

When assessing the likely exposure of the community to mosquitoes in new developments, consideration should be given to any outdoor recreation facilities. As outlined in the discussion of buffer zones and their attributes (see section 6.2.3), open areas of parkland is generally recommended to limit the dispersal of mosquitoes from adjacent wetlands into developments. As a consequence, recreational facilities (e.g. playground or exercise equipment, picnic areas) are often likely to be located in this space also. Should they be inadvertently exposed to increased mosquito impacts, the benefit to the community of these facilities will be greatly reduced.

While it is not feasibly to screen these areas, measures should be taken to ensure the suitability of surrounding areas for mosquitoes is minimised. This includes ensuring areas are not immediately surrounded by dense vegetation. While providing shaded areas is important, to reduce inadvertently creating an opportunity for mosquitoes, artificial shade options may be a preferable as an alternative to extensive tree cover. Detailed descriptions of shade options for playgrounds is provided by Cancer Council of NSW (Guidelines to Shade, 2013).

5.2.6 Nature walks and environmental education

For some developments close to natural wetland or bushland areas, it may be an objective of developers to incorporate nature walks (e.g. boardwalks, bird hides, bike trails) that take the community into areas of high risk of mosquito exposure. There is little that can be done to minimise exposure to mosquitoes in these areas due to the likelihood that mosquito habitats are close by and dense vegetation will provide refuge for mosquitoes. In area where wildlife is also present, there may be an elevated risk of mosquito-borne disease also.

One strategy to be considered is the incorporation of permanent or temporary signage advising visitors that mosquitoes are present and a health threat. These signs could also include advice on person protection measures. Temporary signs could be updated over the course of the year and only be installed during peak periods or when mosquito surveillance identifies a higher risk of pest or public health impacts.

Constructed wetlands and other waterbodies in water sensitive design elements may create opportunities for mosquitoes

5.3 Water sensitive urban design and green infrastructure

Water conservation strategies within urban areas is an increasingly important consideration given potential impacts, and their mitigation, of climate change. Together with efforts to increase green space in urban areas to reduce the impact of increasingly frequent heatwaves and provide habitat for local wildlife, the construction of wetlands and stormwater management devices are an increasingly common component of new residential and industrial areas. These initiatives, however, may provide opportunities for mosquitoes onsite and in additional to the installation of rainwater tanks and other water storage devices may contribute to increased mosquito populations. Constructed wetlands will be addressed specifically in section 5.4

Water Sensitive Urban Design systems can be complex and contain many elements (e.g. drains, swales, bioretention basins, wetlands, rain gardens), each bringing a different level of risk regarding the creation of actual and potential mosquito habitats. However, mosquito risk can be highly site-specific and influenced by a wide range of factors, not least of all the extant mosquito populations and the relative importance of new water bodies or water-storage structures in contributing to the creation of mosquito habitat. Some general guidelines and scientific publications have highlighted elements of these constructed water bodies that may increase mosquito risk, there are no specific regulations in place stating how mosquito risk should be managed or mitigated.

The key determining factors as to whether these waterbodies create opportunities for mosquitoes is the retention of water following rainfall or associated surface flows. It is common that such structures are designed to facilitate infiltration of water within 48h or sooner so there is generally considered to be minimal mosquito risk. However, over time, through the accumulation of sediments and invasive aquatic plants, the infiltration rates of these waterbodies are reduced, leading to increased suitability for mosquitoes.

With regard to bioretention swales and raingardens, the rate of infiltration is achieved through careful consideration of construction and soil types. However, over time there can be factors that change this infiltration rate and potential raise the potential for mosquito production. Sedimentation during the construction phases, or shortly after, can slow infiltration rates while the establishment of vegetation in the structures can assist sedimentation rates and accumulation of organic material that will also slow infiltration rates. These habitats can also be further modified through maintenance, especially where vegetation is managed through mowing. Compaction can occur, as can wheel ruts, which may create opportunities for mosquitoes

For mosquitoes to complete development in these habitats, surface water must be retained for at least 7 days. For structures that contain water for extended periods of time (e.g. weeks), mosquitoes such as *Coquillettidia linealis*, *Culex annulirostris*, *Culex quinquefasciatus*, and *Mansonia uniformis* could become problematic depending on the types of vegetation present and water quality. In some instances, particularly during the warmer months, mosquitoes could complete development in approximately 5 days. Water bodies that are routinely holding water for these period and then drying out will become more suitable for a different suite of mosquitoes including those such as *Aedes multiplex*, *Aedes procax*, *Aedes vigilax*, and *Verrallina funerea* depending on salinity and vegetation types present. In summary, ensuring water is retained in water bodies no longer than 5 days will greatly reduce the likelihood that suitable conditions for mosquitoes will be created. It should be noted that while *Aedes vigilax* and *Verrallina funerea* are typically associated with estuarine habitats, they will lay eggs around waterbodies where a small degree of soil salinity is present and can hatch and complete development should favourable conditions occur.

For some stormwater devices, retention of water is expected. For example, gross pollutant traps. For devices of this nature that are designed to allow standing water to persist for more than 48h to facilitate sediment removal or other water quality/pollution objectives, consideration should be given to any potential creation of opportunities for mosquitoes. In these structures, water is often heavily polluted and the structures are constructed with vertical walls. These characteristics are not consistent with suitable conditions for mosquitoes, especially not mosquitoes of significant pest and public health concern locally. The mosquito most likely to be utilising these habitats is *Culex quinquefasciatus*, this is not a significant nuisance biting pest but will enter dwellings so can cause substantial nuisance.

Green infrastructure is a term to describe initiatives in urban areas to assist in reducing heat impacts and improve stormwater management. These initiatives may include the inclusion of permeable surfaces, tree pits, green walls, green roofs, and/or street trees in new developments.

There is clear overlap in some aspects of green infrastructure and WSUD. The issues associated with increasing street tree coverage and increased tree cover in the region and mosquito risk directly relate to discussion in section 6.2.4

The elements of green infrastructure that should be uniquely considered with mosquito risk in mind are green walls and green roofs. These initiatives may become more common in Ballina Shire Council as they are considered useful in reducing the energy use of buildings while assisting water and wildlife conservation in urban areas. They have also been shown to improve the health and well being of local community. Consideration must to given to where these initiatives create opportunities for mosquitoes. Notwithstanding the inclusion of plants with capacity to trap and store water in their leaves (e.g. bromeliads), the greatest risk comes from irrigation practices. Green walls often have drains or other irrigation devices that may represent habitats for mosquitoes while the design of green roofs may provide similar opportunities.

5.4 Constructed wetlands

Constructed wetlands are becoming increasingly common components of urban developments. These are variously designed for stormwater collection, waste water treatment and/or water storage, sediment management while also often bringing with them side benefits for wildlife conservation, passive recreation, community education and aesthetic appeal. However, mosquitoes including *Culex annulirostris*, *Culex quinquefasciatus*, *Culex orbostiensis*, *Coquillittidia linealis* and *Mansonia uniformis* may become established in these habitats.

The management strategies required to address the mosquito risks associated with constructed wetlands are often site-specific. It would be useful for local government to also consider the actual and potential health risks associated with mosquitoes in the design, construction and maintenance plans for these habitats. Most importantly, the strategies of mosquito management have to be balanced against other requirements such as public safety, water quality and wetland function.

In general, constructed wetlands that contain areas of deep water with large open areas will be generally unsuitable for mosquitoes. The deep water provides refuge for mosquito predators while open water allows wind action and surface water movement to disrupt larval development and discourage mosquito oviposition (i.e. egg-laying). However, where algal growth and abundant floating vegetation occur, these benefits can be undermined as they provide refuge for immature mosquitoes.

Water bodies with simple shapes and a low edge to area ratio are less likely to be productive of mosquitoes. A complex wetland with shorelines and islands that promote heterogeneity of the vegetation zones and the presence of small coves and inlets provides for growth of dense vegetation, and accumulation of floating debris. Under these circumstances, mosquito larvae are protected from wave action and predators. Wetlands with generally linear shorelines provide less area of refuge for larvae from predators than do convoluted shorelines but such linear wetlands may not be conducive to the slowing water flows required to assist pollutant removal These water bodies may not be considered aesthetically pleasing by local residents or may not provide the same ecological value for local wildlife. It has been proposed that situating water bodies so that the long axis of the wetland in line with prevailing summer wind directions but such an approach is often constrained by the local terrain, existing waterways and overall development plan.

A common feature in constructed wetlands is the inclusion of relatively shallow macrophyte zones. These components of a wetland pose the greatest risk of producing mosquitoes as they are typically heavily vegetated, and the dense growth of plants provides food and refuge for mosquitoes. In situations where predators are present (e.g. fish or macroinvertebrates), the dense vegetation can reduce the effectiveness of mosquito control offered by these predators. Ideally, these zones should maintain water depths of at least 300mm to discourage mosquito breeding but there will be exceptions to this where vegetation is dense.

There is limited information available on the associations between specific vegetation types and mosquito productivity in constructed wetlands but a qualitative assessment can be made based on the likelihood of providing suitable conditions for mosquitoes based on growth forms and other biological and ecological characteristics. The species of greatest concern are likely to be *Typha* and *Phragmites* spp. that are prone to wetland invasion and dense growth. These species may "clog" wetland systems, creating refuge for mosquito larvae and restricting access of predators. Also, dead plant material increases the organic content of the water, increasing the suitability of the habitat for mosquitoes. Floating plants such as water hyacinth (*Eichhornia crassipes*), salvinia (*Salvinia molesta*) and duckweed (*Lemna* spp.) all have the potential to increase the suitability of wetlands, particularly open water areas that would otherwise not provide suitable conditions. An abundance of floating vegetation can also enhance specific mosquitoes that prefer those conditions, these may include *Anopheles annulipes*, *Coquillettidia linealis*, *Coquillettidia xanthogaster*, and *Mansonia uniformis*.

It can be beneficial if water level management capabilities are incorporated into the design of the wetland. Water level management will allow for more effective vegetation and sediment management but also assist reducing conditions for mosquitoes. However, while lowering and raising the water level can be can be detrimental to *Anopheles* spp. *Coquillettidia* spp. *Culex* spp., it may also increase the suitability of habitats for some *Aedes* spp. Careful consideration must be given to water management strategies in light of direct and indirect impacts on potential mosquito pests, as well as other elements of the wetland. Prescribed times for drying, or simply lowering water levels, of wetlands must be decided with a view to site-specific issues such as mosquito species, vegetation types, seasonal factors but the incorporation of engineering elements that allow for water level management capabilities will greatly assist future mosquito management.

Beyond macrophyte zones, where relatively shallow water and gently sloping margins are required, increasing the steepness of water body margins will reduce their suitability for mosquitoes. The recommended bank slope of wetlands to minimise mosquito breeding is from 2.5H:1V to 4H:1V, and slopes should not be planted with grasses that may trap water and provide habitat for mosquitoes (alternatively, grasses should be regularly cut to minimise habitat available). It is not just the slope that needs to be considered but the vegetation planned or predicted to occur, especially invasive plant species such as *Typha* or *Phragmites* spp.

Concern for public safety will often result in the incorporation of gently sloped wetland banks but to discourage access to wetlands, spiky, thorny or otherwise impenetrable terrestrial vegetation can be planted, but this strategy is not always desirable as it may be seen to be aesthetically less pleasing than the visual amenity of open water. If the recommended bank steepness cannot be maintained for safety or other considerations, a vertical 'lip' between 100 - 300mm may be used at the water margin, allowing more gradual slopes above the vertical edge. While effective, this strategy will not be effective if water levels cannot be maintained at appropriate levels and this design element may have adverse impacts on other wildlife.

There will be other elements to constructed wetland systems that may increase opportunities for mosquitoes. The mosquito productivity from these components, such as subterranean pipes and gross pollutant traps, can be strongly influenced by prevailing weather conditions. For example, during periods of regular rainfall, much of the infrastructure will be regularly flushed and unsuitable for mosquitoes. However, during periods of dry conditions, enough water remains within the system to support mosquito breeding. These additional elements of the local stormwater infrastructure must remain free draining where possible while gross pollutant traps and sumps are routinely cleaned to reduce their suitability for mosquitoes. Accumulation of sediments, algal mats, or aquatic macrophytes will enhance conditions for mosquitoes, especially *Culex quinquefasciatus*.

As highlighted, maintenance of these water bodies is critical in ensuring they remain completely free of mosquitoes or that mosquito production is minimised. Where possible, all water bodies (including wetlands, bioretention swales, open drains, and raingardens) should be routinely inspected with potential suitability for mosquitoes given careful consideration. These habitats should be appropriately identified within the database of assets held by Ballina Shire Council. A routine inspection and maintenance schedule should be developed that ensure these habitats do not become locally important sources of mosquitoes. Where problematic habitats are identified, consideration should be given to long-term engineering solutions that will reduce the likely recurrence of conditions suitable for mosquitoes.

5.5 Rainwater tanks and other water holding structures

Rainwater tanks have historically been identified as locally important mosquito habitats in northern NSW. Studies from QLD, NSW and WA have shown that these habitats may provide habitat for local pest mosquitoes, especially *Aedes notoscriptus*. However, modern rainwater tanks vary dramatically from those of prior decades and come in a wide range of shapes and sizes and made from a number of different materials, most commonly moulded polyethylene or steel. These modern tanks are designed to reduce their suitability as mosquito habitats through the use of sturdy screens on all openings. A commercially available water tank, correctly installed, may not pose a significant mosquito risk. However, cheaper models and/or those installed inappropriately may be more likely to provide opportunities for mosquitoes.

Developing a database of properties with rainwater tanks will greatly assist surveys and mosquito control should it be required but may not be practical. Education of households to encourage correct installation and maintenance of tanks will reduce the risks that a mosquito problems may develop. In addition, education of retailers or service providers installing or maintaining tanks may also be an opportunity to enhance awareness among the public.

5.6 Wetland rehabilitation

Mosquitoes are a natural presence in coastal wetlands. Historically in coastal NSW, modification of wetlands to drain surface water, or to restrict inundation of tides, has resulted in adverse impacts to the local plants and animals utilising these habitats. Coastal wetland rehabilitation is becoming an important component of environmental management where land has become degraded through neglect or mismanagement. Rehabilitation may be required as offsets associated with new residential or industrial development or as a component of new development applications may be plans to rehabilitate or revegetate existing degraded habitats within the footprint of the proposed development.

There is also increasing interest in the role of coastal wetlands in sequestering carbon to assist mitigation of climate change impacts, in future “blue carbon” may prompt great wetlands conservation, construction and rehabilitation.

In some circumstances, problematic mosquito populations have been identified as a symptom of these degraded habitats. In these wetlands, rehabilitation may bring co-benefits of improving the health of the environment while minimising mosquito abundance. Mosquito populations can be significantly reduced as with more frequent tidal flushing, improved tidal or rainfall infiltration of sediments, or increased abundance of predatory fish populations. While habitat modification to manage *Aedes vigilax* in coastal wetlands of NSW and QLD has proven successful it is important to note that any modification to the environment to reduce the production of mosquitoes may have the potential to impact other components of the local ecosystem and should be fully investigated before any strategies are implemented. Similarly, mosquitoes associated with highly degraded freshwater wetlands can be problematic and improving water flows, managing dense invasive macrophyte stands, or encouraging aquatic biodiversity may be a sustainable strategy to minimise their abundance and impacts.

Where proposed rehabilitation of degraded areas of estuarine wetlands is proposed, or where the creation of new habitats by introducing tidal flows to promote the generation of suitable habitats for native vegetation and wildlife (e.g. shorebirds), consideration should be given to how site-specific projects may bring increased actual and potential mosquito risk. This will be even more pertinent if there is likely to be areas of high public engagement with wetlands (e.g. boardwalks, bird hides, interpretive signage, picnic areas, cafes).

It is important that Ballina Shire Council engage with state government or federal agencies coordinating these projects to ensure that the potential health risks associated with increased mosquito populations are considered. It is critical that a suitably qualified entomologist be appointed to review (engaged by either local council or applicant) the design and management plan for any rehabilitation and/or construction estuarine wetland projects. A balance will always be required between the management of mosquito risk and the overall ecological objectives of wetland management.

5.7 Mosquito management strategies

Mosquito control has a role in play in reducing the pest and public health risks of mosquitoes. Coordinated mosquito control programs in coastal wetlands of SE QLD, NT, NSW and WA have demonstrated ecologically sustainable mosquito control can be successful in suppressing populations of mosquitoes posing pest and public health threats. These programs primarily target immature stages of mosquitoes within the wetlands before they emerge and disperse across the local area. Notwithstanding the operational and financial requirements of these programs, the suitability of broadscale mosquito control in the local area is constrained by the local environment and diversity of mosquito habitats.

Ballina Shire Council contains extensive and diverse wetland areas and would require a significant mosquito control program to be initiated to substantially reduce local mosquito populations. Notwithstanding the financial and operational resources required to undertake an effective broadscale mosquito program across estuarine and brackish-water habitats, permission would be required to undertake mosquito control in habitats of high conservation value such as the Ballina Nature Reserve and wetlands within the coastal protection zone. Mosquito control in these types of habitats is not readily undertaken in NSW.

With regard to the proposal to undertake mosquito control agent applications as a component of mitigation measures in new developments, serious concerns exist around the sustainability and ongoing effectiveness of this strategy. The financial burden of routine mosquito control agent applications may not be sustainable and this routine use of insecticides may have adverse impacts for the local ecosystem. Consistent with Ballina Shire Council's commitment for conserving the local environment, a reliance on ongoing mosquito control agent applications is not considered an appropriate strategy that would allow new developments in areas of high risk of mosquito impact.

Any product used to control mosquitoes (including killing or repelling them) must be registered by the Australian Pesticides and Veterinary Medicines Authority (APVMA). While there are mosquito control agents registered by the APVMA for use against adult mosquitoes, their routine use is not generally considered an ecologically sustainable approach to mitigating the pest and public health risks around residential and recreational areas. Notwithstanding the ongoing commitment to informed application based on monitoring, some products, especially those used to control adult mosquitoes, can have an adverse impact on other insects, and subsequently wildlife, while also increasing the risk that resistance to these control agents may develop in mosquitoes. Should resistance to these control agents develop in the local area, the capacity to use them during periods of health emergency may be greatly diminished.

For the purpose of this document, only mosquito control activities that may be applied to urban developments are discussed here. These products should be considered options for short-term mosquito control or as a component of routine maintenance of some stormwater infrastructure in specific circumstances (for example, short-term mosquito control during extreme weather events or where routine maintenance is delayed). However, these options are not considered sustainable long-term options that overcome the need to have a development designed, constructed, and maintained with an objective of sustained mitigation of mosquito impacts without reliance on insecticides.

There may also be situations where products of this nature are only to be obtained and applied by qualified pest control operators. It is critical that any product used for controlling mosquito populations is used according to the guidelines provided, irrespective of whether it is used by local authorities, professional pest controllers, or individuals.

5.7.1 Adulticides

These products are typically used to knock down or kill adult mosquitoes. It is important to note that, unlike the majority of larvicides (see 6.6.2), adulticides and the nature of their application pose a greater risk of non-target impacts. They are less specific in targeting mosquitoes so a judicious approach is required when applying these products. Non-target impacts can be minimised through operational considerations and an experience pest control operator should be engaged to conduct any adulticide applications.

Most commonly, adulticides are permethrin or synthetic pyrethroid based products (e.g. bioresmethrin). These are typically applied as either a "fog" or "mist" via a range of application equipment (e.g. compression sprayers, backpack or vehicle mounted applicators, thermal foggers, ultra low volume (ULV) generators) delivering very small droplet sizes to kill flying or resting mosquitoes. As well as posing a risk to non-target organisms in the local environment, this approach may not be agreeable to residents when visible "plumes" of insecticides are seen in local area. While these products are considered safe for people when used according to APVMA recommended application rates, the perception of potential health risks to the community would require specific education and awareness programs.

An alternative approach to "fogging" is the application of residual insecticides on vegetation or built structures to create a barrier between sources of pest mosquitoes and human activity.

Known as “barrier treatments”, these approaches have been employed in many locations around Australia, especially SE QLD where biting insects (i.e. biting midges and mosquitoes) dispersing from unmanaged wetlands are causing substantial pest, public health, and economic impacts on local communities.

The “barrier treatment” approach involves the application of a synthetic pyrethroid (e.g. bifenthrin) to vegetation or built structures to provide residual control. These products provide rapid knockdown of adult mosquitoes when taking refuge around built structures and vegetation. Their effectiveness is dependent on favourable weather and appropriate application equipment (as well as training of operators on use and maintenance) but the potential non-target impacts can be minimised through targeted application to priority areas where adult mosquitoes are seeking refuge (e.g. shaded areas around buildings, areas below dense vegetation).

Studies in North America and Australia have shown that this approach can substantially reduce pest mosquitoes in areas where treatments have been undertaken for at least 4 weeks. However, the results are not consistent across all types of mosquitoes. The propensity to disperse and preferences of resting sites may make some mosquitoes more susceptible to treatments. Similarly, there is likely to be specific aspects of the development’s layout and on site vegetation that will influence the utility of such an approach to control mosquitoes.

There are other approaches for the use of insecticides around developments. The installation of networks of fixed points of discharge of insecticides designed to knockdown or kill pest mosquitoes is increasingly being proposed. These systems, commonly known as “misting” or “automatically timed insecticide application” systems typically involve an electric pump system and pipeline connecting a central reservoir of insecticide to a series of nozzles located along a perimeter of a property. Insecticide is then delivered automatically, at programmable intervals. Studies have indicated that the resulting reduction in pest mosquito populations in residential settings is highly variable. The effectiveness of this system will be highly dependent on local mosquito populations, vegetation in and around property, and climatic conditions (e.g. wind direction and strength). As with any adulticide application, mosquitoes are not the only susceptible insect and non-target impacts should be expected.

With regard to adulticide use in new developments, this strategy of mosquito risk mitigation is not sustainable and is not considered appropriate in Ballina Shire Council. Notwithstanding the potential ecological impacts, the financial and operational considerations in maintaining a development wide program of insecticide applications, either through fixed systems or routine treatments, is unlikely to be sustainable approach to mitigate the pest and public health risks of mosquitoes when the development is located close to known sources of mosquitoes.

5.7.2 Larvicides, insect growth regulators, and surface films

These products are designed to be applied to water containing immature mosquitoes to prevent their emergences, either by killing the larvae, pupae, or newly emerged adults. As is the case with adulticides, the routine use of products should not be seen as adequately compensating for poorly designed stormwater infrastructure or other water bodies that represent actual or potential sources of mosquitoes.

A brief summary of the products currently registered by APVMA for use against immature mosquitoes is provided below:

- *Bacillus thuringiensis israelensis* (*Bti*). A larvicide applied to habitats producing mosquitoes. The naturally occurring soil bacterium produces a protein crystal which contains a number of microscopic toxins that when ingested are capable of destroying the gut wall and killing mosquito larvae. This is one of the most commonly used larvicides in Australian estuarine and freshwater habitats, no direct or indirect non-target impacts nor resistance in local mosquito populations have been reported. Generally only available to professional pest controllers, provides little no residual control, and in heavily polluted environments or those containing a high organic content, efficacy of this product is reduced.
- *Bacillus sphaericus* (*Bs*). A larvicide applied to aquatic habitats producing mosquitoes. Another naturally occurring bacterium with a similar mode of action to *Bti*. However, this product has the potential to replicate in the environment and provide residual mosquito control under suitable conditions. Best suited to highly organic freshwater habitats, particularly polluted urban waterways.
- Methoprene. A larvicide applied to aquatic habitats producing mosquitoes. The insect growth regulator, *s*-methoprene is a synthetic mimic of the juvenile hormone produced by insect endocrine systems and, when absorbed by the larvae, development is interrupted and immature stages fail to successfully develop to adults, usually dying in the pupal stage. This product is commonly used in Australia, particularly in highly organic rich environments (e.g. waste-water treatment ponds, drains, septic tanks) where *Bti* may not be as effective. A range of commercial formulations (including liquid, granule, pellet and briquette) are available that provide flexibility in habitat-specific use and, importantly, some formulations provide residual control of mosquitoes for up to three months.
- Monomolecular film. A product applied to aquatic habitats producing mosquitoes. A thin film of silicone based product is spread over the water surface and prevents immature mosquitoes emerging as adults. These products are only registered for use in water holding containers and should not be used in natural environments.

With regard to larvicide use in new developments, this strategy of mosquito risk mitigation is not sustainable and is not considered appropriate in Ballina Shire Council. The financial and operational considerations in maintaining a development wide program of larvicde application to stormwater infrastructure and other water bodies is unlikely to be sustainable approach to mitigate the pest and public health risks of mosquitoes associated with habitats within the development.

5.7.3 Biological control

A number of organisms have been investigated to determine their suitability as effective predators of mosquitoes. These include aquatic invertebrates (e.g. Diptera and Coleopteran larvae, Crustaceans, Notonectids, Odonates) and vertebrate (fish) predators of immature mosquitoes. Recent research has suggested that by increasing the biodiversity of aquatic organisms in a wetland (including constructed wetlands as a component of WSUD), mosquito populations are suppressed. These other organisms in the wetland prey on or compete against immature mosquitoes. While the introduction of these organisms is not necessarily a practical strategy, ensuring all other components of the wetland is healthy will increase the likelihood that a diverse aquatic ecosystem can become established and sustained.

Native fish have been used elsewhere in Australia for mosquito control. However, native fish introductions alone are unlikely to significantly reduce mosquito populations. The plague minnow (also known as the 'mosquitofish'), *Gambusia holbrooki,* was introduced to Australia from North America at the beginning of the 1900s to control mosquitoes but it is now considered a pest and has been implicated in significant adverse impacts on aquatic native fauna. It should never be released into local water ways and the adverse environmental impacts of this fish has been identified as a key threatening process in *Environment Protection and Biodiversity Act* (1999) and *NSW Threatened Species Act* 1995.

Fish can be a useful in constructed wetlands. However, careful consideration is required given the suitability of endemic fish species to be sustained in often poor environmental conditions. The NSW Department of Primary Industries provides information on native fish species that may be suitable for wetlands and other water bodies in the local region.

Insectivorous bats have often been proposed as a potential tool in reducing adult mosquito populations. Although these microbats have been shown to eat mosquitoes, there is no evidence that they offer any substantial control of local pest mosquito populations. Some authorities promote the use of "bat boxes" to assist in mosquito control. While these initiatives are greatly beneficial for bat conservation, there should be a clear understanding that installations of these "bat boxes" will not provide, nor substantially contribute to, control of local mosquito populations.

Many small native birds will eat mosquitoes. Again, these birds will not provide complete control over mosquitoes but it is a co-benefit for creating bird-friendly habitats to encourage these species that they will prey on some mosquitoes in the local area.

With regard to proposed new developments, the inclusion of "biological control" strategies for mosquitoes will not significantly mitigate the pest and public health risks of mosquitoes where productive mosquito habitats exist in close proximity. The proposal to introduce native fish to water bodies or the installation of bat/bird boxes, will not provide a reliable nor sustainable approach to mosquito control.

5.7.4 Mosquito traps and other devices

There is a wide variety of commercial mosquito trapping units are available that utilise attractants (e.g. light, heat, carbon dioxide, odour, etc.) to catch and/or kill adult mosquitoes. While many will collect or kill mosquitoes, there is little quantitative evidence that they can reduce nuisance biting impacts or public health risks.

Mosquito traps, such as carbon dioxide baited EVS traps used by Ballina Shire Council as part of the NSW Arbovirus Surveillance and Mosquito Monitoring Program, will effectively collect mosquitoes and provide a reliable measure of local mosquito population abundance and diversity. However, it is not the purpose of these traps to "control" mosquito populations.

The traps with the greatest potential are those that use carbon dioxide as the main attractant, have a relatively high release rate of the gas and incorporate a suction fan to collect mosquitoes. The mode of carbon dioxide generation can vary from the inclusion of dry ice to the conversion of propane and each will differ in the volume of gas released and the relative attractiveness of the trap to mosquitoes.

Trapping units that use light alone to attract mosquitoes (e.g. blue light electrocutors) have been shown to have little impact on nuisance biting rates and often kill many more harmless insects (e.g. moths, beetles) than mosquitoes.

With regard to the new developments, the incorporation of adult mosquito traps as a strategy to mitigate the impacts of mosquitoes is unrealistic. This approach has been proposed internationally with a range of different trap styles and mosquito attractants incorporated into networks of trap. These networks can take various forms, most commonly designed to act as a barrier between sources of pest mosquitoes and human activity/residential dwellings. In situations where this approach has been assessed as providing some reduction in pest impacts, a large number of traps were required to be operated in close proximity. There is likely to be only very specific circumstances where this approach will provide effective control and there is little evidence in Australia that the operation of traps can substantially reduce the activity of mosquitoes in and around dwellings. Beyond the operational constraints, the associated consumable costs, make this strategy impractical.

With regard to proposed new developments, the operation of a network of adult mosquito traps as a means to mitigate the pest and public health risks of mosquitoes is not considered an appropriate strategy in the absence of evidence that new technologies associated with this style of trap (e.g. mode of action, mosquito attractants) have increased effectiveness. However, regardless of demonstrated effectiveness, the financial burden associated with establishment, maintenance, and consumable expenses is likely to mean that this approach is unsustainable.

5.8 Community education

For most people the public health risks associated with mosquitoes may be overlooked. Mosquitoes are generally considered a nuisance. The perception of serious consequences associated with mosquito bites and transmission of mosquito-borne pathogens within the local area is generally not well understood. As mosquitoes will remain a natural part of the environment around the Ballina area, it is important that the community awareness of how best to "live with mosquitoes" and minimise their impacts is actively promoted.

Even in suburbs relatively close to wetland areas, the production of mosquitoes from backyard habitats, especially *Aedes notoscriptus*, can cause considerable nuisance-biting problems. Key habitats for this mosquito are small to medium sized water-holding container. These can be naturally occurring habitats, such as tree holes, water holding plants (e.g. bromeliads and some lilies) or fallen palm fronds. More commonly, they are artificial containers. Almost any structure that can hold water can be a source of mosquitoes, from a discard lid of a soft drink bottle to an unscreened rainwater tank. Bird baths, roof gutters and drains around backyard, pot plant saucers and self-water planters, neglected childrens' toys, and accumulations of buckets, bottles, cans, unused tires and tarpaulin covered trailers or boats can be important sources of mosquitoes. Particularly productive habitats are.

Studies in northern NSW have revealed that there are many barriers to behaviour change in the community when it comes to reducing opportunities for mosquitoes in backyard habitats. These barriers can be diverse and differ between demographics within and between local regions. While there is substantial ignorance or indifference of the issue among some, others may be aware of the issue but actively choose not to change behaviour. Some individuals are actively hoarding water around the home to assist maintenance of gardens or to provide water for pest or wildlife. Others have expressed uncertainty as to where exactly mosquitoes are breeding and what exactly to do to prevent them. Others, especially older residents, are physically unable to undertake the sometimes strenuous task of moving or emptying medium to large containers.

Personal protection measures can reduce the risks of mosquito-borne disease by preventing mosquito bites or by reducing the activity of mosquitoes in and around the home. This approach of raising awareness of public health risks associated with mosquitoes, together with encouraging behavior that reduces exposure to mosquitoes is critical to mosquito-borne disease management by health authorities across Australia and apply equally to the Ballina Shire Council region.

The use of personal insect repellents is the first line of defense against biting mosquitoes and, consequently, mosquito-borne disease. A wide range of formulations, including aerosols, creams, lotions, and pump sprays are registered for use in Australia by the APVMA. However, regardless of the formulation, the most effective products are those that contain DEET (diethyltoluamide or N,N-diethyl-3-methylbenzamide) and Picaridin, two chemicals known to be effective insect repellents and widely available in commercial formulations. As well as DEET and picaridin, there is another product that may provide effective protection against biting insects. Registered in Australia as “extract of lemon eucalyptus being a modified acid of *Corymbia citriodora*”), PMD is not an essential oil product but rather a chemical derived from the distillation of the lemon eucalyptus plant. These products have been proven to be effective against a range of Australian mosquitoes and very few adverse health impacts have been reported internationally when used as recommended.

In addition to topical mosquito repellents, there is a range of products including to coils, sticks and other ‘burner’ devices that purport to repel mosquitoes. Mosquito coils and sticks that contain insecticides generally provide better protection than those containing plant-derived products. It is also important that care is taken when using mosquito coils inside the house or in confined spaces as the prolonged exposure to the smoke from these products is recommended to be avoided.

There are “smokeless” products increasingly available that are impregnated with an insecticide (usually a pyrethroid) that is released when heated, either by burning (coils and sticks), heated by a small electrical unit (vaporising mat) or dispersed by a battery operated fan (clip-on devices). These products are generally designed for indoor or sheltered outdoor areas and should be used as directed. There is an increasing interest in “spatial repellents” internationally and it is likely a greater number of these products will be available locally in the near future.

Mosquito repellent wrist bands often intrigue with the prospect of avoiding the application of topical repellents. However, studies have shown these products do not provide adequate protection against mosquitoes and, if worn on the wrist, will certainly not stop mosquito bites elsewhere on the body. These should not be recommended, even though some products are currently registered with the APVMA.

The promotion of public health messages raising awareness of the pest and public health threats associated with mosquitoes is a key component of mosquito-borne disease management programs around Australia. There is a standard suite of fact sheets that contain generic warnings of mosquito-borne disease (as relevant to the local region) and recommended steps to avoid mosquito bites provided by Ballina Shire Council and informed by information provided by NSW Health. This information is used for content to create flyers, brochures, posters, newspaper advertisements, websites and other printed/online material. This material is then augmented by specific media releases/health warnings from Ballina Shire Council, Lismore Public Health Unit (Northern NSW LHD), or NSW Health. The timing of these media releases/warnings are typically decided by local authorities based on data from mosquito, mosquito-borne pathogen or human disease surveillance data.

Coverage in local media remains an important line of communication with the community but new technologies are assisting with this task. Various social media platforms (e.g. Ballina Shire Council Facebook page) are helping target local communities with advice on how best to avoid mosquito bites. This is important as local community groups, or specific demographics in the local area, may be more exposed to elevated mosquito risks. Fishing, boating, bushwalking, and birdwatching groups may be more likely to be in close proximity to productive mosquito habitats. For these groups, mosquito awareness material could be included with activity specific material produced by local authorities (e.g. tide charts, bird watching guide, and bushwalking track maps). For high risk areas, temporary or permanent warning signs could be installed in the local area (e.g. in bird hides, boat ramps, next to interpretive signage). Sporting groups may also be exposed to increased mosquito risk. Golf courses and sporting fields adjacent to wetlands may be more prone to impact from mosquitoes, this is especially the case for summer sports or the early season training groups for winter sports.

One-off or seasonal activities could also be a focus. Music festivals, night markets, open air cinemas, and other activities that involve large congregations of people in areas adjacent to productive mosquito habitats could be targeted. The organisers of these events, often local authorities, have a choice to provide information on suitable personal protection measures or may offer free insect repellent in the same way free sunscreen may be offered at daytime events.

Consideration should also be given to community groups, organisations or companies undertaking outdoor work where there may be a risk of mosquitoes. Volunteer bushcare or community clean up groups or companies involved in bushcare are likely to have exposure to mosquitoes. Identification and engagement with these groups would be useful to recommend appropriate personal protection measures. Similarly, those working on roadwork or building projects close to wetlands may be similarly exposed. The key to better communications with the community is the identification of specialist groups that may appreciate information on mosquito bite prevention.

6. REFERENCES & FURTHER READING

Byun R and Webb CE. (2012) Guidelines for mosquito risk assessment and management in constructed wetlands. Western Sydney Local Health District, NSW Health.

Carlson, D.B., Dale, P.E., Kurucz, N., Dwyer, P.G., Knight, J.M., Whelan, P.I. and Richards, D.D., 2019. Mosquito control and coastal development: How they have coexisted and matured in Florida and Australia. *Journal of the American Mosquito Control Association*, 35(2), pp.123-134.

Dale, P.E., Knight, J.M. and Daniels, P.L., 2018. Using present value as a simple approach to compare mosquito larval control methods. *Journal of the American Mosquito Control Association*, 34(1), pp.25-33.

Dale, P.E.R. & Hulsman, K. (1990) A critical review of salt marsh management methods for mosquito control. *Aquatic Science*, 3: 281-311.

Dwyer, P.G., Knight, J.M. and Dale, P.E.R., 2016. Planning development to reduce mosquito hazard in coastal peri-urban areas: case studies in NSW, Australia. In Balanced urban development: options and strategies for liveable cities (pp. 555-574). Springer, Cham.

Faraji, A. and Unlu, I., 2016. The eye of the tiger, the thrill of the fight: effective larval and adult control measures against the Asian tiger mosquito, *Aedes albopictus* (Diptera: Culicidae), in North America. Journal of Medical Entomology, 53(5), pp.1029-1047.

Fradin, M.S. & Day J.F. (2002) Comparative efficacy of insect repellents against mosquito bites. *The New England Journal of Medicine*. 347: 13-18.

Gilles, M., Galloway, D., Horwitz, P. and Larson, A., 2004. Reintegrating coastal development and public health in Western Australia. EcoHealth, 1(4), pp.340-350.

Glasgow, K.M., Bateman-Steel, C.R., Pope, B. and Ferson, M.J., 2018. The right kind of viral: boosted Facebook advertisements for health protection messages. *The Medical Journal of Australia*, 209(10), p.447.

Hanford, J.K., Webb, C.E. and Hochuli, D.F., 2019. Habitat traits associated with mosquito risk and aquatic diversity in urban wetlands. Wetlands, pp.1-16.

Hanford, J.K., Hochuli, D.F. and Webb, C.E., 2019. Oviposition behavior of *Culex annulirostris* (Diptera: Culicidae) is affected by the recent presence of invasive *Gambusia holbrooki* (Cyprinodontiformes: Poeciliidae). Journal of Medical Entomology, 56(4), pp.1165-1169.

Hunter G. (2003) Wetlands for stormwater management: water, vegetation and mosquitoes – a recipe for concern. In: Waterplants in Australia: A field guide (Sainty, G and Jacobs S). Sainty and Associates, Potts Point, Australia

Jardine, A., Neville, P.J. and Lindsay, M.D., 2015. Proximity to mosquito breeding habitat and Ross River virus risk in the peel region of Western Australia. Vector-Borne and Zoonotic Diseases, 15(2), pp.141-146.

Johnson, B.J., Manby, R. and Devine, G.J., 2020. What happens on islands, doesn't stay on islands: Patterns of synchronicity in mosquito nuisance and host-seeking activity between a mangrove island and adjacent coastal development. Urban Ecosystems, https://doi.org/10.1007/s11252-020-00998-0.

Kline, D.L., 2006. Traps and trapping techniques for adult mosquito control. Journal of the American Mosquito Control Association, 22(3), pp.490-497.

Lamichhane, R.S., Neville, P.J., Oosthuizen, J., Clark, K., Mainali, S., Fatouros, M. and Beatty, S., 2017. The highs and lows of making a bucket list—quantifying potential mosquito breeding habitats in metropolitan backyards. Frontiers in Public Health, 5, p.292.

Lawler, S.P., Jensen, T., Dritz, D.A. & Wichterman, G. (1999) Field efficacy and nontarget effects of the mosquito larvicides temephos, methoprene and *Bacillus thuringiensis* var. *israelensis* in Florida Mangrove Swamps. *Journal of the American Mosquito Control Association*, 15: 446-452.

Lawler, S.P. (2017) Environmental safety review of methoprene and bacterially-derived pesticides commonly used for sustained mosquito control. *Ecotoxicology and Environmental Safety*, 139, pp.335-343.

Lowe, E.C., Latty, T., Webb, C.E., Whitehouse, M.E. and Saunders, M.E., Engaging urban stakeholders in the sustainable management of arthropod pests. *Journal of Pest Science*, pp.1-16.

McGinn, D., Frances, S.P., Sweeney, A.W., Brown, M.D. and Cooper, R.D., 2008. Evaluation of Bistar 80SC (bifenthrin) as a tent treatment for protection against mosquitoes in Northern Territory, Australia. Journal of Medical Entomology, 45(6), pp.1087-1091.

Mosquito Control Association of Australia Inc. (2009) *Australian Mosquito Control Manual*. Mosquito Control Association of Australia.

Muller, M. & McGinn, D. (1997) Saltmarsh mosquito control – towards best practice. *Arbovirus Research in Australia*, 7: 194-196.

Mwebaze, P., Bennett, J., Beebe, N.W., Devine, G.J. and De Barro, P., 2018. Economic valuation of the threat posed by the establishment of the Asian Tiger Mosquito in Australia. *Environmental and Resource Economics*, 71(2), pp.357-379.

Pollard, E.J., Russell, T.L. and Burkot, T.R., 2019. Maximising mosquito collections from barrier screens: the impacts of physical design and operation parameters. Parasites & Vectors, 12(1), p.31.

Ramírez, A.L., van den Hurk, A.F., Meyer, D.B. and Ritchie, S.A., 2018. Searching for the proverbial needle in a haystack: advances in mosquito-borne arbovirus surveillance. *Parasites & Vectors*, 11(1), p.320.

Ratnayake, J., Dale, P.E., Sipe, N.G. and Daniels, P., 2006. Impact of biting midges on residential property values in Hervey Bay, Queensland, Australia. Journal of the American Mosquito Control Association, 22(1), pp.131-134.

Russell, R.C. (1990). *Mosquitoes and Mosquito-Borne Disease in Southeastern Australia*. Published by the Department of Medical Entomology, Westmead Hospital and the University of Sydney. 306pp.

Russell, R.C. (1998) Mosquito-borne Arboviruses in Australia: The current scene and implications of climate change for human health. *International Journal of Parasitology*, 28: 995-969.

Russell R.C. (2009) Mosquito-borne disease and climate change in Australia: time for a reality check. *Australian Journal of Entomology*, 48: 1-7.

Russell RC. (1999) Constructed wetlands and mosquitoes: Health hazards and management options – An Australian perspective. Ecological Engineering, 12: 107-124.

Russell RC (2001) Constructed wetlands in Australia: Concerns & constraints, compromises & complements for effective mosquito management. Arbovirus Research in Australia, 8: 314-323.

Russell RC and Kuginis L. (1998). Mosquito risk assessment and management. In: The Constructed Wetlands Manual. NSW Department of Land and Water Conservation (Young R, White G, Brown M, Burton J, Atkins B, eds) Volume 1: 181-191.

Russell, T. and Kay, B. (2008) Biologically based insecticides for the control of immature Australian mosquitoes: a review. *Australian Journal of Entomology*, 47: 232-242.

Stephenson, E.B., Peel, A.J., Reid, S.A., Jansen, C.C. and McCallum, H., 2018. The non-human reservoirs of Ross River virus: a systematic review of the evidence. *Parasites & Vectors*, 11(1), p.188.

Tai, A.Y., Athan, E., Friedman, N.D., Hughes, A., Walton, A. and O'Brien, D.P., 2018. Increased Severity and Spread of *Mycobacterium ulcerans*, Southeastern Australia. *Emerging Infectious Diseases*, 24(1), p.58.

Toi, C.S., Webb, C.E., Haniotis, J., Clancy, J. and Doggett, S.L., 2017. Seasonal activity, vector relationships and genetic analysis of mosquito-borne Stratford virus. *PloS One*, 12(3), p.e0173105.

Tomerini, D.M., Dale, P.E. and Sipe N. (2011) Does mosquito control have an effect on mosquito-borne disease? The case of Ross River virus disease and mosquito management in Queensland, Australia. *Journal of the American Mosquito Control Association*, 27: 39-44.

Trout, R.T., Brown, G.C., Potter, M.F. and Hubbard, J.L., 2007. Efficacy of two pyrethroid insecticides applied as barrier treatments for managing mosquito (Diptera: Culicidae) populations in suburban residential properties. Journal of medical entomology, 44(3), pp.470-477.

Vally, H., Peel, M., Dowse, G.K., Cameron, S., Codde, J.P., Hanigan, I., and Lindsay M.D.A. (2012). Geographic information systems used to describe the link between the risk of Ross River virus infection and proximity to the Leschenault estuary, WA. *Australian and New Zealand Journal of Public Health* 36, 229-235.

van den Hurk, A.F., Hall-Mendelin, S., Johasen, C.A., Warrilow, D, Ritchie, S.A. (2012). Evolution of mosquito-based arbovirus surveillance systems in Australia. *Journal of Biomedicine and Biotechnology* doi: 10.1155/2012/325659

Walker, L.J., Selvey, L.A., Jardine, A., Johansen, C.A. and Lindsay, M.D., 2018. Mosquito and virus surveillance as a predictor of human Ross River virus infection in south-west Western Australia: how useful is it? The American Journal of Tropical Medicine and Hygiene, 99(4), pp.1066-1073.

Walsh, M.G. and Webb, C., 2018. Hydrological features and the ecological niches of mammalian hosts delineate elevated risk for Ross River virus epidemics in anthropogenic landscapes in Australia. *Parasites & Vectors*, 11(1), p.192.

Webb, C.E. (2015) Are we doing enough to promote the effective use of mosquito repellents? *The Medical Journal of Australia*, 202(3), pp.128-129.

Webb, C.E. and Russell, R.C., 2019. Dispersal of the mosquito *Aedes vigilax* (Diptera: Culicidae) from urban estuarine wetlands in Sydney, Australia. Journal of Medical Entomology, 56(5): 1290–1295.

Webb, C.E. and Hess, I.M. (2016) A review of recommendations on the safe and effective use of topical mosquito repellents. *Public Health Research & Practice*, 26(5): e2651657.

Webb, C.E., Doggett S.L. and Russell R.C. (2016) A guide to the mosquitoes of Australia. CSIRO Publishing, Clayton South, Australia.

Webb, C.E. & Russell, R.C. (2001) Do we spray? Did it work? Indices for control of *Aedes vigilax* larvae in Homebush Bay. *Arbovirus Research in Australia*, 8: 387-390.

Webb CE (2013) Managing mosquitoes in coastal wetlands. In Paul S (ed) Workbook for managing urban wetlands in Australia, 1st edn. Sydney Olympic Park Authority, Sydney, Australia, pp 321-340

Webb CE. (2013) Managing mosquitoes in constructed freshwater wetlands. In. 'Workbook for managing urban wetlands in Australia' (Ed. S. Paul) 1st edn. (Sydney Olympic Park Authority) ISBN 978-0-9874020-0-4

Whelan, P. (1997) Guidelines for preventing biting insect problems for urban residential developments or subdivisions in the top end of the Northern Territory. Territory Health Services.

Willems, K.J., Webb C.E. & Russell, R.C. (2005) A comparison of mosquito predation by the fish *Pseudomugil signifer* Kner and *Gambusia holbrooki* (Girard) in laboratory trials. *Journal of Vector Ecology*, 30: 87-90.

7. SUMMARY OF ADULT MOSQUITO SAMPLING IN BALLINA SHIRE COUNCIL, 2009-2010 THROUGH 2018-2019

Table 7.1. Total mosquitoes collected at the Ballina trap site, Ballina Shire Council, as part of the NSW Arbovirus Surveillance and Mosquito Monitoring Program, 2009-2019.

Week of Season	2018-2019	2017-2018	2016-2017	2015-2016	2014-2015	2013-2014	2012-2013	2011-2012	2010-2011	2009-2010
Ae. aculeatus	0	0	24	4	25	0	15	3	1	3
Ae. alternans	126	141	352	63	335	42	43	39	7	80
Ae. burpengaryensis	1	0	19	2	2	2	17	8	2	0
Ae. gahnicola	0	0	0	0	2	0	0	2	0	0
Ae. kochi	12	4	16	12	5	1	2	3	4	0
Ae. lineatopennis	0	0	0	0	1	0	0	0	0	0
Ae. multiplex	25	127	805	195	2544	7	29	7	53	51
Ae. notoscriptus	251	564	651	610	567	727	927	1889	1554	938
Ae. procax	1	8	390	8	214	6	30	10	38	14
Ae. quasirubithorax	0	0	13	3	2	0	0	0	0	0
Ae. sp. Marks 51	0	0	1	0	0	0	0	0	0	0
Ae. tremulus	0	0	1	0	0	0	0	0	0	0
Ae. vigilax	429	212	1349	33	165	202	140	245	80	552
Ae. vittiger	0	0	4	0	1	0	0	0	0	0
An. annulipes	1	7	1	2	27	1	1	5	3	0
Cq. linealis	42	40	2	192	9	0	11	270	139	9
Cq. variegata	0	4	2	13	127	0	0	253	5	1
Cq. xanthogaster	25	252	26	2231	211	4	27	1847	997	15
Cs. antipodea	0	0	0	0	0	0	0	1	0	0
Cx. annulirostris	103	121	803	248	1628	20	299	263	186	83
Cx. australicus	2	0	155	2	4	5	4	2	2	0
Cx. bitaeniorhynchus	0	0	0	0	5	0	1	0	0	0
Cx. edwardsi	0	0	1	3	333	0	3	1	4	0
Cx. halifaxii	0	0	0	0	0	0	10	0	0	0
Cx. orbostiensis	7	128	136	439	1044	5	177	58	239	48
Cx. postspiraculosus	0	0	0	0	1	0	0	0	1	0
Cx. pullus	0	0	0	0	0	0	0	0	0	0
Cx. quinquefasciatus	2	15	12	3	1	2	0	6	0	5
Cx. sitiens	4198	1904	7106	2861	1258	2740	967	1231	320	1633
Cx. sp. Marks No. 32	0	0	0	9	3	0	0	0	3	3
Cx. squamosus	0	1	2	2	13	0	5	16	8	1

Ho. cairnsensis	0	0	0	0	0	0	0	0	0	1
Ma. uniformis	17	23	1	258	79	0	0	61	656	0
Mi. elegans	0	0	1	0	3	0	0	0	0	0
Tp. marksae	0	0	0	1	1	1	0	0	0	0
Ur. lateralis	58	30	0	0	34	0	11	1	1	1
Ur. nivipes	0	0	0	0	0	0	0	0	0	0
Ur. pygmaea	0	0	0	0	0	0	0	0	0	0
Ve. funerea	977	1734	2250	1704	2300	829	2927	3575	2224	2978
Ve. sp. Marks No. 52	0	1	5	0	104	0	9	100	9	0
Weekly Totals	6282	5319	14159	8922	11125	4594	5674	9961	6665	6437

Table 7.2. Total mosquitoes collected at the Lennox Head trap site, Ballina Shire Council, as part of the NSW Arbovirus Surveillance and Mosquito Monitoring Program, 2009-2019.

Week of Season	**2018-2019**	**2017-2018**	**2016-2017**	**2015-2016**	**2014-2015**	**2013-2014**	**2012-2013**	**2011-2012**	**2010-2011**	**2009-2010**
Ae. aculeatus	0	1	3	0	64	5	44	1	0	0
Ae. alternans	243	130	58	3	319	30	33	0	1	91
Ae. burpengaryensis	2	0	12	0	23	0	2	1	0	0
Ae. gahnicola	0	0	0	0	0	0	0	0	0	0
Ae. kochi	1	13	3	13	8	0	8	0	2	1
Ae. lineatopennis	0	0	0	0	0	0	0	0	0	0
Ae. multiplex	2200	3630	4577	4058	4344	345	288	260	210	276
Ae. notoscriptus	11	38	70	67	466	31	72	1	9	1
Ae. procax	114	47	685	142	352	8	157	25	34	74
Ae. quasirubithorax	3	0	0	0	5	0	0	0	0	0
Ae. sp. Marks 51	0	1	5	0	0	0	0	2	0	0
Ae. tremulus	0	0	0	0	1	0	0	0	0	0
Ae. vigilax	776	67	517	15	204	413	92	10	5	93
Ae. vittiger	0	1	0	0	3	0	0	0	0	0
An. annulipes	1	12	0	10	34	0	3	7	6	2
Cq. linealis	6	76	5	377	19	3	20	160	187	3
Cq. variegata	9	71	18	49	112	1	104	12	59	5
Cq. xanthogaster	155	435	8	1219	144	18	35	762	841	32
Cs. antipodea	0	0	0	1	2	0	0	0	1	0
Cx. annulirostris	106	223	240	77	1020	29	335	101	321	33
Cx. australicus	0	0	17	1	6	0	1	0	0	0
Cx. bitaeniorhynchus	3	1	1	2	12	0	6	0	7	0
Cx. edwardsi	6	317	0	18	159	31	43	34	128	7
Cx. halifaxii	0	0	0	0	0	0	3	0	3	1
Cx. orbostiensis	48	621	180	1165	1488	15	832	137	813	56
Cx. postspiraculosus	0	1	0	0	0	0	0	0	0	0
Cx. pullus	0	0	0	0	1	0	0	0	0	0
Cx. quinquefasciatus	0	2	0	0	1	0	0	0	0	0
Cx. sitiens	2971	3025	3251	680	2765	1867	611	81	72	217
Cx. sp. Marks No. 32	0	0	0	5	7	1	0	0	0	0
Cx. squamosus	0	6	1	5	18	0	25	23	50	0
Ho. cairnsensis	0	0	0	0	1	0	0	0	0	0
Ma. uniformis	61	31	27	159	110	77	41	73	582	39
Mi. elegans	2	0	2	0	1	1	1	0	0	0

Tp. marksae	0	0	0	0	0	0	0	0	0	0
Ur. lateralis	54	28	6	11	42	1	2	0	0	0
Ur. nivipes	0	1	0	1	0	0	0	0	0	1
Ur. pygmaea	1	0	0	0	5	0	0	0	0	0
Ve. funerea	4653	1996	1589	1852	2048	937	1351	826	2446	87
Ve. sp. Marks No. 52	6	3	16	29	704	0	8	2	9	0
Weekly Totals	11595	10993	11308	9970	14540	3816	4127	2530	5814	1026

8. SUMMARY OF ROSS RIVER AND BARMAH FOREST VIRUS DISEASE REPORTED IN NORTHERN NSW, 2001 THROUGH 2018

Table 8.1. Total number of human notifications of Ross River virus disease between 2001 and 2018 for Northern NSW. Data provided by NSW Health Notifiable Conditions Information Management System (NCIMS), Communicable Diseases Branch and Centre for Epidemiology and Evidence, NSW Health.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2001	8	6	22	26	33	9	2	3	1	3	3	2	118
2002	2	2	3	4	6	4	0	0	2	0	0	0	23
2003	0	5	12	68	123	39	12	4	1	4	5	3	276
2004	4	1	31	56	45	6	1	3	0	1	6	2	156
2005	4	4	30	14	16	3	4	4	3	4	4	5	95
2006	3	36	125	60	22	8	5	2	0	1	3	1	266
2007	2	8	10	9	14	7	8	6	3	9	6	8	90
2008	15	33	48	22	9	6	9	6	8	5	8	7	176
2009	7	4	4	16	62	45	20	12	6	9	8	3	196
2010	7	3	18	39	34	15	2	4	3	10	10	11	156
2011	1	3	13	28	11	7	1	6	4	3	4	8	89
2012	3	10	12	25	14	8	2	2	5	5	8	6	100
2013	6	10	9	23	28	7	6	6	8	2	11	4	120
2014	3	2	13	6	15	12	3	7	5	16	14	18	114
2015	29	137	155	63	27	6	7	4	8	8	10	9	463
2016	6	6	15	15	16	11	2	2	1	2	6	6	88
2017	11	13	6	15	41	31	8	5	7	5	4	5	151
2018	5	10	8	11	9	5	5	2	2	1	1	2	61

Table 8.2. Total number of human notifications of Barmah Forest virus disease between 2001 and 2018 for Northern NSW. Data provided by NSW Health Notifiable Conditions Information Management System (NCIMS), Communicable Diseases Branch and Centre for Epidemiology and Evidence, NSW Health.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2001	2	8	9	13	31	8	10	5	3	3	4	4	100
2002	5	5	8	4	5	8	0	2	3	1	3	1	45
2003	7	7	9	51	98	34	19	9	6	13	7	4	264
2004	11	12	14	18	6	6	7	8	6	5	12	11	116
2005	10	11	10	15	21	7	6	5	5	8	10	6	114
2006	10	11	18	27	22	11	5	4	4	10	7	5	134
2007	13	8	7	17	13	5	6	8	3	11	10	11	112
2008	13	25	44	31	15	6	6	10	9	7	16	8	190
2009	11	13	12	9	14	9	5	6	6	5	9	14	113
2010	9	2	9	8	12	5	4	2	6	7	13	9	86
2011	25	14	27	5	12	10	14	9	6	10	14	7	153
2012	10	18	22	13	12	10	10	8	11	13	16	6	149
2013	11	20	24	24	26	13	13	16	13	10	14	7	191
2014	5	5	7	2	4	8	2	1	1	2	0	1	38
2015	2	4	15	18	9	6	3	4	3	5	1	2	72
2016	3	3	1	2	4	1	1	3	0	0	0	2	20
2017	2	0	3	3	8	9	5	9	6	2	7	2	56
2018	4	5	3	4	2	2	2	3	4	2	3	1	35

9. CHECKLIST OF CONSIDERATIONS WHEN DEVELOPING A MOSQUITO RISK ASSESSMENT FOR PROPOSED DEVELOPMENTS

Consideration	Notes
1. Type of development	▪ Does the development hold potential for bringing the community (inc. residents, visitors, workers) into greater contact with mosquitoes? ▪ Does the development’s intended purpose exposure relatively vulnerable individuals to mosquitoes? For example, seniors housing (aged care facilities), child care centres, and respite day care centres ▪ Is the development likely to expose individuals to high mosquito risk where previous awareness of the health risks associated with mosquitoes, and adequate personal protection measures, may not exist? For example, tourist and visitor accommodation ▪ Does the proposed development include any stormwater treatment devices or other water features? For example, elements of water sensitive urban design or green infrastructure
2. Location of proposed development	▪ Is the proposed development within the “Coastal Plains and Lowlands” or “High Mosquito Risk Area” as identified in the Ballina Shire Council Mosquito Management Map? ▪ Is the proposed development in close proximity to any known productive mosquito habitats within the “Elevated Lands” as identified in the Ballina Shire Council Mosquito Management Map?
3. Local mosquito habitats	▪ Are there known or suspected estuarine mosquito habitats (e.g. saltmarsh, mangroves) located in close proximity (approximately 1km) of the proposed development? ▪ Are there known or suspected brackish-water mosquito habitats (e.g. coastal swamp forest, she-oak woodland) located in close proximity (approximately 100m) of the proposed development? ▪ Are there known or suspected pest mosquito habitats within the footprint of the proposed development?
4. Local mosquito populations	▪ Is there any available information on the abundance and diversity of mosquitoes founding within the proposed development or habitats within close proximity (approximately 1km)? ▪ Are there known abundant pest mosquito populations reported from within the proposed development?
5. Pest and public health risks	▪ Are there records of complaints to Ballina Shire Council prompted by nuisance-biting associated with mosquitoes within the proposed development area or those in moderate proximity (approximately 3km) ▪ Are there any confirmed locally acquired cases of mosquito-borne disease within the proposed development area or moderate proximity (approximately 3km) ▪ Are there known or suspected populations of macropods (e.g. kangaroos and wallabies) or substantial water bird populations within close proximity (approximately 3km) of the proposed development?
6. Changes to local mosquito habitats during and/or following development	▪ Are there known or suspected mosquito habitats within the footprint of the proposed development that will be removed, retained, or rehabilitated? ▪ Does the proposed development include any stormwater treatment devices or other water features?

	▪ Does the proposed development include any stormwater treatment devices or other water features designed to retain water for more than 48h (e.g. gross pollutant traps, constructed wetlands, rainwater tanks) and have they been designed and assessed by a suitably qualified entomologist? ▪ Is there expected to be substantial areas of terrestrial vegetation retained or revegetated within the footprint of the proposed development? ▪ Has local mosquito risk been clearly identified in relevant plans of management for the proposed development? For example, terrestrial and aquatic vegetation, stormwater treatment devices and other water features ▪ Has the impact of the proposed development on the suitability and productivity of surrounding habitats for mosquitoes been satisfactorily assessed? For example, do stormwater discharge points, surface flows, or other changes to local hydrology enhance conditions for the production of pest mosquitoes in surrounding habitats
7. Proposed development layout and building design	▪ Does the layout of the proposed development allow for a “mosquito hazard reduction” buffer zone of at least 100m and containing sparse and low growing vegetation between residential allotments and known or suspected productive brackish-water mosquito habitats (e.g. coastal swamp forest, she-oak woodland) ▪ Is the “mosquito hazard reduction” buffer zone clearly indicated on the final plan of management for the proposed development, clearly differentiating this zone from other environmental protection and asset protection zones? ▪ Does the building/dwelling design incorporate the appropriate requirements regarding provision of insect screens fitted to windows, doors, and balconies? ▪ Are suitably screened outdoor areas provided for development types including seniors housing (aged care facilities), child care centres, and respite day care centres?
8. Mosquito risk assessment	▪ Has a formal “mosquito risk assessment” or “biting insect risk assessment” been undertaken for the proposed development by a suitably qualified entomologist? ▪ Has there been specific mosquito habitats and mosquito population sampling undertaken in the preparation of a mosquito risk assessment? Has appropriate reference been made to existing mosquito and mosquito-borne disease data provided by Ballina Shire Council and/or NSW Health? ▪ Have all aspects of the proposed development and surrounding habitats been assessed with reference to current and future risks associated with pest and public health concerns of local mosquitoes? ▪ Have all relevant plans been cross checked and referenced in the final mosquito risk assessment report submitted with development application to Ballina Shire Council?

10. GUIDE TO EVALUATION OF MOSQUITO RISK ASSESSMENT REPORTS ACCOMPANYING PROPOSED DEVELOPMENTS

The following a recommended guide for Ballina Shire Council staff to assist in the assessment of mosquito risk assessment reports submitted in conjunction with new development proposals. It is noted that there may be unique aspects to specific development types and locations that may necessitate additional considerations.

1. **Qualifications of entomologist:**

- Brief summary of qualifications and relevant experience with regard to providing mosquito risk assessment? Provision of brief curriculum vitae required
- Member of the Mosquito Control Association of Australia?
- Member of the American Mosquito Control Association?
- A member of any other international mosquito/vector control associations?
- Has consultant entomologist participated in any professional development activities over past three years?

2. **Demonstrated understanding of local mosquito populations and associated health risks:**

- Has consultant report cited relevant components of the Ballina Shire Council Development Control Plan (Mosquito Management) as they relate to proposed development type?
- Has the consultant report acknowledged the existing data provided through the NSW Arbovirus Surveillance and Mosquito Monitoring Program (Environmental Health Protection, NSW Health)?
- Has the consultant presented human notification data for Ross River virus disease and Barmah Forest virus disease in the Northern NSW Local Health District (NSW Health Notifiable Conditions Information Management System (NCIMS), Communicable Diseases Branch and Centre for Epidemiology and Evidence, NSW Health)?

3. **Assessment of local mosquito populations and their habitats:**

- Has the consultant undertaken mosquito sampling related to the proposed development?
- Over what time period (i.e. dates) was mosquito sampling undertaken?
- If the consultant has not undertaken mosquito sampling during the preferred period between November and March, have they provided justification for these date selections and relevance of data collected.
- Has the consultant provided information on prevailing environmental conditions (for example, temperature, rainfall, and tides) and relevant influence on local mosquito populations at the time of assessment and relevance to existing data and assessment of mosquito risk?
- How many trap sites and on how many occasions were adult mosquitoes collected?
- What types of traps did the consult use?
- If the consultant did not use Encephalitis Virus Surveillance (EVS) styled traps (as used by Ballina Shire Council in the NSW Arbovirus Surveillance and Mosquito Monitoring Program), have they provided sufficient information to allow a comparison between the data collected as part of the Mosquito Risk Assessment and existing mosquito abundance and diversity data?
- Does the consultant report present all mosquito trapping data, including the abundance of all mosquito species collected at each trap site and collection date?

- Has the consultant undertaken a habitat assessment of the proposed development site, including both on and offsite habitats? Are maps provided in the mosquito risk assessment report clearly identifying the identified mosquito habitats and relative productivity (e.g. low, moderate, high risk)?
- Has the consultant undertaken larval mosquito sampling as part of the risk assessment of the proposed development? Is the location of sampling sites and data collected presented in the report?
- Has the consultant provided an assessment of key actual and potential mosquito habitats within 3km radius of the proposed development site? (this enables assessment of both *Aedes vigilax* and *Verrallina funerea* populations)
- Has the consultant provided an assessment of potential change to mosquito habitats within and adjacent to the proposed development site as a result of changes to stormwater discharge, surface runoff, or other hydrological considerations?

4. Assessment of proposed development layout and building design:

- Does the mosquito risk assessment cross reference the most recent proposed development's plan of management including specific management plans for stormwater, vegetation, and site layout?
- Does the mosquito risk assessment provide assessment on building design, with specific comment on the provision of screened windows, doors, and other openings to dwellings?
- Does the mosquito risk assessment discuss the appropriateness of providing outdoor screened recreational areas as relevant to specific development types?
- Does the mosquito risk assessment discuss the provision of "mosquito hazard reduction" buffer zones and their vegetation composition? Are "mosquito hazard reduction" buffers clearing identified in the mosquito risk assessment with reference to other environmental and asset protection zones?
- Does the mosquito risk assessment address retention and revegetation plans within the proposed development with reference for these areas to provide refuge for adult mosquitoes and/or facilitate movement of mosquitoes from adjacent habitats and development?
- Does the mosquito risk assessment address planting guides for parklands and residential allotments with specific recommendations regarding plants that may provide refuge or mosquitoes or water-holding plants (e.g. bromeliads) that may ne a source of mosquitoes?

5. Stormwater infrastructure, other water bodies and green infrastructure

- Does the mosquito risk assessment state that the entomologists has been involved in the design of stormwater management devices, other water bodies, and/or relevant aspects of green infrastructure? Aspects such as the design include size, depth, batters, inflow/outflow devices, vegetation plans (where required), and maintenance considerations.
- Does the mosquito risk assessment provide evidence, including reference to relevant plans, that proposed stormwater devices will not retain water for more than 48h?
- For stormwater devices and other water bodies that are designed to retain water for more than 48h, does the mosquito risk assessment provide an assessment of potential mosquito risk and concomitant recommendations to minimise or mitigate those risks?
- Does the mosquito risk assessment make reference to operational considerations (e.g. heavy machinery access) for stormwater infrastructure maintenance and, if required, mosquito control activities?

- Does the mosquito risk assessment propose a schedule for assessment of any revised plans related to stormwater infrastructure and/or inspection of final constructed devices/water bodies?

6. Assessment of relevant maintenance plans

- Does the mosquito risk assessment identify roles and responsibilities for the maintenance of "mosquito hazard reduction" buffer zones? Where multiple responsibilities exist (e.g. private, Ballina Shire Council, other state or federal authorities) are recommendations in place to ensure vegetation is maintained in a condition to satisfactorily sustain the utility of the zones.
- Does the mosquito risk assessment reference the inclusion of mosquito and mosquito habitat considerations in maintenance plans for stormwater, other water bodies, green infrastructure, and onsite vegetation. This may include mosquito-specific monitoring of habitats where relevant.