Mosquito Management Plan
Byron Shire Council

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Front cover photograph: Adult female *Aedes procax*, a species associated with coastal swamp habitats (courtesy S. Doggett).

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All photographs used in this document have been taken by members of staff from the Department of Medical Entomology, University of Sydney and Westmead Hospital, including Dr. Cameron E Webb and Mr. Stephen L Doggett.

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1 EXECUTIVE SUMMARY

Byron Shire provides suitable habitat for over 60 species of mosquito but relatively few pose a serious threat to the community. However, there are major pest species associated with coastal swamp and estuarine wetland environments, as well as backyard habitats, that have the potential to cause serious nuisance-biting impacts and may transmit Ross River virus (RRV) and/or Barmah Forest virus (BFV).

Given the diversity of the mosquito habitats within the region, combined with the fact that many important habitats fall within areas managed by the National Parks and Wildlife Service (NPWS), broadscale mosquito control is not a viable strategy for mosquito management by Byron Shire Council. The most cost effective and sustainable strategies are the development of a mosquito awareness program and informed urban planning strategies supported by an ongoing mosquito monitoring program.

Maintaining Byron Shire Council's involvement in NSW Health's Arbovirus Surveillance and Mosquito Monitoring Program will provide reliable information on local risks posed by changes in the abundance of pest mosquitoes and the activity of RRV and BFV. Local monitoring data, together with data shared with other local councils will provide an "early warning" system of increased mosquito activity and elevated risks of mosquito-borne disease.

Much of the increased risk of mosquito-borne disease in coastal NSW can be attributed to the encroachment of urban development close to productive mosquito habitats. Byron Shire Council should consider amending Draft DCP – Chapter B7 Mosquito and Biting Midge Controls to ensure conformance with the current management plan. Such a planning instrument would allow Byron Shire Council to highlight problems of mosquitoes and biting midges in the local area and provide guidelines for new developments to minimise exposure to mosquito risk and reduce any onsite mosquito production.

While it is unlikely that Byron Shire will experience an increased risk of mosquito-borne disease as a direct result of predicted climate change, future public health risks within the region may be influenced by the introduction of dengue mosquitoes (e.g. *Aedes aegypti* or *Aedes albopictus*). Should either of these mosquitoes be detected in the region, it is critical that Byron Shire Council work with NSW Health and nearby councils to address the situation.

Although the abundance of mosquitoes in Byron Shire is generally lower than other regions in coastal NSW, the incidents of human disease caused by RRV and BFV is one of the highest with over 70 cases of mosquito-borne disease reported every year.

As Byron Shire supports a growing residential population and is a major tourist destination, the risks to the community posed by mosquito-borne disease should be addressed with the development of appropriate and sustainable strategies.

Overall, it is key to the success of any mosquito management strategy that there is thorough consultation and engagement with the community as a whole to reduce the risk of mosquitoes and mosquito-borne disease.

The objective of a mosquito awareness program should be to inform residents and visitors of the risks posed by local mosquito populations and the steps they can take to protect themselves from biting mosquitoes. In addition, information on the strategies available to reduce mosquito activity around the home is important to reduce the risk of mosquito-borne disease.

The first line of defence against biting mosquitoes is the use of personal insect repellents. It is important that that accurate information is provided with regards to the most effective products and their safe use.

2 ACTION PLAN

Strategies	Strategic actions	Partners	Estimated cost	Priority
Mosquito monitoring	1.1 Continue adult mosquito population sampling in conjunction with the NSW Arbovirus Surveillance and Mosquito Monitoring Program. 1.2 Consumables for adult mosquito population sampling. 1.3 Purchase three additional mosquito traps for back up and "one off" use to investigate mosquito complaints/enquiries.	NSW Health	$7000/year[1] $1000/year[1] $600[2]	High
Mosquito awareness program	2.1 Add "Mosquitoes & Biting Midges" page to Council's website. 2.2 Develop regionally specific fact sheets [inc. mosquito-borne disease risks, repellent use, reducing mosquitoes around home]. 2.3 Produce printed material for distribution. 2.4 Establish protocol for dealing with enquiries from the public regarding mosquitoes or biting midges.	NSW Health Councils[3]	$1000 $1000 $3000 $1000	High
Urban planning	3.1 Consider amending Draft DCP – Chapter B7 Mosquito and Biting Midge Controls to ensure conformance with the current management plan. 3.2 Based on "mosquito risk zone" maps, developers should be required to address actual or potential mosquito risk in development or land rezoning requests. 3.3 Any proposed constructed wetlands should be assessed to determine potential change to local mosquito risk.	Councils	$4000 Nil[4] Nil[4]	High
Mosquito control	4.1 Consider the role of mosquito control agent use in sustainable mosquito management strategies within region including emergency response.	NSW Health Councils OE&H[5]	ND[6]	Medium
Dengue mosquito response	5.1 Consider the response by Council to detection of dengue mosquitoes in region.	NSW Health AQIS	ND[6]	Medium
Review mosquito management plan	6.1 Review Mosquito Management Plan five years after adopted by Council.	NSW Health	$5000	Low

1 Within existing Environmental Services budget.
2 Based on an approximate cost of $200 per trap.
3 This includes neighbouring councils including Ballina Shire Council, Tweed Shire Council, Lismore Shire Council and Kyogle Shire Council.
4 No cost to Byron Shire Council.
5 Office of Environment and Heritage.

6 Cannot currently be determined as will be dependant on nature of emergency/abundance and distribution of dengue mosquitoes.

3. INTRODUCTION

Mosquito-borne disease is a growing concern in Australia. Notwithstanding the potential to spread disease-causing pathogens such as Ross River virus and Barmah Forest virus, nuisance-biting by mosquitoes can have a substantial impact on local residents and tourists. While they may be pests, mosquitoes are also an important component of the local ecosystem, providing food for some birds, bats, amphibians, fish and insects. As a consequence, the management strategies to reduce the risk of mosquito-borne disease requires careful consideration.

Like many coastal regions in NSW, the far north coast is undergoing significant population growth and the rapidly increasing residential population, combined with ever increasing tourism in the region, will raise pressures for expanding urbanisation. As new areas are developed close to productive mosquito habitats, the contact between people and mosquitoes will increase as will the potential for mosquito-borne disease transmission.

There are many different types of mosquito, each closely associated with particular habitats and representing a range of nuisance and public health risks. Mosquitoes are, however, an integral part of the environment and, regardless of the management strategies implemented, mosquitoes will always be active locally during the warmer months.

This management plan is designed to provide a resource for Byron Shire Council to assist in the management of nuisance-biting and public health risks associated with local mosquito populations through the provision of scientific data on the mosquito fauna, activity of mosquito-borne disease and an overview of the strategies that can be implemented to minimise the local pest and public health risks.

4. SCOPE OF MANAGEMENT PLAN

This mosquito management plan has been developed according to the requirements of Byron Shire Council. The key requirement was that a comprehensive plan be developed based on data gathered on local mosquito populations in a scientific manner with a view to developing maps of “mosquito risk” that may, in turn, form the basis for future site-specific mosquito-borne disease management strategies.

This management plan specifically covers the Byron Shire Council LGA. Within this region, however, there are large areas of the natural environment that are under the control of the National Parks and Wildlife Service (NPWS) and the Office of Environment and Heritage (OEH). Byron Shire Council has no direct control over the national parks and nature reserves within the local government area. However, mosquitoes dispersing from these habitats can impact the local community. While this management plan must address the risks of mosquitoes dispersing into the community from these habitats, there are no site-specific mosquito management strategies included in this plan for those habitats.

While it is not possible to provide detailed, site specific management strategies for all actual and potential mosquito habitats within Byron Shire, this management plan has been designed to provide important and relevant information on the biology, ecology and pest status of mosquitoes known within the region and an overview of the most effective management strategies that may be employed by Byron Shire Council.

Detailed information on how the data was collected for mosquito diversity, mosquito abundance, nuisance-biting impacts, public health risks and mosquito-borne disease activity in the Byron Shire, as well as elsewhere on the far north coast of NSW, is included in Appendix 1.

5. ENVIRONMENTALLY SUSTAINABLE MOSQUITO MANAGEMENT

First and foremost, it is important to remember that mosquitoes are a natural part of the Australian environment. The ecological associations for some species result in large population abundances, triggered by favourable local climatic and environmental factors, and for these species, there are no “natural” strategies to minimise their populations. In addition, the pathogens (i.e. arboviruses such as Ross River virus and Barmah Forest virus) that have the potential to cause human illness circulate naturally between mosquitoes and native animals. To manage mosquito-borne disease risk, strategies are required that either disrupt these natural cycles or influence the activity of the community to minimise their exposure to mosquitoes.

Strategies to reduce the risks of mosquito-borne disease and the impacts of nuisance-biting can include:

- Plan urban development to reduce exposure of the community to mosquitoes
- Educating the community on the most effective personal protection strategies
- Reducing the productivity of mosquito habitats through environmental modification
- Reducing mosquito populations through the judicious use of control agents

Environmentally sustainable mosquito management should follow the principles of Integrated Pest Management (IPM). Managing public health and/or pest risks requires a multidisciplinary approach informed by reliable scientific data on local mosquito fauna. Before an effective strategy can be implemented, it is essential to understand the locally important mosquito species, their habitats and associations with disease-causing pathogens. Monitoring mosquito populations and mosquito-borne disease activity is the keystone of effective mosquito management but monitoring alone will not reduce the risks of nuisance-biting or mosquito-borne disease.

It is important to inform and educate the community, not only on the risks of mosquito-borne disease but the measures individuals and households can make to protect themselves from exposure to mosquitoes. To enable dissemination of information to the community, effective monitoring programs are required. Legislation requires that local health authorities are notified of positively identified human cases of mosquito-borne disease. However, once this data is available, the periods of high risk of mosquito-borne disease have often passed. Monitoring programs that record relative changes in local mosquito population abundance, as well as the activity of arboviruses within mosquito populations, can provide a much more effective tool to enable public health warnings of elevated risks.

Personal protection strategies are available to individuals and households that can greatly reduce the risks of mosquito exposure. Such strategies may include the removal of mosquito breeding sources within their properties, the use of personal insect repellents and/or the installation of screening on dwellings. Even a change in behaviour to avoid mosquito habitats at time of greatest mosquito activity can reduce the risks of disease. However, for these strategies to be effective there must be engagement with the community and communication informed by mosquito monitoring and research.

It would not be possible, or desirable, with methods currently available to eradicate mosquitoes entirely. However, broadscale mosquito control has been shown to significantly reduce the abundance of targeted species and may assist in reducing the risks of mosquito-borne disease. Broadscale mosquito control can be expensive and the effectiveness of the program can often be limited by the fact that control activities may not be possible in locally important mosquito habitats (e.g. national parks and nature reserves) beyond the control of local authorities. It is important to note, however, that even on a smaller scale, targeted mosquito control may be beneficial if “hot spots” of mosquito activity are identified or if there is a disease outbreak. There is a range of products currently registered for use in Australia that, when used as recommended, can reduce mosquito populations without adversely impacting the environment.

A cost effective and sustainable approach to mosquito-borne disease management is to consider mosquito risk when planning future urban development, including both the location of developments and water sensitive urban design within them. There is a range of options available for the design of both new residential and tourist developments that will assist in minimising mosquito risk. Similarly, the design and maintenance of constructed and rehabilitated wetlands, either for wildlife conservation of waste-water treatment, can incorporate strategies to minimise the risk of mosquitoes.

One strategy to improve the efficiency and funding base for mosquito management, regardless of the strategies employed, is for neighbouring councils to co-operate and work together and acknowledge that mosquitoes do not adhere to the boundaries of local authorities. In the late 1970s, local authorities in south-east Queensland, came together to form a Contiguous Local Authority Group (CLAG) to promote a regional approach to mosquito management. Similar regional groups have subsequently been formed elsewhere in QLD as well as Western Australia. In NSW, the North Coast Mosquito Focus Group (NCMFG), coordinated by the then Northern Rivers Public Health Unit and including representatives of Ballina, Tweed, Byron, Pristine Waters, Maclean and Lismore Councils, as well as wetland ecologists and entomologists, met on a number of occasions to discuss issues surrounding mosquitoes and mosquito-borne disease. However, the group has not been active for many years.

One successful regional program in NSW has been coordinated by the “Living with Mosquitoes” Group in the Hunter and Mid-North Coast region. The group was established in 2005 and included representatives of local (including five adjoining local councils), state and federal government agencies with an interest in mosquito-borne disease management in the region. While no mosquito control activities were undertaken, the group coordinated monitoring activities to fill gaps in local mosquito and mosquito-borne disease knowledge and considerable effort was invested in a community education program designed to increase awareness of local mosquito-borne disease risks.

There is no single, easy to implement, strategy to managing mosquitoes and mosquito-borne disease risk. Effective management requires integrated strategies that target specific factors that can influence the risks of mosquito-borne disease now and into the future (Figure 1). It is these strategies that will be discussed throughout this document.

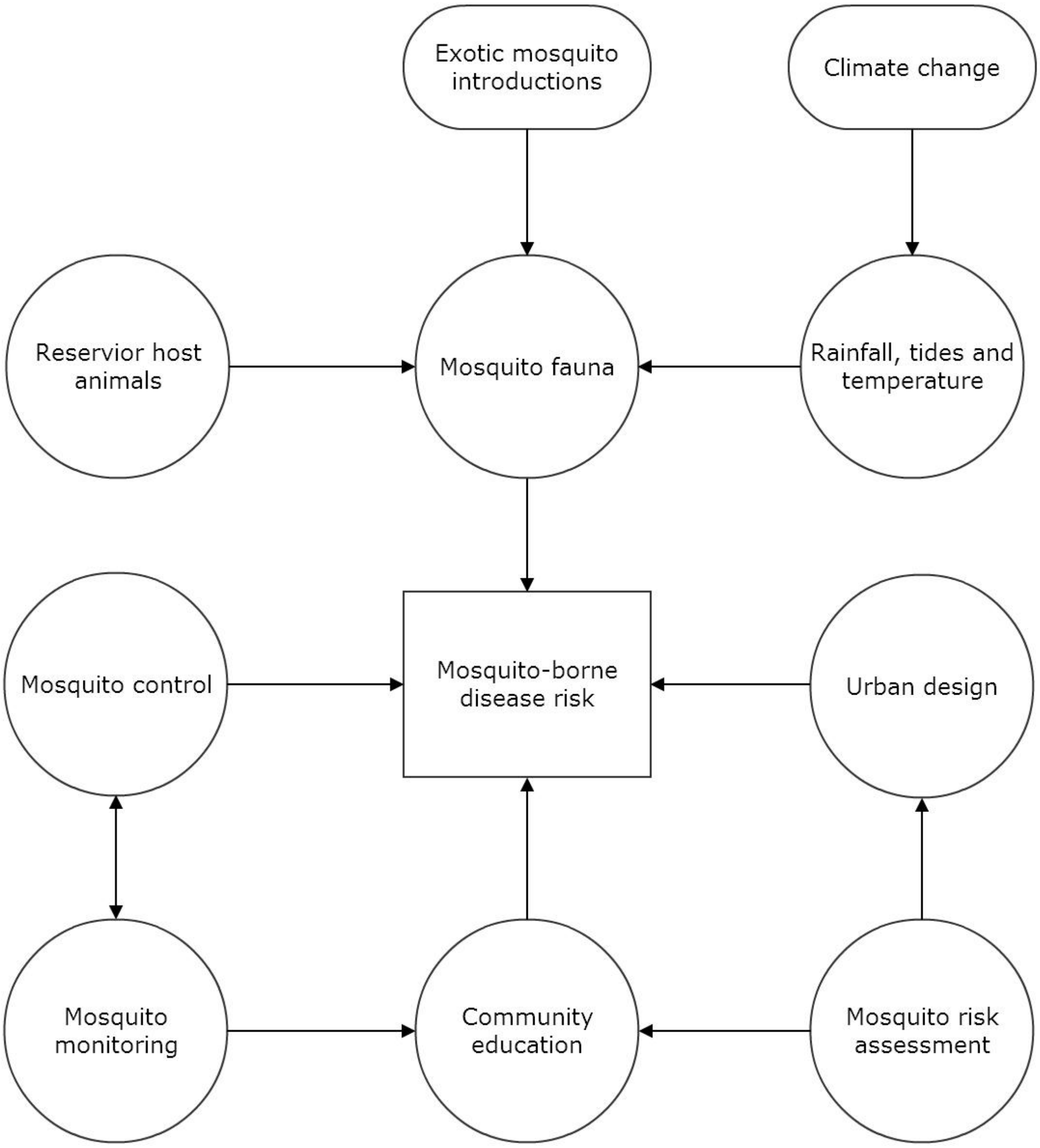

Figure 1. Illustration of direct and indirect factors influencing mosquito-borne disease risk in the local area that must be addressed by a mosquito management plan.

6. MOSQUITO BIOLOGY

Mosquitoes are small blood sucking insects that belong to the family of flies called Culicidae (Order Diptera) and within Australia there are more than 300 different species. Each of these species is closely associated with particular habitats, and the nuisance and public health risks vary markedly between species, but overall they have similar biological requirements.

Mosquitoes have a relatively short but complex life cycle consisting of eggs, four aquatic larval stages (instars), an aquatic pupal stage and a terrestrial adult stage. Mosquitoes are dependent on water, with the immature stages being totally aquatic, and 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 dry areas are producing the mosquitoes.

A gravid adult female mosquito will 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 (eg. tins, tyres etc).

While some mosquito eggs (usually those laid by *Aedes* or *Verrallina* species) can be desiccation resistant, most eggs (particularly those laid by *Culex* and *Anopheles* species) will hatch within two to three 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 two 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 generally is about one to two weeks from the hatching of eggs to the emergence of adults.

On average, a female mosquito may live approximately two to three 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. 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 up to 50 kilometres downwind from the larval habitats.

Within their lifetime, both adult male and female mosquitoes will feed on nectars and other plant sugars, to provide an energy resource, but it is only the female that will seek a blood meal. The blood meal is required to provide protein for 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. After engorging on the host's blood the female will find a resting place to digest her meal and develop eggs before flying off to deposit them in a suitable habitat. On average, most mosquitoes will lay up to three batches of eggs in their lifetime.

7. MOSQUITOES AND THEIR HABITATS

7.1 Mosquito diversity

There are over 60 mosquito species known to exist in coastal NSW with a large percentage of those species found on the far north coast. Despite this high level of diversity, however, relatively few species pose a major threat to the community through nuisance-biting and/or disease transmission. In fact, many of the species found on the far north coast are either so rare or do not bite humans and so, as a consequence, do not pose any risk to the community at all.

Byron Shire Council has undertaken mosquito monitoring at Byron Bay and Ocean Shores from 2008-2009 through until 2010-2011 as part of the NSW Arbovirus Surveillance and Mosquito Monitoring Program coordinated by NSW Health. Neighbouring councils Tweed Shire Council and Ballina Shire Council have been involved in the program for over a decade and the data from their sites assists in putting the mosquito populations of Byron Shire into perspective.

The diversity of mosquito species is very similar between the three local council areas (Table 1). The most commonly recorded mosquitoes on the far north coast of NSW that represent actual or potential pest problems are *Aedes notoscriptus*, *Aedes vigilax*, *Aedes multiplex*, *Aedes procax*, *Aedes notoscriptus*, *Coquillettidia linealis*, *Coquillettidia xanthogaster*, *Culex annulirostris* and *Verrallina funerea*.

While there may not be a noticeable difference in the diversity of the mosquito populations, there is a difference in their relative abundance. Ballina consistently records the highest populations of mosquitoes (all species combined) with over twice as many mosquitoes collected compared to all other trap sites (Figure 2). This variation is due to a number of factors, but most important is the availability of larval habitat.

As well as a spatial difference in mosquito abundance, there is also a temporal difference in mosquito abundance. Taking the Byron Bay and Ocean Shores traps sites as examples, there can be considerable difference in the mean weekly abundance of all mosquito species both within each season as well as between each season. This is illustrated when the total weekly collections at both sites are compared over the three seasons 2008-2009, 2009-2010 and 2010-2011 (Figure 3). The total abundance of all mosquito species recorded at Byron Bay and Ocean Shores for the three seasons, 2008-2009, 2009-2010 and 2010-2011 is shown in Table 2.

The difference in abundance of mosquitoes is driven both by differences in the availability of suitable habitat across the region as well as differences in the patterns of rainfall and tidal inundation. The abundance of estuarine mosquitoes is driven by both tidal inundation of coastal wetlands, as well as rainfall, with the majority of other species driven by the quantity and distribution of rainfall over the season. For those mosquitoes associated with backyard habitats or urban waterways, rainfall as well as human activity (watering gardens, storing rainwater, modification of drainage systems etc) can influence their abundance in any given season.

7.2 Mosquito habitats

Firstly, it is important to note that within the Byron region, there are extensive areas of actual and potential mosquito habitat that are currently National Parks or Nature Reserves managed by National Parks and Wildlife Service (NPWS) and The Office of Environment and Heritage. Although mosquitoes produced from these habitats have the potential to impact the community of Byron Shire, surveys and mapping of habitats in these zones was beyond the scope of this investigation and local council will be unable to undertake any mosquito control in these habitats.

Table 1. The mosquito species recorded from the sampling sites on the far north coast by the NSW Arbovirus Surveillance and Mosquito Monitoring Program 2008/2009 through until 2010/2011.

Week of Season	**North Creek Ballina**	**Lennox Head**	**Tweed Heads**	**West Tweed Heads**	**Byron Bay**	**Ocean Shores**
Aedes aculeatus	+	+	+		+	+
Aedes alternans	+	+	+	+		+
Aedes burpengaryensis	+		+	+	+	+
Aedes candidoscutellum						+
Aedes gahnicola				+	+	+
Aedes kochi	+	+	+	+	+	+
Aedes multiplex	+	+	+	+	+	+
Aedes notoscriptus	+	+	+	+	+	+
Aedes palmarum			+	+	+	+
Aedes procax	+	+	+	+	+	+
Aedes pseudonormanensis				+		+
Aedes quasirubithorax				+		+
Aedes sp. Marks 51						+
Aedes vigilax	+	+	+	+	+	+
Aedes vittiger	+					
An. annulipes	+	+	+	+	+	+
Coquillettidia linealis	+	+	+	+	+	+
Coquillettidia variegata	+	+			+	+
Coquillettidia xanthogaster	+	+	+	+	+	+
Culiseta antipodea		+				
Culex annulirostris	+	+	+	+	+	+
Culex australicus	+		+	+	+	+
Culex bitaeniorhynchus		+	+	+	+	
Culex edwardsi	+	+	+	+		+
Culex halifaxii	+	+			+	+
Culex orbostiensis	+	+	+	+	+	+
Culex postspiraculosus	+					
Culex pullus					+	+
Culex quinquefasciatus	+	+	+	+	+	+
Culex sitiens	+	+	+	+	+	+
Culex sp. Marks No. 32	+				+	+
Culex squamosus	+	+	+	+	+	
Mansonia uniformis	+	+	+	+	+	+
Tripteroides marksae					+	+
Tripteroides tasmaniensis						+
Uranotaenia lateralis	+		+	+		
Uranotaenia nivipes		+				
Uranotaenia pygmaea						+
Verrallina funerea	+	+	+	+	+	+
Verrallina sp. Marks No. 52	+	+	+		+	+
Total number of species	**27**	**24**	**24**	**26**	**27**	**33**

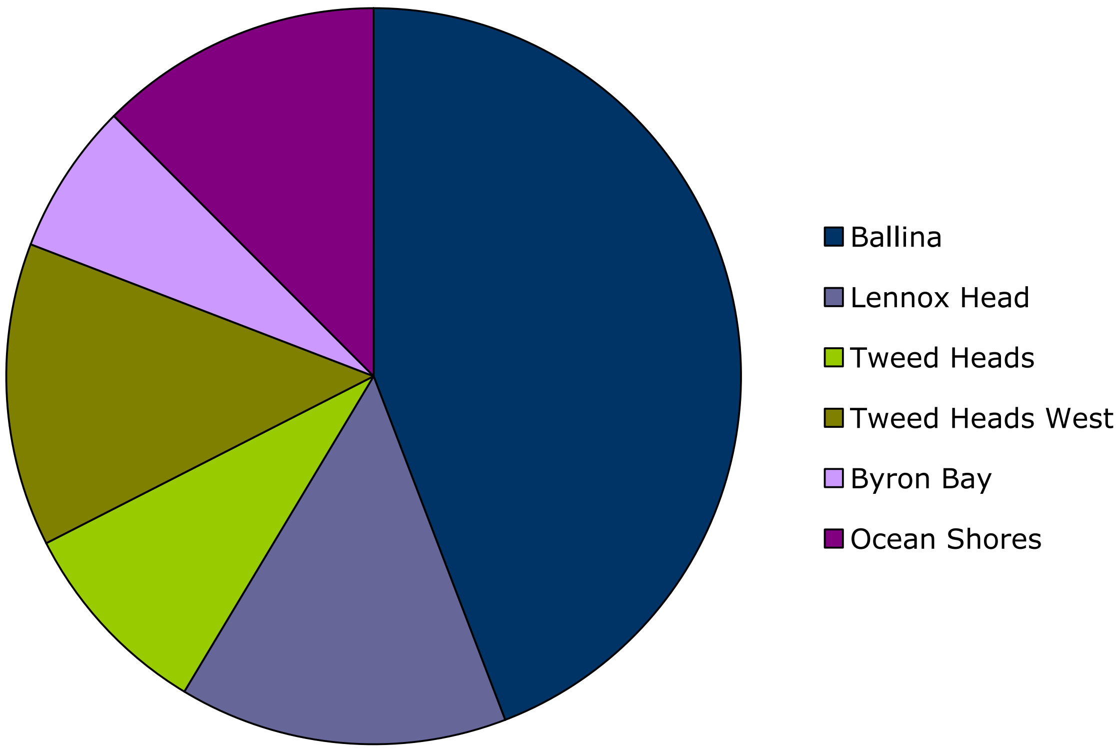

Figure 2. Mean relative abundance of mosquitoes (all species) collected per trap night over three monitoring periods between 2008-2009 and 2010-2011 as collected by the NSW Arbovirus Surveillance and Mosquito Monitoring Program.

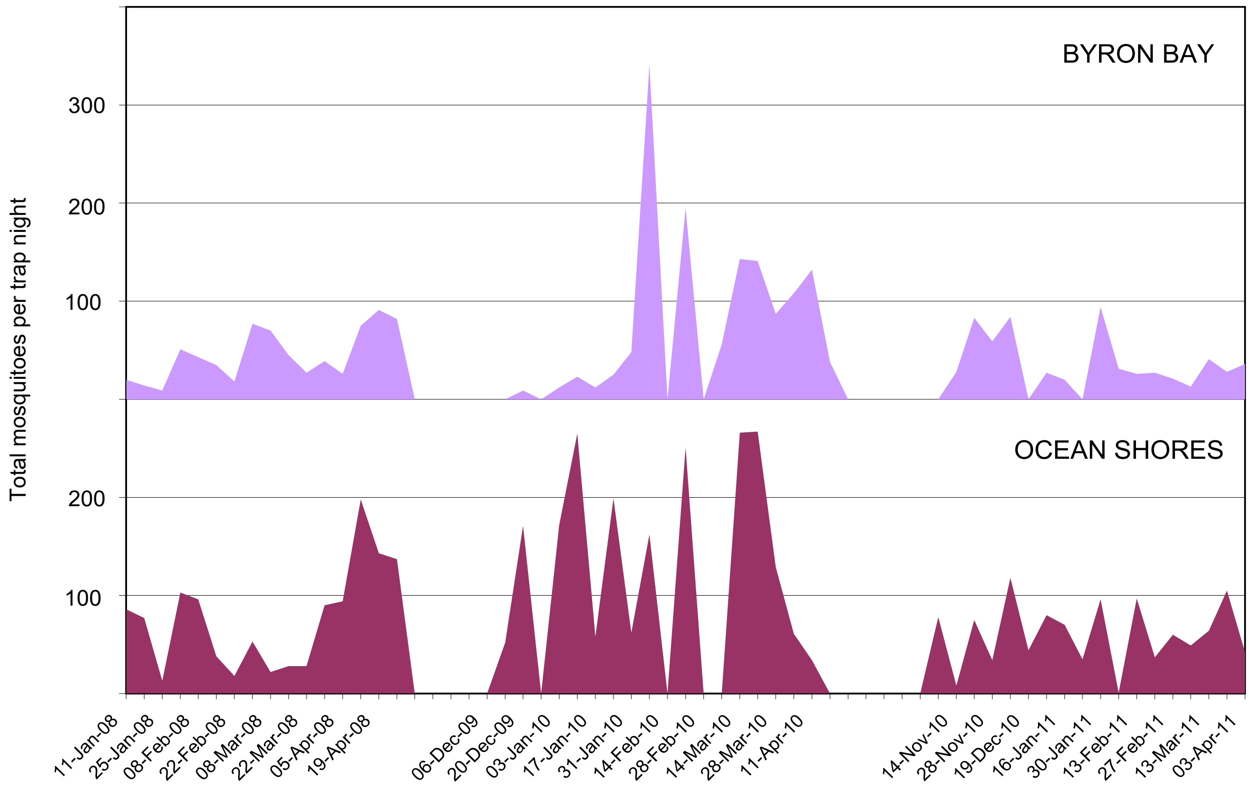

Figure 3. Weekly abundance of all mosquitoes species collected each week from traps at Ocean Shores and Byron Bay as part of the NSW Arbovirus Surveillance and Mosquito Monitoring Program 2008-2009 through until 2010-2011.

Table 2. The mosquito species recorded from the Byron Shire as part of the NSW Arbovirus Surveillance and Mosquito Monitoring Program 2008/2009 through until 2010/2011.

Mosquito Species	Byron Bay			Ocean Shores		
	2010-11	2009-10	2008-09	2010-11	2009-10	2008-09
Aedes aculeatus	0	51	0	0	0	4
Aedes burpengaryensis	0	37	0	2	4	1
Aedes candidoscutellum	0	0	0	1	0	1
Aedes gahnicola	0	6	5	0	1	0
Aedes kochi	7	15	5	100	65	43
Aedes multiplex	171	247	104	83	167	14
Aedes notoscriptus	232	542	370	605	1541	669
Aedes palmarum	1	16	0	10	46	9
Aedes procax	14	150	102	136	305	221
Aedes quasirubithorax	0	0	0	1	0	0
Aedes sp. Marks 51	0	0	0	0	11	155
Aedes vigilax	2	87	15	6	83	20
An. annulipes	0	1	0	0	1	0
Cq. linealis	80	40	81	10	0	14
Cq. variegata	1	1	3	0	1	0
Cq. xanthogaster	51	4	27	8	0	0
Cx. annulirostris	1	7	2	13	26	9
Cx. australicus	1	0	4	8	1	7
Cx. bitaeniorhynchus	3	0	0	0	0	0
Cx. edwardsi	0	0	0	3	0	0
Cx. halifaxii	1	0	0	0	1	0
Cx. orbostiensis	36	156	30	52	78	9
Cx. pullus	1	0	0	10	0	0
Cx. quinquefasciatus	2	2	4	6	7	1
Cx. sitiens	0	32	9	7	261	25
Cx. sp. Marks No. 32	1	0	0	0	0	1
Cx. squamosus	5	0	0	0	0	0
Ma. uniformis	3	4	3	16	0	0
Tp. marksae	0	1	0	1	5	0
Tp. tasmaniensis	0	0	0	0	2	0
Ur. pygmaea	0	0	0	0	1	0
Ve. funerea	0	20	0	10	31	17
Ve. sp. Marks No. 52	1	24	3	0	5	7
Total	614	1443	767	1088	2643	1229

Ae=Aedes, An=Anopheles, Cq=Coquillettidia, Cx=Culex, Ma=Mansonia, Tp=Tripteroides, Ur=Uranotaenia, Ve=Verrallina

Byron Shire Council has extensively mapped their local vegetation communities and this resource can be utilised to map the relative risk zones impacted by local mosquito species. The vegetation classes of greatest concern are those that provide suitable habitat for either estuarine mosquitoes or coastal swamp mosquitoes and the specific vegetation classes are shown in Table 3. It is important to note that these habitats represent both potential immature habitats (i.e. where ground pools provide suitable conditions for immature mosquito development) as well as refuge sites for adult mosquitoes.

Estuarine wetlands can be divided into two main categories; the mangrove forests and saltmarsh. The term “saltmarsh” may be used to describe a number of different vegetation communities, with over 200 flowering plants known to occur in NSW saltmarshes. However, the most important larval habitats are those primarily vegetated with *Sarcocornia quinqueflora*, *Sporobolus virginicus* and *Triglochin striatum*.

Coastal swamp habitats include sedgeland communities including *Juncus*, *Eleocharis* and *Baumea* species can provide important mosquito habitat with productivity dependent on inundation and the abundance of pools and depressions. Similarly, tea tree, paperbark and swamp oak, where there is an abundance of ephemeral pools persisting after rainfall, provide suitable conditions for a range of pest mosquitoes. These habitats are often extensive and difficult to survey and, as a result, little is known of the specific habitat characteristics that may predispose some areas to being productive mosquito habitats.

The distribution of these two main categories of vegetation in Byron Shire are shown in Figure 4 along with the areas currently managed by NPWS. It is important to note that the vegetation classes within the national parks and nature reserves within coastal Byron Shire are similar in nature to those adjoining them and are dominated by paperbark, swamp oak, tea tree, sedgeland and some saltmarsh communities. For the purpose of this management plan, all national parks and nature reserves are categorised as coastal swamp habitats.

Table 3: The vegetation classifications provided by Byron Shire Council and the major pest mosquito species associated with them.

Mosquito habitat	**Primary/Secondary**	**Vegetation classes**
Saltmarsh mosquito habitat[1]	Primary	Saltmarsh
	Secondary	Grey Mangrove/River Mangrove Grey Mangrove/River Mangrove/Swamp Oak
Coastal swamp mosquito habitat[2]	Primary	Paperbark Swamp Oak/Paperbark Swamp Schlerophyll Forest Tea Tree
	Secondary	Sedgeland/Fernland/Grassland

An example of the estuarine wetlands in the Brunswick Heads area. These wetlands include mangrove and saltmarsh plant species and provide habitats for estuarine mosquitoes such as *Aedes vigilax*, *Culex sitiens* and *Verrallina funerea*.

An example of the Coastal swamp wetlands within the Byron Shire region. These wetlands include paperbark, tea-tree, swamp oak and sedgeland plant species and provide habitat for mosquito species such as *Aedes procax*, *Aedes multiplex* and *Coquilettidia xanthogaster*.

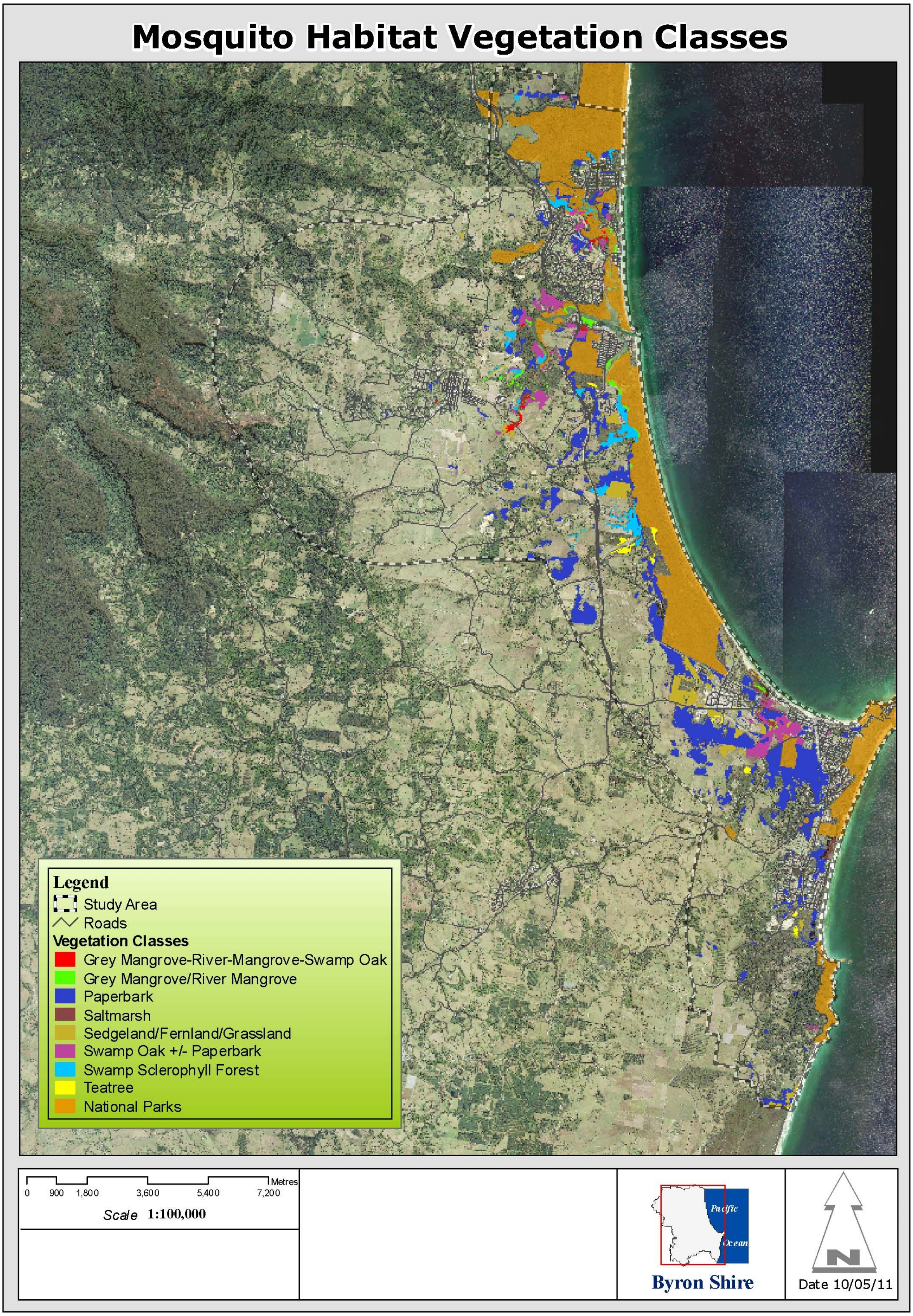

Figure 4: Distribution of vegetation communities closely associated with pest mosquito populations in the Byron Shire as well as habitats currently managed by the NPWS.

In addition to the estuarine and coastal swamp habitats, there is a range of habitats within urban environments that may support the production of mosquitoes. Generally, these habitats are divided into those usually high in organic content, associated with stormwater and waste-water structures, such as drains, detention basins, Gross Pollutant Traps (GPT), and small water holding containers found around residential and/or industrial areas.

Finally, there are freshwater habitats throughout the Byron Shire that may provide habitat for freshwater mosquito species. These habitats, beyond those in association with the coastal swamp habitats, are generally represented by small areas of marshlands, creeklines, farm dams or other low-lying areas where inundation may persist following major rainfall events. As the elevation of the local environment increases towards the hinterland of Byron Shire, suitable mosquito habitats become relatively rare and are generally limited to small slow-flowing creeklines, farm dams and water holding containers on residential properties such as rainwater tanks and septic tanks.

There may also be some small environmental niches in the rainforest habitats that provide habitats for some mosquito species but these mosquitoes are unlikely to pose any substantial nuisance-biting or public health problem and any substantial habitats of this nature are likely to be within national parks or nature reserves.

The relative abundance of all mosquito species combined is presented in Figure 5. The most noteworthy result from analysis of the data is that the abundance of mosquitoes is greatest in coastal regions and generally similar between northern and southern suburbs.

7.3 Estuarine mosquitoes

Mosquitoes associated with estuarine wetlands have the potential to cause severe nuisance-biting impacts. Mosquito species associated with these habitats in the Byron Shire are shown in Table 4.

The major pest mosquito in coastal NSW is the saltmarsh mosquito *Aedes vigilax*. This species can often be found in extremely high populations and the species has been recorded travelling many kilometres from saltmarsh habitats. However, the saltmarsh habitats within the Byron Shire are markedly different to many elsewhere in NSW. The estuarine habitats are generally associated with intermittently open and closed lakes or lagoons (ICOLL) that are closed, or at least with restricted entrances. As a result, the estuarine wetlands are not extensively flooded by spring tides and, generally, are not as productive as some estuarine habitats found nearby in Tweed Shire or Ballina Shire. This difference in habitat productivity is illustrated by the significantly lower abundance of these mosquitoes in the Byron Shire.

The results of mosquito surveys in accessible saltmarsh habitats within Byron Shire indicated that there are relatively few areas where extensive productive mosquito habitats are likely to occur. Much of what is classified as saltmarsh is dominated by saltmarsh plants such as *Suaeda australis* or sedge species (*Juncus* spp or *Isolepis* spp) within very sandy soils that do not represent productive mosquito habitats.

Mangrove habitats, generally, do not represent important mosquito habitats. Typically existing in the intertidal zone, these habitats are frequently flushed by tides and are usually characterised by abundant fish populations. However, in situations where tidal flows to mangrove areas are restricted, or mangroves have colonised channels or pools within saltmarsh areas, mosquito production can be high on occasion.

Verrallina funerea is closely associated with brackish water environments and has shown to be a severe nuisance-biting pest and is considered to play a potentially important role in the transmission of RRV and BFV in SE QLD and northern NSW. Unlike *Ae. vigilax*, this species does not disperse far from larval habitats.

In summary, although estuarine mosquito species such as *Ae. vigilax* and *Ve. funerea* are present in the Byron Shire, have the potential to cause pest impacts and should be given due consideration in mosquito management plans, their relative abundance in the local area is generally lower than elsewhere on the Far North Coast of NSW.

The relative abundance of estuarine mosquito species combined is presented in Figure 6. The most noteworthy result from analysis of the data is that the abundance of mosquitoes is generally greatest in northern coastal regions where suitable habitat conditions are most common.

7.4 Coastal swamp mosquitoes

Mosquitoes associated with coastal swamp habitats have the potential to cause severe nuisance-biting impacts. The key mosquito species associated with these habitats in the Byron Shire are shown in Table 5.

These mosquitoes represent the most important pests in the Byron Shire. There is a suite of species associated with these habitats and, on occasion, estuarine species such as *Ae. vigilax* and *Ve. funerea* will be found in these habitats. The most common species found during the surveys, as well as those detected in the NSW Arbovirus Surveillance and Mosquito Monitoring Program were *Aedes multiplex*, *Aedes procax*, *Coquillettidia linealis*, *Coquillettidia xanthogaster* and *Verrallina* Marks #52. However, not only will the abundance and distribution of these species vary across the Byron Shire between years but there are also a number of other species that may pose localised pest impacts when climatic conditions are ideal. These species may include *Aedes aculeatus*, *Aedes kochi* or *Mansonia uniformis* but the impacts of these species are likely to be localised and only for relatively short duration.

The abundance of these coastal swamp mosquitoes will be primarily driven by local rainfall. There are extensive areas contained with the coastal swamp vegetation communities that represent potentially suitable habitats but without sufficient rainfall, the abundance of these species may not reach levels that cause significant nuisance-biting impacts. However, during seasons with above average rainfall, pest impacts may be substantial.

Another factor to consider when assessing the potential impacts of these species is that most of the coastal swamp mosquitoes do not disperse far from larval habitats. Unlike pest species such as *Ae. vigilax* that travel many kilometres, these species generally travel less than 1km and for many species, less than 500m. As a result, there is far greater spatial variation in the local pest impacts across the Byron Shire caused by these species.

The relative abundance of coastal swamp mosquito species combined is presented in Figure 7. The most noteworthy result from analysis of the data is that the abundance of mosquitoes is greatest in coastal regions and generally similar between northern and southern suburbs but substantially greater than the estuarine mosquitoes.

7.5 Backyard mosquitoes

Despite the potential for large mosquito populations to be produced from the natural wetlands of Byron Shire, mosquitoes associated with backyard habitats in residential, rural and industrial properties can have a substantial influence on local nuisance-biting and public health risks. The key mosquito species associated with these habitats in the Byron Shire are shown in Table 6.

The larvae of *Aedes notoscriptus* are usually associated with small water holding containers around dwellings such as tins, pots, ornamental ponds, roof guttering, water tanks and discarded tyres, as well as water holding plants (eg. bromeliads) and tree holes. Essentially, any small to medium sized water holding container can be used by this species.

The larvae of *Culex quinquefasciatus* and *Culex molestus* (although this species is suspected of being present in the Byron Shire, it has not been recorded to date) are usually associated with habitats with a high organic content such as drains, sullage pits, septic tanks and other water holding and water storage areas. Any structure constructed as part of the stormwater or waste-water system that retains water and is accessible by mosquitoes can provide habitat for these species.

The relative abundance of backyard mosquito species combined is presented in Figure 8. The most noteworthy result from analysis of the data is that while the abundance of mosquitoes was generally lower than estuarine and coastal swamp mosquitoes, they were generally common in all areas of Byron Shire council where collections were made.

7.6 Other types of local mosquitoes

There is a wide range of mosquito habitats including permanent freshwater wetlands, marshland, flooded pastureland, creeks, farm dams and ephemeral ground pools in bushland areas.

Based on mosquito population sampling the most common mosquito species that falls into this category is *Culex annulirostris*. This species is the major nuisance biting throughout inland areas of NSW, particularly in the major river basins and irrigation areas, and is associated with the transmission of RRV and BFV. While the importance of this species in Byron Shire is generally overshadowed by relatively larger populations of estuarine and coastal swamp mosquitoes, *Cx. annulirostris* has been implicated in mosquito-borne disease activity in coastal SE QLD.

This species was not considered abundant in either the mosquito surveys or in data collected by the NSW Arbovirus Surveillance and Mosquito Monitoring Program. However, during periods of above average rainfall when extensive areas of pastureland remain inundated for many weeks during the warmer months, populations of this species may cause some localised pest impacts.

Culex annulirostris, along with species including *Cq. linealis* and *Ma. uniformis*, may be a concern for any large scale constructed freshwater wetlands in Byron Shire. These species can colonise newly created habitats and is abundant where aquatic vegetation is present, including both emergent and floating vegetation, suitable conditions for these species may be created.

An adult female *Aedes vigilax*. The relative abundance of this mosquito in the Byron Shire is generally lower than elsewhere on the Far North Coast of NSW but can still cause some nuisance-biting problems (courtesy S. Doggett).

An adult female *Aedes notoscriptus*. The species is the most important pest mosquito in urban areas in Australia and is common in backyards across Byron Shire (courtesy S. Doggett).

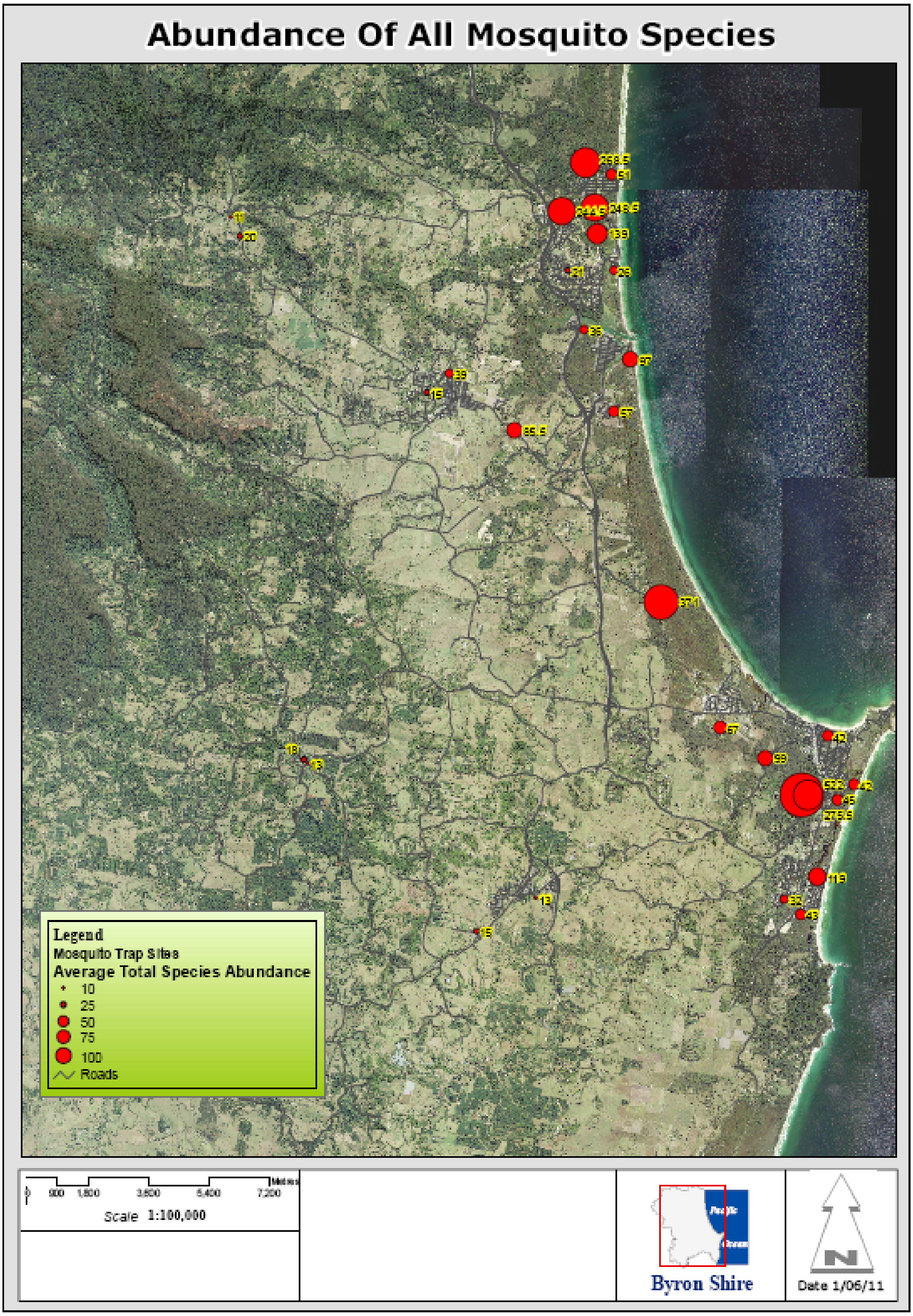

Figure 5: Relative abundance of all mosquito species collected in carbon dioxide baited light traps in the Byron Shire region, March – April 2011.

Table 4: Common mosquito species associated with estuarine wetlands in the Byron region.

Estuarine mosquitoes		
Mosquito species	**Habitat associations**	**Public health risks**
Aedes alternans	Tidally influenced saltmarsh but can also be found in freshwater habitats. Larvae are predatory and feed on other mosquito larvae.	Potential nuisance-biting pest but is not considered an important vector of RRV or BFV.
Aedes vigilax	Tidally influenced saltmarsh but also other saline and brackish water habitats such as flooded sedgelands and coastal swamp forests. Travels many kilometres from larval habitats.	Severe nuisance biting pest and vector of RRV and BFV. One of the most important pest species in coastal NSW.
Culex sitiens	Permanently inundated saline to brackish habitats, including saltmarsh and mangroves.	Is not considered a nuisance-biting pest as it prefers to bite birds and is not considered an important vector of disease.
Verrallina funerea	Saline and brackish habitats including coastal swamp forests and the margins of saltmarsh. Does not travel far from larval habitats.	Severe nuisance-biting pest and a vector of RRV and BFV.

Table 5: Common mosquito species associated with coastal swamp wetlands in the Byron region.

Coastal Swamp mosquitoes		
Mosquito species	**Habitat associations**	**Public health risks**
Aedes multiplex	Freshwater and mildly brackish flooded habitats in *Melaleuca* forests. Does not travel far from larval habitats.	Will bite humans but rarely a serious nuisance-biting pest. Role in RRV and BFV transmission is unknown.
Aedes procax	Freshwater and mildly brackish flooded habitats in *Melaleuca* forests. Does not travel far from larval habitats.	Will bite humans but is generally not considered a serious nuisance-biting pest. May play an important role in RRV and BFV transmission.
Coquillettidia linealis	Close association with well vegetated freshwater wetlands.	Nuisance-biting pest and may play a role in transmission of RRV and BFV
Coquillettidia xanthogaster	Close association with well vegetated freshwater wetlands and sedgelands.	Nuisance-biting pest and may play a role in transmission of RRV and BFV
Verrallina Marks #52	Freshwater and mildly brackish flooded habitats with *Melaleuca* forests. Does not travel far from larval habitats.	The pest status of this species has not been documented and the role this species plays in RRV and BFV transmission is unknown.

Table 6: Common mosquito species associated with backyard habitats in the Byron region.

Backyard mosquitoes		
Mosquito species	**Habitat associations**	**Public health risks**
Aedes notoscriptus	Small water holding containers around dwellings such as tins, pots, ornamental ponds, roof guttering, bird baths, as well as water holding plants (eg. bromeliads) and tree holes. Does not travel far from larval habitats.	Severe nuisance-biting pest and vector of RRV and BFV. This is the most important pest mosquito in urban areas across Australia.
Culex quinquefasciatus	Ground pools or artificial structures containing highly organic water such as drains, sullage pits and septic tanks.	Will bite humans but generally not considered a significant nuisance-biting pest. May play a role in the transmission of RRV and BFV.

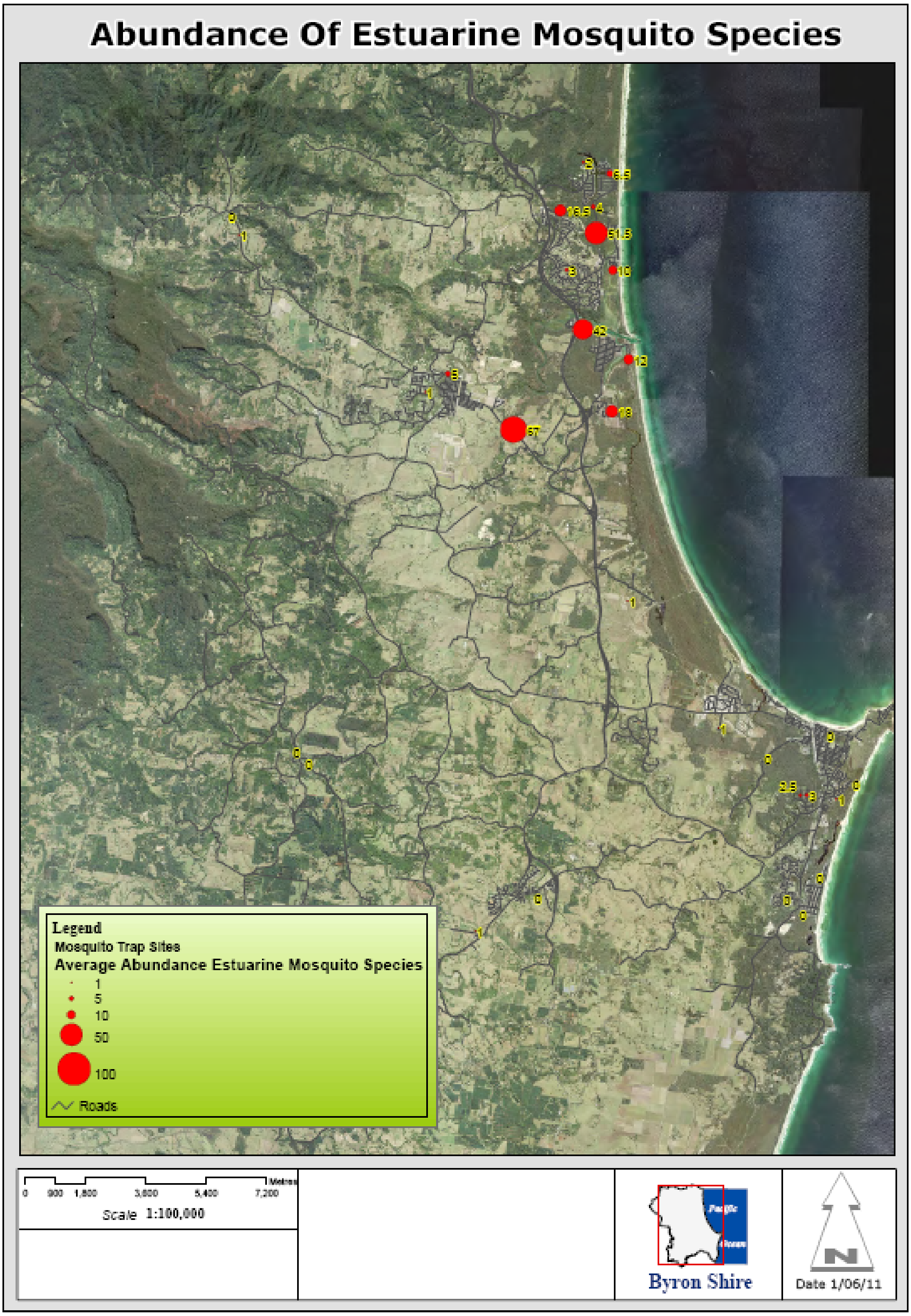

Figure 6: Relative abundance of estuarine mosquito species collected in carbon dioxide baited light traps in the Byron Shire region, March – April 2011.

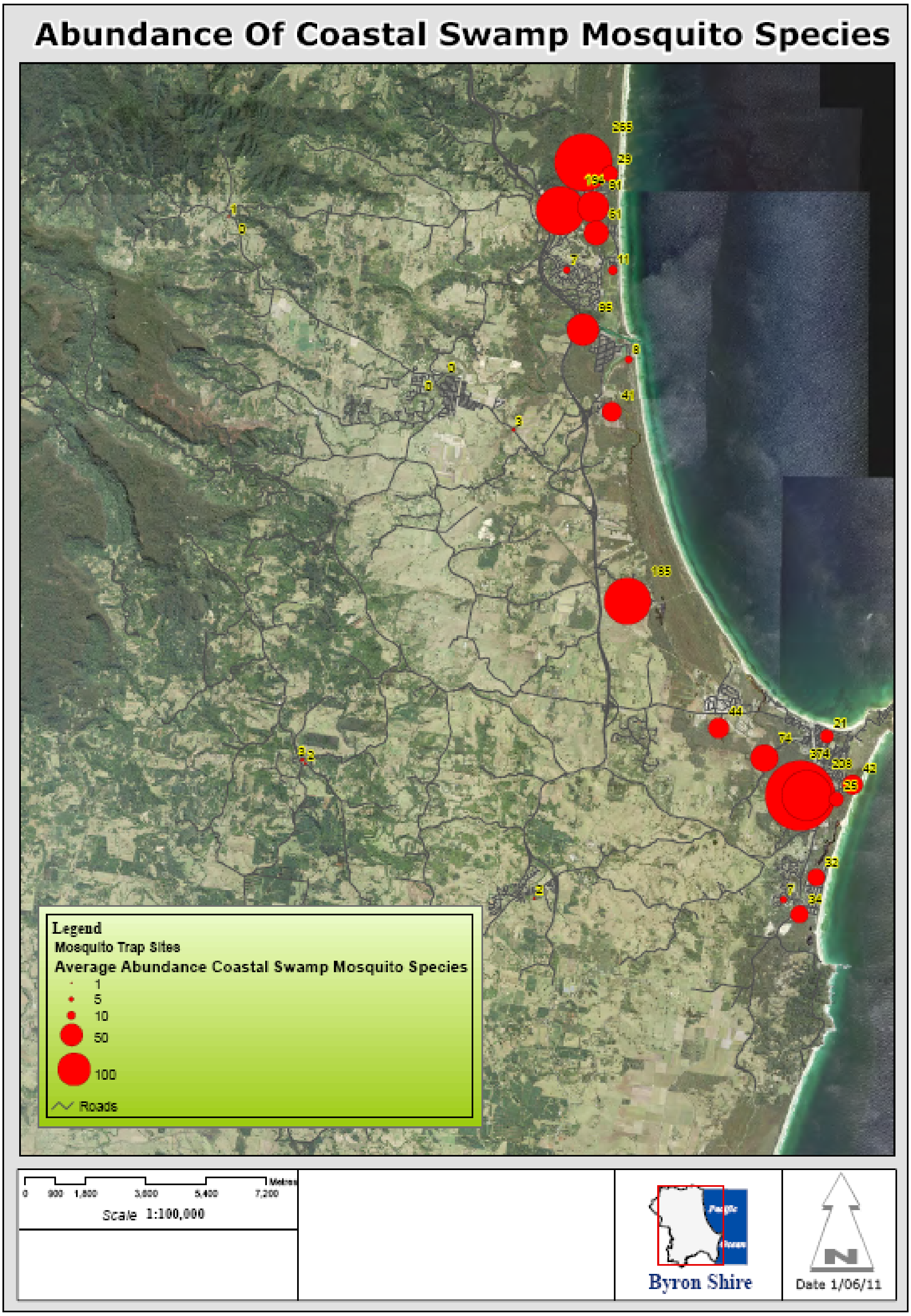

Figure 7: Relative abundance of coastal swamp mosquito species collected in carbon dioxide baited light traps in the Byron Shire region, March – April 2011.

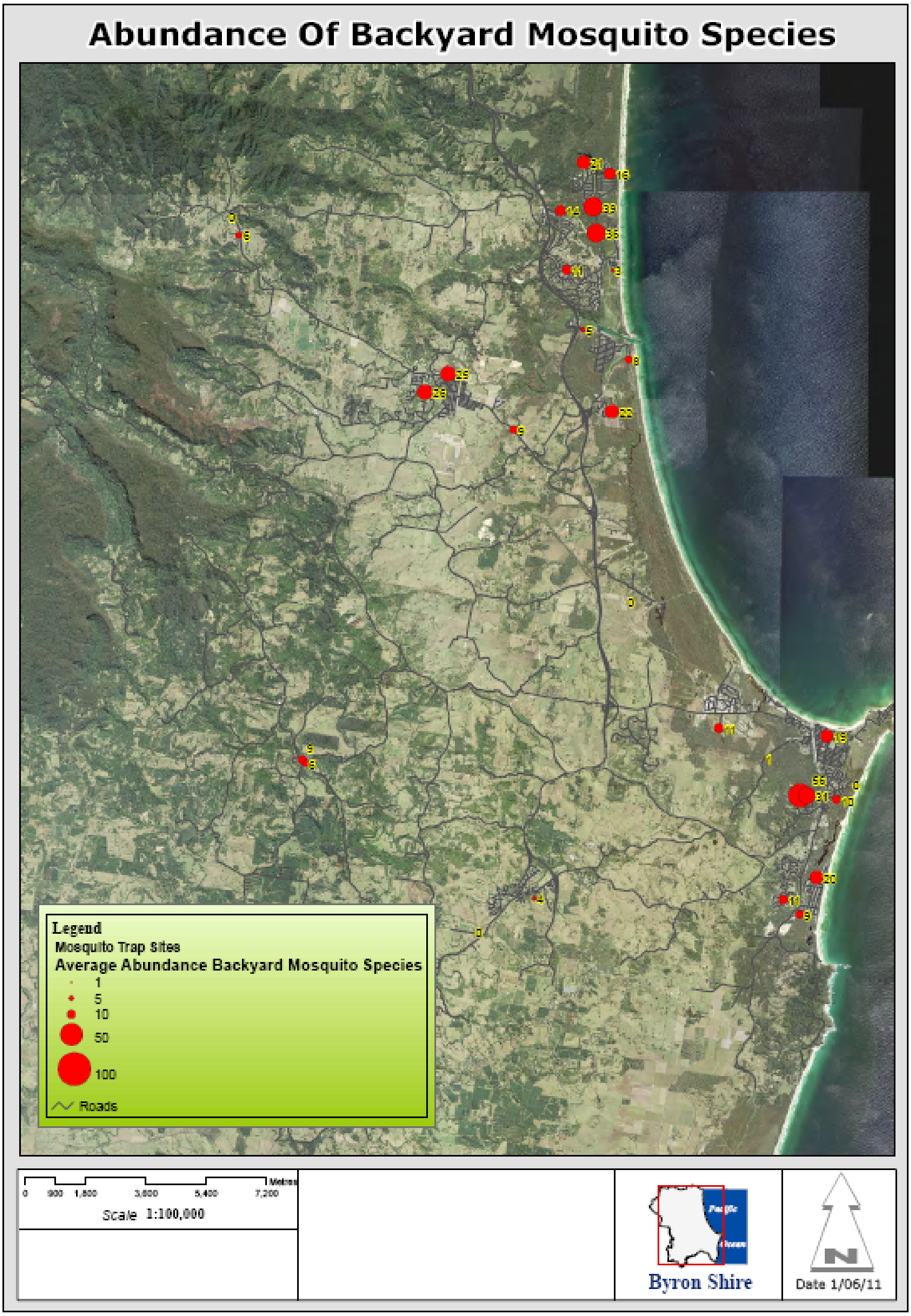

Figure 8: Relative abundance of backyard mosquito species collected in carbon dioxide baited light traps in the Byron Shire region, March – April 2011.

7.7 Important pest mosquitoes from outside the region

While not currently known to occur in the Byron Shire, there are two mosquitoes, *Aedes aegypti* and *Aedes albopictus*, that would be considered a concern if they were introduced. The importation (either from Far North QLD or overseas) and establishment of these species is possible, and it is important that the appropriate steps are taken by the authorities to intercept any incursions of these species, or response to their detection, in the local region.

7.7.1 *Aedes aegypti* is a day-biting mosquito and, as well as a nuisance biting pest, is a vector of dengue viruses in far north Queensland. There are historical records of this species from various parts of Australia (including NSW) but the species is now mostly restricted to Queensland in areas north of Townsville, with occasional interceptions at international ports in various states. The larvae may be found almost exclusively in man-made, water-holding containers such as tins, bottles, discarded tyres, water-barrels, rainwater tanks and wells, and can even be found breeding in smaller containers such as vases inside houses and other buildings. The resurgence of rainwater tanks that may provide suitable habitats for this species, combined with the impact of climate change on the distribution of this species, has raised concern regarding the reintroduction of this species into SE QLD and the far north Coast of NSW.

7.7.2 *Aedes albopictus*, the Asian Tiger Mosquito, is a significant pest species and a secondary vector of dengue viruses. It has a natural range throughout eastern and southeastern Asia, but over recent decades has become established in the Pacific, North and South America, Africa and parts of Europe. Although originally a forest species, *Aedes albopictus* has become closely associated with human environment and, as well as natural containers such as tree holes, plant axils & bamboo stumps, the species exploits a wide range of water holding containers associated with human habitation. Concern for the introduction of *Aedes albopictus* to mainland Australia has increased following the recent discovery of newly established populations of the species on Torres Strait islands, with the mosquito presumably having been introduced from Papua New Guinea. Computer modelling has predicted that, should this species be introduced to mainland Australia, it may spread substantially further south than the current distribution of *Aedes aegypti*.

7.8 The ecological role of mosquitoes

Mosquitoes are small but incredibly complex organisms that have evolved to exploit even the tiniest of environmental niches. Mosquitoes have adapted their larval and adult morphology, ecology, physiology, and life cycles to suit a diverse range of environments. While some mosquitoes have adapted to the hypersaline conditions of saltmarsh habitats, others exploit small quantities of water inside tree holes or the leaf axils of tropical plants. The larval development of some mosquitoes can be completed in less than a week to take advantage of small ephemeral ground pools, while other species have a prolonged larval development lasting many months in more permanent habitats.

While mosquitoes are well known as potential biting pests and vectors of disease, only relatively few mosquitoes pose a serious risk to humans. There are many species of mosquito that rarely come in contact with humans, due to their relatively low abundance or limited dispersal from larval habitats. Many mosquitoes do not seek out a blood meal from humans at all, preferring to take blood from other mammals, birds or frogs.

There is very little published information available on the role of mosquitoes in Australian coastal ecosystems. However, like many other aquatic invertebrates, mosquito larvae provide food for predators while assisting nutrient recycling. Mosquito larvae feed on detritus and other organic material in the water and are a food source for aquatic organisms including fish and some macroinvertebrates. It is unlikely that any vertebrate or invertebrate predator relies solely on mosquito larvae but, particularly when larvae are present in large numbers, they can represent a commonly consumed prey item. The larvae of some mosquito species (e.g. *Aedes alternans* and *Culex halifaxii*) have specialised mouth parts and are predatory on other mosquito larvae and various aquatic macroinvertebrates.

As well as providing prey for aquatic predators, mosquito larvae may be an important source of food for wading birds. Many species of wading bird have been observed undertaking feeding behaviour within known mosquito habitats and, although there are often alternative prey available (e.g. bottom dwelling chironomid or chaoborid larvae) and there is no evidence to suggest that these birds selectively feed on mosquito larvae alone as a primary food source, it is likely mosquitoes are commonly consumed.

Adult mosquitoes provide food for a range of terrestrial invertebrates, birds, mammals, amphibians and reptiles as well as playing a role in the pollination of some plants (particularly the male mosquitoes that feed exclusively on plant juices). Quantifying the role of mosquitoes in food chains is difficult but given that they have a short life span and dramatic fluctuations in abundance, they may simply represent ‘snack food’ for many animals rather than a regular food source. However, while there is no evidence that any animal specifically relies on mosquitoes alone, the large abundance of mosquitoes on occasion may provide important nutritional boosts to juveniles or migratory birds prior to departure from wetland habitats at the end of summer.

Studies have shown that a number of insectivorous microbat species exhibit foraging behaviour above saltmarsh habitats and, given the local abundance of mosquitoes, it is likely that they form a major component of the bat’s diet during these periods. It is difficult, however, to determine the relative importance of mosquitoes to each animal group and the preferences these insectivorous predators have for mosquitoes or other insects. Current research in coastal NSW is attempting to quantify the importance of mosquitoes, compared to other flying insects, to the diet of bats.

Studies with frogs and spiders have indicated that for these groups, larger animals tend to favour the consumption of smaller quantities of larger prey (e.g. moths) rather than large quantities of small prey (e.g. mosquitoes), but further studies are required to identify and quantify these and other ecological relationships.

8. NUISANCE BITING AND PUBLIC HEALTH RISKS

8.1 Nuisance biting

Nuisance biting alone can have a deleterious impact on the standard of living in the community as well as having economic impacts on residential, recreational and tourist developments. It is extremely difficult to quantify the impact of nuisance biting as the tolerance level of individuals varies substantially and is often dependent on the extant mosquito populations and previous experiences.

The greatest difficulties lie in determining what constitutes a nuisance biting problem. While relatively small populations of backyard mosquitoes may cause annoyance, their pest impacts would be significantly overshadowed by large populations of saltmarsh mosquitoes in areas close to estuarine wetlands.

There are many mosquito species present in Byron Shire that will bite humans. However, subtle differences in their habitat associations, population abundance and flight range means that there is no one single species that should be considered the main pest. The analysis of mosquito abundance data suggests that, along with backyard mosquitoes, the most important nuisance-biting pests are likely to be the suite of species associated with coastal swamp environments. Although these species do not travel far from larval habitats, the extensive habitats present in the Byron Shire, as well as the proximity of residential areas, indicate that these species are the most important pest species.

Variability in the activity, and resulting nuisance-biting impacts, of mosquitoes across the Byron Shire, as well as between seasons, is most effectively measured with a routine adult mosquito sampling that enables a comparative measure of mosquito abundance during and between mosquito seasons.

8.2 Public health risks

The mechanisms involved in the transmission of vector-borne disease can be complex and vary with both the mosquito species and pathogen. When a mosquito bites a bird or mammal infected with an arbovirus it takes in a small amount of blood, which may contain virus. If the mosquito species is susceptible to infection with the virus, the virus will move through the body of the mosquito from the gut wall to the salivary glands. If the salivary glands become infected, the mosquito can pass on the virus when it injects saliva during blood feeding. This process of virus infection is called the incubation period and can take between three and twelve days to complete, depending on virus type, mosquito species and temperature. The mosquito will not be able to transmit the virus until the salivary glands are infected. The biological processes involved in producing an infective mosquito are very specific and that is why only arboviruses are transmitted by mosquitoes and not other viruses such as influenza, measles, hepatitis and HIV that are degraded by the digestive process of the mosquito.

An overview of the mosquito-borne disease-causing pathogens of concern in the Byron Shire are shown in Table 7. Ross River virus (RRV) and Barmah Forest virus (BFV) are the most common disease-causing pathogens spread by mosquitoes in Australia. There are approximately 5,000 cases of disease caused by these viruses notified per year across Australia. The presence of specific antibodies showing infection with RRV and BFV can be determined with a blood test, with samples being taken during the acute and convalescent phases of the illness, and a fourfold rise in antibody levels will confirm the clinical diagnosis. Under the NSW Public Health Act 1991, both viruses are classified as a notifiable infectious disease.

The number of human notifications in the north coast of NSW (as reported by the Northern NSW Local Health District) have fluctuated over the last sixteen years with RRV generally more common than BFV (Figure 9). When the mean monthly number of human disease cases is compared, the period of greatest risk is generally between February and May every year (Figure 10). With respect to other local areas on the far north coast, the human notification data for Byron, Tweed and Ballina indicated that the risks of RRV (Figure 11) and BFV (Figure 12) are comparable to the two neighbouring areas. Over the six years to June 2011, there had been a total of 430 human cases of disease resulting from RRV and BFV combined in Byron compared to 359 in Tweed and 181 in Ballina.

The transmission cycles for RRV and BFV generally require the presence of suitable reservoir hosts. Serological studies and laboratory investigations have indicated that native mammals (in particular native macropods such as kangaroos and wallabies) are natural hosts for RRV, but little is known about the hosts of BFV and they may include birds as well as mammals (including macropods and bats). However, RRV transmission from human to mosquito to human (thus occurring without the involvement of an animal) appears to occur in some circumstances, particularly during periods of intense virus activity. Some cases of ‘urban transmission’ have been reported in Brisbane and Perth when mosquito populations are high and the virus has been introduced with humans returning from rural areas.

There have been a number of disease-causing pathogens isolated from field collected mosquitoes in the Byron Shire and Ballina Shire (Table 7). Four different arboviruses have been isolated, RRV, Stratford virus, Sindbus virus and Edge Hill virus, as well as 12 unidentified arboviruses. The arboviruses were isolated from a range of mosquito species.

There are a number of mosquito-borne diseases that do not occur in the Byron Shire but may raise concern in the community if disease is identified from returning travellers or when there are media reports of these diseases from elsewhere in Australia (Table 8).

Murray-Valley encephalitis virus (MVEV) is one of the most significant mosquito-borne pathogens in Australia as it can cause serious illness, and in some cases, be potentially fatal. It is endemic to the north west of Western Australia where there is annual activity and may occasionally occur in the western areas of NSW and northern Victoria if climatic/environmental conditions are favourable. Kunjin virus (KUNV) can cause human disease with similar symptoms to MVE but no deaths have been reported in Australia resulting from this virus.

Dengue is currently considered one of the most important viral diseases transmitted by mosquitoes to humans in a world context. In Australia, most locally acquired cases of dengue occur only in North Queensland, particularly around Townsville and Cairns, where the vector mosquito, *Aedes aegypti* is abundant in the urban environments. Historically, both the mosquito vector and locally acquired cases occurred in NSW. However, in the mid 1950s, the distribution of the vector appears to dramatically decline and is currently not considered established south of Gladstone.

There has been some suggestion that the risk of dengue may return to far north NSW with an increase in suitable habitats for *Ae. aegypti* provided by the proliferation of rainwater tanks. The decline in rainwater tanks is often cited as a contributing factor in the decline of the species. However, there have been two detailed surveys in far north NSW, the most recent surveys were conducted in 2008, and have not found any evidence that the species is present in the local area.

Australia was declared malaria free in the 1980s and any cases reported from NSW are acquired overseas. There is no risk of malaria activity in the Byron region.

Table 7: Mosquito-borne pathogens that may be of concern in the Byron region

Pathogen	**Comments**
Ross River virus	Annual activity in the Byron Shire 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 thought to be macropods (i.e. kangaroos and wallabies).
Barmah Forest virus	Annual activity in the Byron Shire 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 rash tends to be more florid with BFV infection but the arthritic pain is greater with RRV infection. The primary animal hosts of BFV are thought to be birds but mammals also play a locally important role.
Sindbis virus Edge Hill virus Stratford virus Gan Gan virus	These mosquito-borne viruses may circulate locally between mosquito and animal populations within the Byron Shire region. Infection with these viruses may cause symptoms including myalgia, arthralgia and muscle fatigue, although there have been few confirmed human cases reported. These viruses are not considered a serious health concern.

Table 8: Mosquito-borne pathogens outside the Byron region

Pathogen[1]	**Comments**
Murray Valley encephalitis virus	There has been no recorded activity of this virus in the Byron Shire region. While there is typically annual activity in NW Australia, occasional activity may occur in NSW west of the Great Dividing Range. Symptoms include a sudden onset of fever, anorexia and headache, vomiting, nausea, diarrhoea and dizziness. Drowsiness, confusion, convulsions and neck stiffness may also be experienced. The disease can be fatal. The primary animal hosts of MVE are thought to be birds.
Kunjin virus	There has been no recorded activity of this virus in the Byron Shire region. While there is typically annual activity in NW Australia, occasional activity may occur in NSW but is extremely rare in coastal regions. Symptoms are similar to MVE but no deaths have been reported. The primary animal hosts of KUNV are thought to be birds.
Dengue viruses	While historically dengue viruses may have been transmitted locally, there is no current risk posed by these viruses in the Byron Shire region due to the absence of mosquito species capable of transmitting dengue viruses. However, travellers returning from overseas may be diagnosed by local health authorities.
Malaria	There is no current risk posed by this parasite in the Byron Shire region. Australia has been declared malaria free by the World Health Organisation (WHO). However, travellers returning from overseas may be diagnosed by local health authorities.

[1] These disease-causing pathogens are not known from the Byron region. However, travellers returning from interstate or overseas may present themselves to local health authorities and/or media reports on these pathogens may raise concern in the local community.

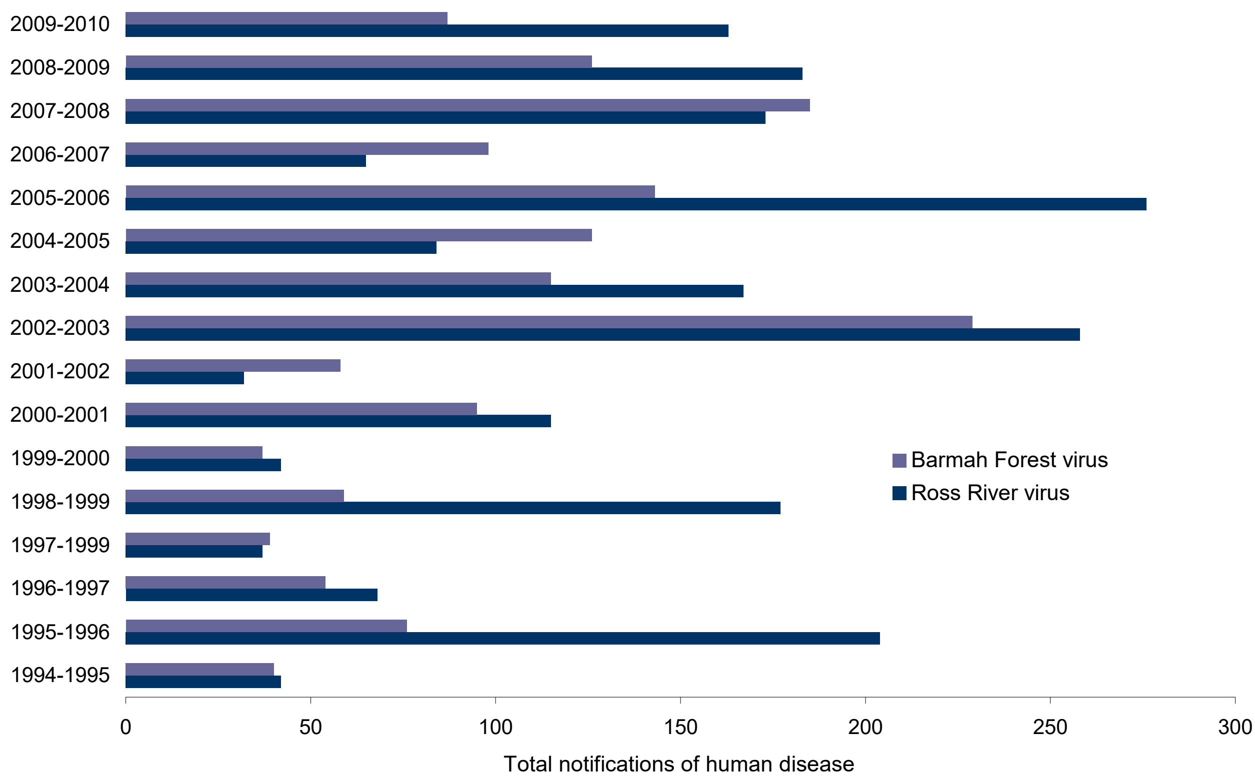

Figure 9. Mean number of human disease notifications resulting from Ross River virus and Barmah Forest virus in the Northern NSW Area Health District, 1994-1995 through 2009 – 2010. (source: NSW Arbovirus Surveillance Program)

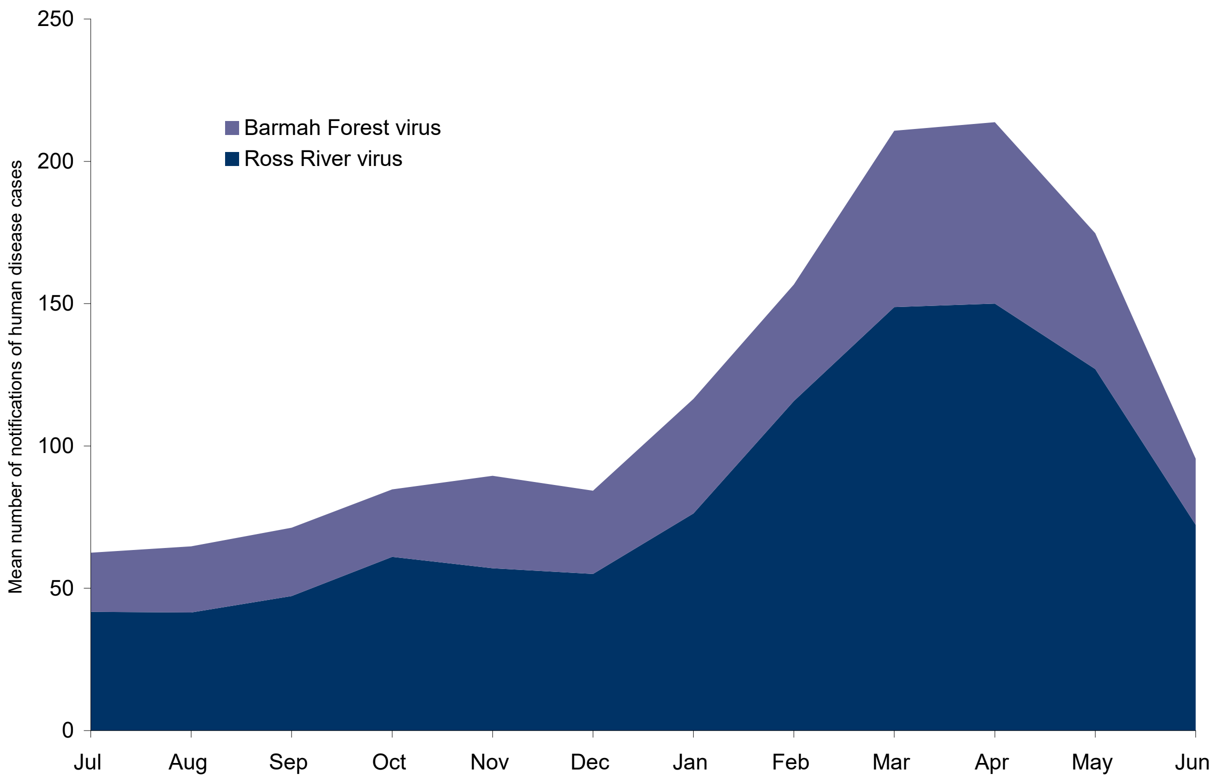

Figure 10. Mean number of human disease notifications resulting from Ross River virus and Barmah Forest virus in NSW, 2005 – 2011. (source: NSW Arbovirus Surveillance Program)

Figure 11. Total number of human disease notifications resulting from Ross River virus at Byron, Tweed and Ballina, 2005 – 2011. (source: NSW Arbovirus Surveillance Program)

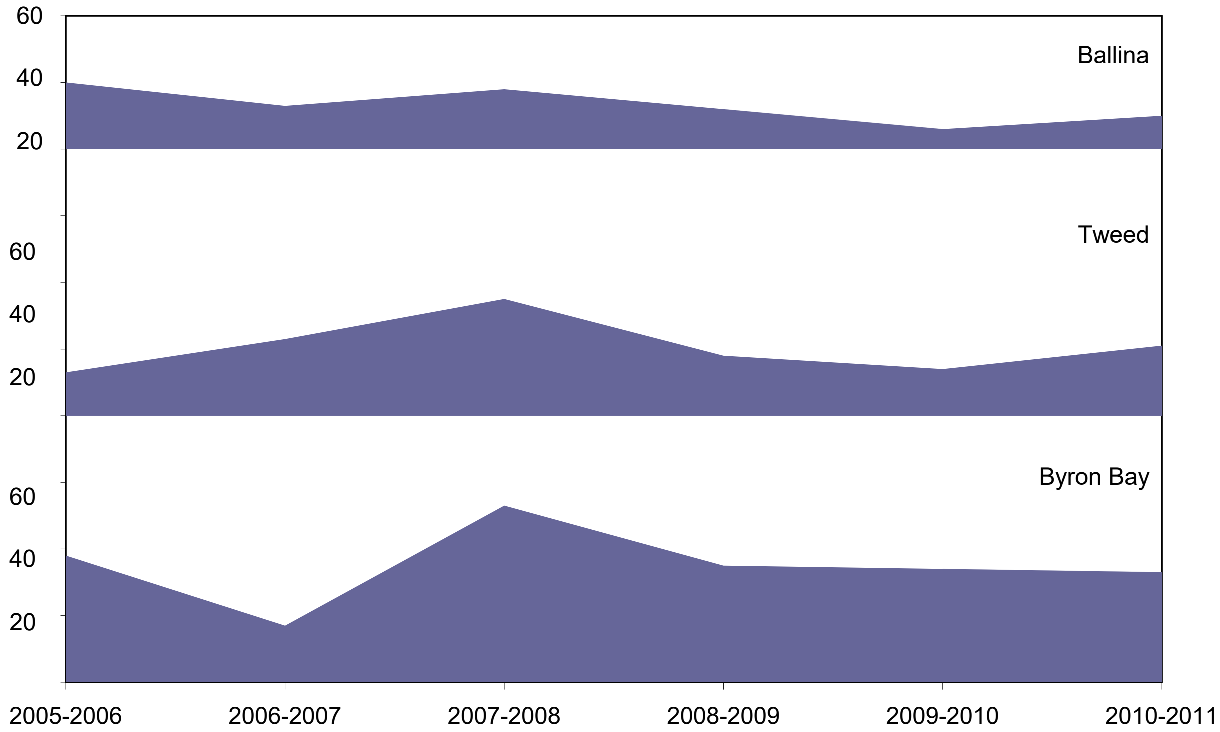

Figure 12. Total number of human disease notifications resulting from Barmah Forest virus at Byron, Tweed and Ballina, 2005 – 2011. (source: NSW Arbovirus Surveillance Program)

Table 9. Arbovirus isolates from mosquitoes collected in the Far North Coast region in the NSW Arbovirus Surveillance and Mosquito Monitoring Program, 1989-2011.

Arbovirus isolated	Mosquito species	Number	Location	Season
Stratford virus	*Aedes notoscriptus*	1	Byron Bay	2009-2010
Stratford virus	*Aedes procax*	2	Byron Bay	2009-2010
unidentified[1]	*Aedes procax*	1	Ballina	2007-2008
Sindbus virus	*Coquillettidia variegata*	1	Ballina	2005-2006
Ross River virus	*Coquillettidia variegata*	1	Ballina	2004-2005
unidentified	*Coquillettidia xanthogaster*	1	Ballina	1998-1999
unidentified	*Aedes multiplex*	1	Ballina	1998-1999
unidentified	*Culex sitiens*	1	Ballina	1998-1999
Edge Hill virus	*Aedes procax*	1	Ballina	1994-1995
Sindbus virus	*Culex sitiens*	1	Ballina	1993-1994
unidentified	*Culex sitiens*	1	Ballina	1992-1993
unidentified	*Culex sitiens*	1	Ballina	1992-1993
unidentified	*Culex annulirostris*	1	Ballina	1992-1993
unidentified	*Culex sitiens*	1	Ballina	1992-1993
Ross River virus	*Verrallina. funerea*	2	Ballina	1991-1992
Ross River virus	*Aedes vigilax*	1	Ballina	1991-1992
unidentified	*Culex sitiens*	1	Ballina	1991-1992
Ross River virus	*Verrallina funerea*	1	Ballina	1991-1992
unidentified	Pooled sample[2]	1	Ballina	1991-1992
unidentified	*Culex orbostiensis*	1	Ballina	1989-1990
unidentified	Pooled sample[3]	1	Ballina	1989-1990

[1]Virus was present in the sample of mosquitoes but was not identified as one of the major Alphaviruses or Flaviviruses
[2]Pooled sample containing *Aedes alternans*, *Aedes multiplex*, *Culex australicus*, *Culex orbostiensis*, *Ve. funerea*.
[3]Pooled sample containing *Aedes multiplex*, *Cq. xanthogaster.*

9. MOSQUITO MANAGEMENT STRATEGIES

9.1 Mosquito monitoring

Mosquito monitoring should form the basis of the mosquito management plan in Byron Shire. The provision of reliable information on mosquito populations, as well as mosquito-borne disease activity, will be crucial in shaping mosquito management strategies. However, it is important to note that monitoring alone does not "control" mosquito populations. Monitoring strategies should be designed to determine the changes in relative mosquito abundance, as well as activity of arboviruses, that can then be used to assist the design of other strategies including community awareness programs and management of urban planning.

To monitor the activity of pest mosquitoes and assess the impact of control strategies, adult mosquito populations should be sampled on a weekly basis between December and April. Adult populations should be sampled using dry-ice baited Encephalitis Vector Surveillance (EVS) traps operated at fixed sites. 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, thinking the trap may actually be an animal, a small light serves as a focus and a battery operated fans blows the incoming mosquitoes into a catch bag). Traps are usually set in the late afternoon and collected the following morning. Collections may be influenced by wind and rain but, if appropriate adult trap site are selected, the influence of these factors can be minimised while optimising mosquito collections.

Mosquito monitoring can provide important information on the activity of pest species and provide triggers for public health warnings and an assessment of any mosquito control activities. Importantly, adult surveillance can identify species creating a pest nuisance in the community that are not being produced from particular sites and this provides for optimal strategic approaches to mosquito management.

The NSW Arbovirus Surveillance and Mosquito Monitoring Program commenced in the summer of 1984/85 with the program designed to cover the period of seasonal increase and decrease in the populations of the major arbovirus vectors, from mid-spring to mid-autumn, and also to cover the period for natural activity and transmission of arboviruses (especially the alphaviruses and the flaviviruses). The program provides a laboratory resource to enhance data collected from local mosquito surveillance programs

The processing of mosquito collections for virus infection can greatly assists mosquito management by identifying locally significant viruses and vector species that can inform mosquito management policy decisions, and the surveillance of mosquito and arbovirus activity can provide an early warning of arbovirus activity and an increased risk of human disease, allowing local authorities the option of undertaking mosquito control activities and issuing public health warnings.

Detailed information on a range of mosquito surveillance techniques including sampling techniques for larval, pupal and adult populations is included in the Australian Mosquito Control Manual (Mosquito Control Association of Australian 2009), Mosquitoes and Mosquito-Borne Disease in South-eastern Australia (Russell 1993) and Mosquito Ecology Field Sampling Methods 3rd Edition (Silver 2008).

An example of the mosquito trap used to collect mosquitoes for monitoring purposes. Such traps offer limited assistance with regards to reducing mosquito numbers.

9.2 Habitat modification

Advances in habitat modification techniques have shown that the suppression of mosquito populations is possible without reliance on chemical control or jeopardising the flora, fauna or ecological function of the wetland itself. However, 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.

Strategies to reduce the productivity of mosquito habitats without the use of control agents is generally directed towards the manipulation of water flows and/or vegetation to reduce the suitability of the habitat for mosquito production. In urban environments, source reduction is generally directed towards habitats such as sullage pits, drains, guttering, backyard containers and other areas where water is retained for long periods of time.

In estuarine wetlands, the primary objectives of habitat modification is to increase the frequency of tidal flushing, improve the drainage of water and maximise access of fish to mosquito habitats to minimise production of saltmarsh mosquitoes. The most common form of habitat modification currently practiced in saltmarsh habitats for mosquito control is runnelling, the construction of shallow, spoon-shaped channels (generally less than 300mm deep) that connect pools and depressions on the saltmarsh and allow improved exchange of tidal water over the marsh.

Studies in Australia have shown that the construction of runnels has significantly reduced mosquito breeding when compared to pre-runnelling sampling and non-runnelled habitats, and there have been very few adverse impacts on the estuarine wetland reported. However, due to changes in the soil moisture of the runnelled area, a reduction in the suitability of the habitat immediately surrounding the runnel for the grapsid crab, *Helograpsus haswelliannus*, has been identified in southeast Queensland saltmarshes. It is also important to note that, as runnels promote increased tidal inundation of the saltmarsh, there is the potential for increased mangrove propagule dispersal and, consequently, mangrove colonisation at higher elevations on the marsh – potentially threatening the overall area of saltmarsh.

When tidal exchange within estuarine wetlands is restricted through human interference or natural sedimentation processes, the wetlands may become degraded. Restricted tidal flows may contribute to increased mortality of vegetation, increased sedimentation and blocked drainage channels. Lack of drainage from these habitats following substantial tidal and/or rainfall inundation often results in extensive inundation of habitats and facilitates the production of mosquitoes. In habitats with restricted drainage, the construction of channels through degraded mangrove habitats has been shown to increase the frequency of tidal inundation and increase the volume of water flushing the habitats, resulting in a substantial reduction in mosquito populations.

In coastal swamp forests, there are limited opportunities for habitat modification and there are no well documented examples of strategies to reduce mosquito productivity from these habitats in Australia. In situations where urban runoff may be contributing to a greater extent of flooded habitats, measures to reduce the quantity of runoff may reduce the productivity of habitats. However, as the productivity of these habitats is driven primarily by temporal rainfall patterns, it may be difficult to develop a strategy that consistently achieves a noticeable reduction in mosquito productivity.

Mosquito production from natural and constructed freshwater wetlands is dependent on a combination of physical and vegetative characteristics. Aquatic vegetation management is the most useful strategy for mosquito management in these habitats. When wetlands contain large areas of open water and vegetation at the margin is sparse, wind/wave action is relatively high and predatory fish have unobstructed access to larvae – all these contribute to a reduction in larval populations but may not completely eliminate mosquito production.

In urban environments, structures associated with stormwater retention (e.g. inlet pits, sullage pits or gross pollutant traps) or drains may contain free-standing water that persists and provides suitable habitats for some mosquitoes. The production of mosquitoes from these areas can be avoided by ensuring that the structures are self draining, have the siltation depth shallow enough to encourage evaporative drying, and that the accumulation of organic material is maintained at low levels. Also, smaller structures as part of domestic drainage (eg. courtyards, pool areas, driveways, car parks etc) should have the same principles of design. In addition to the design of these drainage structures, a routine maintenance program is essential to remove the inevitable buildup of organic material (leaves and other plant material, sediment and general rubbish) that can create blockages and, subsequently, opportunities for mosquito breeding.

9.3 Mosquito control agents

Under the *Pesticides Act 1999*, it is illegal to use a pesticide in NSW unless it is registered by the Australian Pesticides and Veterinary Medicines Authority (APVMA) for agricultural and veterinary chemicals, or covered by permit issued under the *Commonwealth Agricultural and Veterinary Chemical Code Act 1994*.

Products currently registered for use in Australia for mosquito control include:

9.3.1 Adulticides. Generally permethrin or synthetic pyrethroid based, adulticides are typically applied as either a “fog” or “mist” delivering very small droplet sizes or are applied to the sides of buildings or surround vegetation to form a barrier. Adulticides can be expensive, their effectiveness is dependent on favourable weather, multiple treatments are often required and potential non-targets are a concern, so the use of adulticides is not common in Australia but may be required during epidemics of mosquito-borne disease.

9.3.2 Temephos. An organophosphate compound that has been used in mosquito control since the early 1950’s but as is not totally selective for mosquitoes, may have toxic effects on non-target organisms and as there are concerns regarding the development of resistance in target species, local mosquito control authorities have reduced the use of temephos in favour of alternative control agents. However, for the treatment of water holding containers where contact with non-target organisms is minimal, such as tyre piles, this product may be appropriate.

9.3.3 Bacillus thuringiensis israelensis. The naturally occurring soil bacterium *Bacillus thuringiensis israelensis* (*Bti*) produces a protein crystal which contains a number of microscopic pro-toxins that when ingested are capable of destroying the gut wall and killing mosquito larvae. This is the most common larvicide used in Australia and despite broadscale use in many estuarine and freshwater habitats, no direct or indirect non-target impacts have been reported.

9.3.4 Methoprene. 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 B.t.i. may not be as effective. There are commercial sustained release formulations of this product available that may provide residual control of mosquitoes for up to three months

9.3.5 Monomolecular film. A thin film of alcohol or silicone based product is spread over the water surface and prevents immature mosquitoes emerging as adults. Monomolecular films have only recently been registered for use in Australia and, due to unresolved concerns regarding possible non-target impacts (i.e. macroinvertebrates that use the air-water interface) this product is only registered for use in water holding containers in domestic situations.

9.4 Barrier treatments

A relatively new strategy for protection against adult mosquito populations is through the treatment of mosquito harbourage sites with a residual insecticide. These treated areas then create a “barrier” between residential and/or recreational areas and mosquito habitats.

The product most commonly used for this purpose is the synthetic pyrethroid bifenthrin. The product provides a residual layer of pesticide that kills resting mosquitoes and is currently registered for treating mosquito resting places (internal & external areas of domestic, commercial, public and industrial buildings). However, there are some environmental concerns surrounding the widespread use of this product, in particular for non-target insects and aquatic organisms. There are warnings on the label that the product is toxic to bees, fish and aquatic organisms and that mud, sand, mangroves and other aquatic habitats should not be directly treated or exposed to spray drift.

As with all adulticides, targeting adult populations rather than larval (immature) populations will be less effective, particularly for pest mosquitoes such as the saltmarsh mosquito that can disperse widely from breeding habitats. While barrier treatments may provide protection in the immediate surrounds of a treated dwelling, they will not reduce mosquito impacts beyond the treated area.

9.5 Biological control

A number of organisms have been investigated to determine their suitability as effective predators of mosquitoes. These include aquatic invertebrate (e.g. Diptera and Coleopteran larvae, Crustaceans, Notonectids, Odonates) and vertebrate (fish) predators of immature mosquitoes. 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.

A number of native fish have been identified that may be appropriate for mosquito control in Australia. The most likely candidates are *Pseudomugil signifer* (Pacific Blue-eye), *Hypseleotris compressa* (Empire Gudgeon), *Hypseleotris galii* (Firetail Gudgeon) or a range of *Melanotaenia* species (Rainbowfish). While native fish introductions alone will not significantly reduce mosquito populations, they do provide an important component of integrated mosquito management and have been shown to provide a valuable link to the wider community promoting environmentally sensitive mosquito management.

Tadpoles are often mistakenly promoted as effective predators of mosquito larvae, but most are general herbivores and suspension feeders and there is little evidence that effective control of mosquito larvae can be achieved. Recent studies have shown that, although tadpoles of *Limnodynastes peronii*, *Limnodynastes tasmaniensis*, *Litoria aurea* and *Litoria peronii* consume mosquito larvae in small containers, there is no evidence that they are actively preying on immature mosquitoes.

Insectivorous bats have been proposed as a potential tool in reducing adult mosquito populations. However, although these microbats have been shown to eat mosquitoes, there is no evidence that they offer any substantial control of local pest mosquito populations.

9.6 Mosquito repellents

The use of personal insect repellents is the first line of defense against biting mosquitoes and, consequently, mosquito-borne disease. A summary of the registered active ingredients found in insect repellents and their relative protection times are summarized in Table 9. These products are available in a wide range of formulations, including aerosols, creams, lotions, pump sprays and sticks. Regardless of the formulation, the most effective products are those that contain at least 20% DEET (diethyl toluamide or N,N-diethyl-3-methylbenzamide) or Picaridin, two chemicals known to be effective insect repellents.

DEET was originally released to the public in 1957, and has been shown to be effective in repelling many species of mosquitoes in both laboratory and field trials worldwide. The chemical repels mosquitoes by confounding their sensory organs and inhibiting their host seeking stimuli. When applied according to manufacturers recommendations, there are no serious side effects to the use of DEET. Picaridin was developed more recently and it also has shown similarly good repellency against a range of mosquitoes and other biting insects, and is widely available in various formulations.

As well as DEET and picaridin, there is another product that may provide effective protection against biting insects. PMD (registered in Australia as "extract of lemon eucalyptus being a modified acid of C*orymbia citriodora*") is not an essential oil product but rather a chemical derived from the distillation of the lemon eucalyptus plant. In Australia, it is currently only available in a 30% formulation. This product has been tested overseas and has been shown to be as effective as low dose DEET or picaridin products.

The decision of which formulation is most appropriate is probably best made by the individual but the key point to remember is that, for complete protection, the entire surface of exposed skin must be covered. For this purpose, sprays are often effective for arms and legs while creams and towelettes are good for the face. Some repellents are available as patches or plastic wrist bands but these only offer limited and localised protection (i.e. if any protection is provided, it is generally only immediately around the product). However, when used in combination with other repellents (or long-sleeved shirts), wrist bands may be worth a try for those wanting to avoid getting repellent on their hands.

Increasingly, manufacturers are looking to combine insect repellents with other cosmetics including sunscreen and skin moisturizers. Studies have shown that the combination of sunscreen with repellents does not reduce repellency. However, there can often be confusion over the recommended use of these products with sunscreen requiring reapplication every two hours, a higher reapplication rate than would otherwise be recommended for some repellents with a high DEET concentration. In most circumstances, the reapplication of a low dose DEET-based repellent combined with sunscreen every two hours will offer the best protection against both UV radiation and biting insects without unnecessary or excessive applications of repellent.

There is a large quantity of repellents available that contain ‘natural’ compounds derived from plants, including eucalyptus, tea-tree, catmint and citronella extracts. While such products are available for individuals wishing to avoid so-called ‘chemical’ repellents, it should be recognized that they also are chemicals and some persons will find they cause skin irritations. More importantly, however, they generally offer substantially lower protection times when compared to those containing DEET and will therefore need to be reapplied more frequently to provide protection.

A range of live plants (e.g. *Citronella geranium*, *Leptospermum* spp., *Chrysanthemum* spp.) are often marketed as mosquito repellents, with claims they are suitable for keeping mosquitoes away from outdoor areas where they have been planted. The basis for these claims is that these plants contain strongly aromatic oils that may have some mosquito repellent qualities, but studies have shown that these plants offer no useful protection from mosquitoes.

In addition to mosquito repellents that can be applied directly to the skin, there are a range of products including to coils, sticks and other ‘burner’ devices that purport to repel mosquitoes. These products are impregnated with an insecticide (usually a pyrethroid) that is released when heated, either by burning (coils and sticks) or heated by a small electrical unit (vaporising mat). These products are generally designed for indoor or sheltered outdoor areas and should be used as directed. Prolonged use in confined spaces should be avoided as some respiratory problems may result.

While there is demand from the community for repellents, particularly alternatives to topical creams and lotions, entrepreneurs will always be looking to make a quick dollar or two. While not always common in Australia, products often pop up that purport to use sound to repel mosquitoes. These gadgets can range from key ring sound emitters and plug in “sonic” devices to mobile phone ring tones and wrist watches. There is no scientific basis to these claims and scientific trials have repeatedly shown that these units are not effective.

Table 10. Registered topical mosquito repellents and their estimated reapplication times[1] in Australia.

Mosquito repellent	**Concentration**	**Estimated reapplication times[2]**
Diethytoluamide (DEET)	<10%	2 hr
	10-20%	3-4 hr
	20-40%	4–6 hr
	80%	As required
Picaridin	<10%	2 hr
	10-20%	3-4 hr
Extract of Lemon Eucalyptus (PMD)	30%	2 hr
Eucalyptus oil	<10%	1 hr
Melaleuca oil	<10%	1 hr
Citronella oil	<10%	1 hr
Blend of botanical extracts	<10%	1 hr

[1] Estimated reapplication times are based on mean protection times recorded in laboratory tests conducted against *Aedes aegpyti*.
[2] It is advised that repellents be reapplied as soon as any biting mosquitoes are noticed. The estimated reapplication times can be influenced by an individual's activity, climatic conditions and local mosquito populations. However, over application of a repellent will not increase protection times.

9.7 Mosquito traps and other gadgets

A number of commercial trapping units are available that utilise attractants (e.g. light, heat, carbon dioxide, odour, etc.) to catch and/or kill adult mosquitoes. There are many different types of units available and, while many will collect mosquitoes, there is no quantitative evidence that they can reduce nuisance biting impacts or public health risks. 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) than mosquitoes.

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. The larger units that convert propane to carbon dioxide are most effective, collecting greater numbers of mosquitoes than units that have a low release rate of carbon dioxide, use light as the main attractant or rely on sticky paper to collect the mosquitoes.

While these units may offer some limited protection for individual homeowners, a network of multiple traps would need to be employed to completely protect a large area from exposure to mosquitoes and there is no information available in Australia regarding the design of effective trapping networks to achieve such an objective.

These products usually fail to offer complete protection because they do not compete adequately with the stimuli of a living, breathing human. While some of the components of overall human attractiveness can be broken down and replicated, and used in such devices, these individual components will rarely be as attractive as the whole package (i.e. a human) itself.

9.8 Legislative requirements

There is currently no legislation in place that makes it mandatory for local governments to control mosquito populations in NSW. However, mosquito control activities are typically undertaken by local governments in NSW while in other states, health authorities may play a role as coordinators or funding providers.

NSW Health does not have a specific policy on mosquito control. However, the NSW Arbovirus Disease Control Strategy Green Paper (1998) states that mosquito management should be directed towards reducing the risks of disease transmission through the reduction of mosquito populations as opposed to their complete elimination and there is an acknowledgement that there may be considerable ongoing financial outlays for local councils undertaking mosquito control.

In NSW, there is legislation in place that will influence many of the possible mosquito management strategies available. A recent paper by Webb, Prichard, Plumb and Russell (2009) titled “How does legislation influence mosquito-borne disease management in New South Wales?” appeared in Arbovirus Research in Australia, 10: 176-182.

Some examples of legislation that may influence mosquito management strategies include:

9.8.1 State Environmental Planning Policy No 14—Coastal Wetlands. The aim of this policy is to ensure that the coastal wetlands are preserved and protected against clearing, draining, filling or any other form of habitat modification except with appropriate consent.

9.8.2 Fisheries Management Act 1994. The Act aims to conserve NSW fishery resources by protecting habitats, conserving threatened species, populations and communities and encouraging ecologically sustainable development. Approval must be sought for mosquito management strategies that may impact on fisheries including the construction of runnels, removal of mangroves or other aquatic vegetation, regulation of natural tidal flows and introduction of fish.

9.8.3 Threatened Species Conservation Act 1995. Habitats that are listed as Endangered Ecological Communities (e.g. coastal saltmarsh) are protected to conserve biological diversity and promote ecologically sustainable development by protecting the threatened ecological communities, and eliminate or manage certain processes that threaten the species, populations and communities. Any mosquito control activities in these habitats will require a licence.

9.8.4 Environmental Planning and Assessment Act 1979. This Act aims to provide protection of the environment, including the conservation of native animals and plants, including threatened species, populations and ecological communities, and their habitats by encouraging ecologically sustainable development. Mosquito management activities on NPWS property will be required to be assessed under Part 5 of this Act (Environmental Assessment) to determine if there is likely to be a significant impact on ecological communities and their habitats.

9.8.5 Pesticides Act 1999. Under this Act it is illegal to use a pesticide in NSW unless it is registered by the Australian Pesticides and Veterinary Medicines Authority (APVMA) or covered by permit issued under the *Commonwealth Agricultural and Veterinary Chemical Code Act 1994*. There are a number of rules under this Act that relate to the training and record keeping associated with commercial pesticide use, including individuals employed by local council, government agency or statutory authorities. Pest management technicians must have a Certificate of Competency issued by Workcover NSW who administers safety laws to ensure that their staff and the people who use their services are not adversely affected by pesticides under the *Occupational Health & Safety Regulation*

2001 and the *Occupational Health & Safety Act 2000.* The *Pesticides Regulation 2009* requires public authorities, such as local councils and government agencies, to notify the community when they use pesticides in public places (e.g. recreational parks, sporting fields, national parks, State forests, Crown land or any public land owned or controlled by a public authority such as road verges). Notification will be via a pesticide use notification plan that lists the name of the pesticide, location where it will be used, dates when it will be used, the purpose of the pesticide's use and any relevant warnings on the label.

9.8.6 Native Vegetation Conservation Act 1997. This Act provides for the conservation and management of native vegetation on a regional basis and encourages the rehabilitation and revegetation of land with appropriate native vegetation. Consideration should be given to this Act when considering any mosquito habitat modification (i.e. creation of vegetation free buffer zones).

9.9 Ecological effects of mosquito control programs

There is considerable debate surrounding mosquito control in NSW, particularly since the major nuisance-biting pest and arbovirus vector is associated with coastal saltmarsh, itself an endangered ecological community protected by legislation. There is strong evidence (from both laboratory and field testing) indicating that the commonly used mosquito control agents in Australia (i.e. *Bti* and methoprene) have little impact on water quality and very few non-target impacts when used at the recommended application rates as advised by the APVMA. Studies have found that these control agents had no significant impact on shrimp (*Leander tenuicornis*) or fish (*Melanotaenia duboulayi, Pseudomugil signifer*) that may be found in the same habitats as saltmarsh mosquitoes.

When direct non-target impacts have been recorded, it is generally only when the control agents are applied at substantially higher rates than recommended. It is important to note that some scientific publications may report direct non-target impacts of these larvicides against some organisms, but the simulated 'application rates' in laboratory trials substantially exceed the levels approved by the APVMA for field use (e.g. thousands of times the recommended quantity of larvicides would need to be applied to cause direct non-target impacts).

There are considerable gaps in our knowledge of coastal wetland ecosystems and the design of mosquito control programs will greatly benefit from an increased understanding of invertebrate fauna, their biology, ecology and spatial and temporal distribution. There are few published studies that have investigated the indirect impact to the wider environment of an ongoing significant reduction in adult mosquito populations resulting from a broad scale mosquito control program. Without local long-term studies, or quantitative studies identifying the relative importance of mosquitoes as specific components of the ecosystem (e.g. as a food source, pollinator or nutrient recycler), it is difficult to accurately assess the indirect environmental impacts of mosquito control programs. With year to year fluctuations across a range of environmental variables, natural changes in the abundance, diversity and behaviour of local wildlife will further complicate these assessments.

Most importantly, a balance must be assessed between any potential ecological impacts of mosquito control activities and the benefits to public health through a reduction in mosquito populations. These are decisions that must be made in conjunction with local stakeholders including Byron Shire Council, NSW Health and NPWS/OE&H.

10 BITING MIDGES

10.1 What is a biting midge?

The term biting midge describes a group of biting flies closely related to mosquitoes that belong to the Family Ceratopogonidae (Order: Diptera). In Australia these insects are often mistakenly referred to as sand flies but true sand flies do not occur in Australia, they belong to a group of biting insects in the subfamily Phlebotominae (Family Psychodidae) and are significant pests and vectors of human disease (e.g. leishmaniasis) in other countries.

Adult biting midges are very small, typically less than 4mm in length and generally a dark colour. They have two wings, six legs and their body is divided into three main sections, the head, thorax and abdomen. They have specialised mouthparts designed to facilitate the piercing of skin and allowing bloodfeeding. They are characteristically more robust than mosquitoes and often have a distinctive pattern of dark and light grey colouration on their wings that enables the identification of each species.

Biting midges can be found in a wide range of aquatic and semi-aquatic estuarine and freshwater environments. The major pest species are typically found within coastal estuaries with species specific habitat associations typically classified according to substrate type (sand or mud) and tidal elevation (usually relative to the height of the neap and spring tides). While estuaries provide suitable habitat for pest midges, coastal developments featuring canal estates can enhance these conditions for biting midges.

10.2 Public health risks of biting midges

In Australia, biting midges are not associated with the transmission of any disease-causing pathogens to humans but their nuisance-biting impacts they cause can be severe. Many people react far more severely to bites caused by biting midges than to bites from other common nuisance-biting pests such as mosquitoes.

It is a common myth that biting midges urinate when they bite and that their urine causes the severe irritation associated with their bites. This is not true. The irritation resulting from a bite, as is the case with mosquitoes, is the result of a reaction to their saliva. Unlike the long mouthparts of mosquitoes, the short mouthparts of biting midges do not allow them to penetrate small blood vessels when they feed. They compensate for this by lacerating the tissue underlying the skin at the site of the bite and then feed on the blood and tissue fluids which pool in the damaged area.

The severity of the reaction to a bite can vary between individuals, in general there is swelling at the bite site with redness extending up to a centimetre or more around a central blister. The bites can be extremely itchy and may persist for several days. Scratching due to the itchiness can lead to secondary bacterial infection that further inflames the site and may lead to scarring.

10.3 Pest species of biting midges

The most common nuisance biting pest species in the local area is generally thought to be *Culicoides molestus,* a species typically associated with sandy soils in open areas, such as tidally influenced river foreshores and sandbars, or beneath sparse mangrove canopy between the mean tide level and mean high water spring tide level. This species is a serious pest associated with the beaches of artificial canal developments in south-east Queensland and the far north coast of NSW.

Culicoides subimmaculatus (this name applies to a group of morphologically similar species) is found in coastal areas of northern NSW, most commonly in association with clean to muddy sand in the open or under light mangrove cover between high water neap and high water spring.

When abundant, *Culicoides longior* can be a serious pest and is closely associated with fibrous mud beneath mangrove cover between the high water neap and high water spring tide levels.

Another species of note, that is not currently known from the Byron Shire, is *Culicoides ornatus*. This species is associated with estuarine wetlands and is considered the most important nuisance-biting species in northern Australia due to its widespread distribution, the large numbers in which it can occur and its habit of actively dispersing for kilometres away from its breeding habitats. It has recently spread along many of the tidal waterways of the Brisbane River in southeast Queensland creating localised severe nuisance-biting problems. This species has the potential to cause similar problems in the Byron region.

10.4 Management of biting midges

Control of biting midge populations is extremely difficult and there are very few cost effective and/or environmentally friendly strategies available. The two most commonly employed strategies include the use of insecticides, either targeting the adult or immature midge populations, or habitat modification. Unfortunately, these strategies may not be appropriate for ecologically sensitive estuarine environments.

The use of barrier treatments, the application of a residual insecticide (most commonly deltamethrin or bifenthrin) to the outside of dwellings and/or surrounding vegetation, to protect residential properties close to biting midge habitats has become common. Specific vegetation or barriers of fabric have also been installed and treated to assist the effectiveness of this strategy. While this strategy has been shown to provide a reduction in local nuisance-biting impacts, the potential non-target impacts (e.g. moths, butterflies, beetles and bees) and the risks involved in potential contamination of nearby nature wetlands should be given due consideration. Any treatment around the home must be undertaken by a licensed pest control operator.

To protect residents from the impacts of biting midges around their homes and properties, a number of strategies can be implemented. Keeping vegetation around the property to a minimum will reduce the availability of suitable refuge areas of adult biting midges, reduce the localised abundance of the insects and assist is reducing nuisance-biting. All doors and windows should be fitted with insect screens to stop entry of biting midges and, additionally, fly screens can be treated with a residual insecticide that provide additional protection.

Avoid outdoor activity during peak periods of biting midge activity but if outdoors at these times, wear light loose fitting clothing along with an insect repellent containing either diethyltoluamide (DEET) or picaridin. These repellents can assist in preventing biting midge bites and, although there are far few scientific studies assessing the effectiveness of repellents against biting midges compared to mosquitoes, it is generally accepted that repellents that contain botanical based products offer substantially reduced periods of protection.

11. MOSQUITO AWARE URBAN DESIGN

11.1 Mosquito Risk Assessments

Mosquito Risk Assessments (MRA) can provide valuable information to local authorities on actual and potential mosquito impacts resulting from proposed urban developments and constructed wetlands. These assessments usually entail:

11.1.1 an evaluation of the existing mosquito habitats and populations within the vicinity of the site
11.1.2 the collection and identification of the species involved
11.1.3 detail on the risk each species poses with respect to pest nuisance or disease risk
11.1.4 an expert consideration of the proposed development with respect to its potential for producing mosquitoes or adding to any local mosquito populations and their associated problems or concerns and
11.1.5 the provision of expert opinion on these risks with recommendations for their minimisation.

11.2 Urban development approvals

The NSW coast has experienced rapid population growth in recent years with increasing demand for new residential developments. An increasing concern in these areas is the proximity of new residential and recreational developments to estuarine and coastal swamp habitats where mosquitoes may be abundant. Notwithstanding the environmental impacts of urbanisation, as humans are brought closer to mosquito habitats there is a greater likelihood of nuisance biting occurring and health risks increasing. New residents 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, these residents may be at a relatively greater risk.

In response to concern regarding mosquito impacts on the far north coast of NSW, both Ballina Shire Council and Tweed Shire council have produced Development Control Plans (DCP) specifically related to local biting insect populations (i.e. mosquitoes and biting midges). While it is unlikely that a land rezoning request or development application would be rejected on the basis of mosquito risk alone, it does provide a mechanism for the local authorities to ensure that developers turn their minds to the issue of mosquito-borne disease and the strategies to incorporate into their designs to minimise mosquito risk. It also provides new residents with a clear indication that these areas are prone to nuisance-biting and, potentially, mosquito-borne disease risks. Just as the community is made aware of environmental hazards such as coastal processes, flooding, soil instability, bushfire, contaminated land, sewage treatment works and high tension power lines, mosquito risk should be a similarly important consideration.

A key component of these plans is that that the services of a “competent and experienced medical entomologist” be incorporated into the consultancy team preparing development applications and rezoning requests.

11.3 Buffer zones

Buffer zones between urban developments and mosquito habitats are often raised as a possible strategy to assist in minimising the impact of nuisance-biting. However, there are no quantitative studies in NSW indicating the appropriate size or vegetation composition of effective buffers. Guidelines developed for buffer distances to preventing biting insect problems in Tweed Shire range from 50m to 1km, in Ballina Shire over 100m while in the Northern Territory, health authorities recommend that no residential developments should be within 1.6km for large uncontrolled mosquito habitat. However, effective buffer zone distances will be site specific and must be based on the abundance of locally important pest species.

For developments close to estuarine wetlands, it has to be recognised that *Ae. vigilax* is known to disperse many kilometres from larval habitats and buffer zones are not practical as a management option. However, pest mosquitoes associated with coastal swamp habitats, including *Aedes multiplex*, *Aedes procax* and *Ve. funerea,* disperse over much smaller distances and buffer zones should be considered as a valuable option.

Where buffer zones are considered appropriate, they should be maintained as clear or sparsely vegetated zones, so as to not provide continuous harbourage sites for adult mosquitoes and act as a corridor for adult mosquitoes moving between the larval habitat and the human population.

The basic principal of reducing harbourage sites close to residential areas is a worthwhile consideration in assisting in reducing nuisance-biting impacts. Minimising dense vegetation close to residential areas, particularly immediately surrounding buildings, will reduce the density of mosquitoes in close proximity to residents. These harbourage sites contribute to an increase in the pest impacts of mosquitoes by acting as cool humid refuges from which mosquitoes can disperse. As well as contributing to favourable habitat conditions that assist increased longevity of mosquitoes (and consequently increasing the risk of disease transmission), these harbourage sites can 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.

11.4 Building design

While some mosquito activity should be expected in outdoor areas, 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 where possible and maintained regularly. 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.

A fully enclosed, air conditioned building is less likely to be impacted by mosquitoes but before undertaking such a structural response in building design developers should weigh up the advantages of appropriately designed outdoor areas. Daytime mosquito activity will generally only be limited to the period between December and March and in the months before and after this period, mosquito activity will generally be limited to dawn and dusk. Outdoor areas should be designed to restrict the movement of mosquitoes into the indoor areas.

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.

Natural breeze or airflow from fans (e.g. ceiling or ground) can occasionally be employed to limit mosquito activity but such a strategy is unlikely to provide protection when mosquito populations are high.

The challenge in providing protection from mosquitoes in outdoor areas close to wetlands is addressing the conflicts between visual amenity and functionality of outdoor areas while minimizing contact with mosquitoes. A combination of permanent and temporary screened areas can be employed and with the incorporation of retractable and/or removable screens providing additional flexibility to respond to seasonal differences in mosquito activity.

There are an increasing number of options available for providing screening of outdoor settings including insect proof screens. Screening for sun protection (i.e. shade cloth) may also provide a physical barrier to mosquito movement but mesh sizes of more than 5mm x 5mm are likely to allow entry of mosquitoes. There is a range of options available for retractable and removable screens. The technologies currently used to provide adjustable shading for restaurants and commercial buildings may be adapted for use with insect screening. For temporary screening, there are a variety of options available to secure the insect screening that include press studs, velcro, magnets, hooks and spring clamps. However, loose fitting screening (e.g. no secure attachment to vertical sides) will not provide effective protection from mosquitoes. Any type of screening will pose a physical obstruction to mosquitoes but the more ‘complete’ the coverage the better protection provided.

There is no evidence that light intensity or colour plays a significant role in deterring mosquito activity within or nearby to dwellings. However, male mosquitoes and a number of other flying insects (e.g. chironomids) associated with the nearby wetlands may be attracted to lights. Chironomids in particular can occur in exceptionally large numbers and are attracted to lights and light coloured buildings. These insects do not bite but large accumulations of these insects can often cause a serious nuisance problem. Any external lighting around buildings and pathways should be directed towards the ground to minimise illumination of the buildings themselves. The use of lights on balconies and close to windows should be minimised.

11.5 Water sensitive urban design

The construction of stormwater management devices may provide opportunities for mosquitoes to breed onsite and the installation of rainwater tanks may also provide additional habitats for local mosquito species already closely associated with the urban areas of the Byron region.

There has been much debate recently surrounding the role of rainwater tanks in the abundance of local mosquito populations, activity of mosquito-borne disease and by providing habitats for exotic mosquito species that may be associated with the transmission of mosquito-borne diseases including dengue. There are, however, many other factors that will determine the introduction of exotic mosquitoes and diseases beside the installation of rainwater tanks alone.

Currently within Byron Shire, the main concern regarding rainwater tanks is that they may increase the available habitat for *Ae. notoscriptus*. Notwithstanding the nuisance-biting of this species, it has been shown to play a potentially important role in the transmission of both BFV and RRV.

Rainwater tanks have historically been identified as locally significant mosquito habitats. However, these tanks vary dramatically from modern tanks that 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.

NSW State Environmental Planning Policy No. 4 states that rainwater tanks must be maintained at all times so as not to cause a nuisance with respect to mosquito breeding but there are no specific standards relating to mesh size on inlets that prohibit mosquito entry. Similarly, NSW Health recommends all entry points to the water tank be sealed or screened to prevent mosquito breeding.

In Queensland, where dengue mosquitoes have been shown to be associated with unscreened rainwater tanks, regulations (Queensland Health Regulation 1996, Part 8 Mosquito Prevention and Destruction) specify that brass, copper, aluminium or stainless steel gauze not coarser than 1 mm should be fitted to all openings.

The most important consideration is that tanks are properly installed and that any openings (such as inflow, outflow and access points) are completely screened to prevent entry by mosquitoes. Similarly, during maintenance checks of tanks, screens should be checked to ensure that they're intact.

11.6 Wildlife corridors

When designing the layout of new residential developments, some consideration should be given to the likely movement of wildlife through and around the site in environmental management zones. Wildlife conservation is an important consideration in urban design but it must be noted that frequent movement of macropods, that are considered locally important reservoir hosts of RRV and BFV, through the area may increase the relative risk of mosquito-borne disease transmission.

11.7 Constructed wetlands

Constructed wetlands are becoming increasingly common in coastal regions of NSW. Freshwater wetlands are usually associated with urban developments and designed for stormwater treatment, waste water treatment and/or water storage, with side benefits for wildlife conservation, passive recreation, community education and aesthetic appeal. These wetlands are generally small but given their proximity to the community, may increase the relative risk of mosquito impacts. Estuarine wetlands usually are constructed to maintain local saltmarsh habitat, primarily for its conservation value, and also are generally small but they can provide additional habitats for estuarine mosquitoes.

The management strategies required to address the mosquito risks associated with constructed wetlands are often site-specific. However, there are general design, construction and maintenance principles that can be incorporated into wetland management to minimise mosquito production. Most importantly, the strategies of mosquito management have to be balanced against other requirements such as public safety, water quality and wetland function.

Constructed freshwater wetlands may range from small, simple linear wetlands to large complex multi-component systems. Mosquito management in these systems, whether large or small, is often constrained by the essential requirements of the wetlands to meet specific purposes. Wetlands are typically located close to urban areas, contain (or at least receive) polluted water, include large areas of shallow, slow moving water and thick vegetation and have gently sloping banks. To meet these requirements, site-specific compromises must be implemented into the design, construction and maintenance of the wetland.

Mosquito populations are minimised where waterbodies are relatively deep, steep sided support endemic mosquito predators (e.g. fish), contain areas of open water and are sparsely planted with emergent aquatic vegetation. However, while the initial design of water bodies may adhere to these requirements, the ongoing growth of vegetation, bank slumping, physical disturbance, accumulation of rubbish and debris, sedimentation, water quality deterioration, water management problems and general climatic conditions will all influence the production of mosquitoes.

From a mosquito management perspective, the most important feature of the constructed freshwater wetlands is the macrophyte zone. This area of a wetland is typically shallow and as vegetation increases and/or accumulated debris or filamentous algal growth restrict water movement, suitable conditions for mosquito production may occur. As vegetation is often a crucial component of constructed wetlands, the incorporation of macrophyte zones can be designed to minimise mosquito populations by locating them in areas surrounded by deeper water or separating sections of dense vegetation by areas of deep water.

There is limited information available on the associations between specific vegetation types and the suitability for mosquito breeding. More structurally diverse stands of vegetation assist the minimisation of mosquito populations by promoting a greater diversity of macroinvertebrates. The plant species of greatest concern are the *Typha* spp. and *Phragmites* spp. that are prone to wetland invasion and exhibit rapid and dense growth. These species may "clog" wetland systems with both actively growing and fallen decaying material that creates refuge and provides enhanced nutrition for mosquito larvae.

Concern for public safety around wetlands is an important consideration and often results in the incorporation of gently sloped wetland banks. To discourage access to wetlands, spiky, thorny or otherwise impenetrable terrestrial vegetation can be planted, but this strategy is not always desirable. The recommended bank slope of wetlands to minimise mosquito breeding is from 2.5H:1V to 4H:1V, and slopes should not be vegetated with grasses that may trap water and provide habitat for mosquitoes (alternatively, grasses should be regularly cut to minimise habitat available). Steep slopes can restrict the density of vegetation, and reduce the area of shallow water, minimising suitable mosquito habitat by maximising the access of predatory fish and exposing larvae to surface water disturbance that may increase larval mortality. 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 and below the vertical edge.

The manipulation of water levels in the wetlands can be a useful tool for managing mosquito populations, but it is important to note that while the life cycles of some major pest species (e.g. *Culex* spp.) may be interrupted, populations of species that prefer habitats prone to temporary drying (e.g. *Aedes* spp.) may be increased.

There are a number of key resources that provide specific details on the design of constructed freshwater wetlands to reduce the risk of increased mosquito populations:

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

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

iii. 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.

iv. Midge Research Group of Western Australia (2007) **Chironomid midge and mosquito risk assessment guide for constructed water bodies.** Department of Health, Government of Western Australia.

v. 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

There is an increasing trend to include saltmarsh habitat in coastal urban developments but the risk of creating additional habitat for *Ae. vigilax* or *Ve. funerea* should be a major concern. Such constructed wetlands are usually small, but their proximity to residential and/or recreational areas increases the relative impact of mosquito populations.

The most important design consideration for constructed saltmarsh is that areas of pooling water following inundation are minimised. While consideration must also be given to the most appropriate conditions for the establishment of saltmarsh plants, having a relatively steep sloping marsh where water can flow away freely will greatly reduce the opportunity for mosquito breeding. A proposed saltmarsh slope of 3% would be sufficient (although as little as 1% may be effective) to ensure adequate drainage of tides and rainwater from the saltmarsh, given an even grade to the sediment and sufficient compaction to resist erosion and slumping.

The frequency of tidal inundation will also influence the suitability of the saltmarsh for mosquito breeding. If the saltmarsh is inundated by only the highest tides of each month, the saltmarsh will dry out between inundations (allowing mosquitoes to lay eggs at the base of vegetation), and restrict the colonisation of mosquito predators (fish and macroinvertebrates) in pools. More frequent inundation is less likely to create suitable conditions for *Ae. vigilax*, but consideration must be given to the impact such a tidal regime will have on the survivorship of saltmarsh vegetation.

Major estuarine wetland rehabilitation projects also have the potential to significantly change the mosquito fauna in some areas. The use of seawalls and floodgates to restrict the landward movement of tidal waters in order to reclaim land for agriculture or mitigate the effect of coastal flooding has had a significant impact on local ecosystems. Re-establishing tidal flow to these areas is thought to assist the creation and rehabilitation of locally, and often internationally, important estuarine wetlands. However, such project may result in an overall increase in mosquito populations and, consequently, increase pressure on local authorities to initiate a broadscale mosquito control program.

An example of a constructed freshwater wetland in the Bangalow area. Appropriately constructed and maintained wetlands can have a number of benefits for the environment and the community.

12. COMMUNITY EDUCATION

12.1 Mosquitoes and the community

It is most important that local authorities can assist in the dissemination of accurate information on the public health risks associated with mosquitoes and strategies to reduce those risks, to the community. It is also crucial that the community is educated on the place of mosquitoes in the local environment and the reasons why specific management strategies have been employed in the region.

There is often a lot of misinformation within the community regarding mosquitoes. A lack of understanding of the diversity of mosquito species, their life cycle and habitat associations is common. Concise, accurate information regarding the local mosquito populations can not only provide important public health messages but garner a greater interest in the ecology of local wetlands and the importance of ecologically sensitive mosquito management.

The public health message regarding mosquitoes dominates most community education programs. However, benefits could be gained by the inclusion of biological and/or ecological facts and figures associated with the local mosquito fauna (e.g. the mosquitoes that don't feed on humans, the specific habitat associations of some common mosquitoes, those mosquitoes that have predatory larvae). Even more so, the incorporation of mosquito information into overall environmental education programs will further promote the understanding that mosquitoes are an integral part of the ecosystem and should not be viewed in isolation.

Public education campaigns often involve the production of posters, fact sheets, stickers and videos, usually undertaken by local government or health authorities. The content, formatting and distribution of this material will be determined by the intended target audience of the campaign (e.g. whole community, primary or secondary school, wetland visitors, tourists etc).

12.2 Nuisance biting complaints

When mosquitoes are abundant, local authorities may receive phone or email complaints regarding nuisance biting in residential or recreational areas. These complaints may provide information on areas where mosquito impacts are greatest. However, the tolerance of individuals to mosquitoes varies greatly and the number of complaints within and between seasons may not be directly related to actual mosquito populations. There are a number of factors that will influence an individual's sensitivity to mosquitoes and also their likelihood of making a complaint to local authorities.

It is important that ongoing mosquito monitoring data is used as the measure of mosquito activity, not the number of complaints to local authorities (unless the two can be statistically associated). The quantity and frequency of complaints may, at times, be due to factors such as increased publicity regarding mosquitoes and arboviruses in the media or within local action groups, and not an actual substantial increase in mosquito abundance. However, if some significant linkage can be established, then a public complaint 'threshold' can be a useful trigger for further investigation or intervention.

When a complaint is made, it is important that it is directed to a person supplied with information on the local mosquito surveillance and management program, and able to provide appropriate information on reducing nuisance-biting impacts. A database of complaints should be kept and, if time and resources allow, an adult trap could be operated overnight in the local area to determine the mosquitoes likely to be causing the nuisance impacts. These short investigations also provide an excellent opportunity to connect the local community with the mosquito management program.

12.3 Dealing with the media

The local media regularly include mosquito stories during the summer months, often instigated by action groups within the community lobbying for greater levels of mosquito control or in response to health warnings by local authorities (or sometimes just because it is that time of the year).

Dealing with the media is an important component of community education because it provides an opportunity for the dissemination of accurate information on mosquitoes and personal protection strategies, as well as opportunities to publicise the local mosquito management program.

It is crucial that representatives of local authorities dealing with media have appropriate training and/or resources to answer questions regarding general mosquito biology, locally important pest mosquitoes, personal protection strategies and background on the local mosquito surveillance and any mosquito management programs.

While the majority of mosquito related articles in the media relate to pest and/or public health issues, opportunities to promote mosquitoes as an important component of the local environment should be pursued. There are many interesting aspects to mosquito biology and ecology that will provide the basis of radio, newspaper or television segments that have a wide appeal to audiences.

13. CLIMATE CHANGE & FUTURE RISKS

Mosquitoes and mosquito-borne disease are often discussed, as a major concern should climate change result in global warming and/or sea level rise. The greatest concern is that, with increased temperatures, the geographic range of pest and vector species will increase and with it the risk of human disease, particularly “tropical” diseases such as malaria and dengue. However, there are many factors beside temperature, including the availability of suitable habitats, short term changes in rainfall and tidal heights, urbanisation and mosquito control programs, that influence the distribution and abundance of mosquitoes as well as the incidence of human disease.

While the risks of mosquito-borne diseases such as dengue or malaria are unlikely to change with predicted climate change, there may be local increases in the risk of RRV and BFV. With overall warmer temperatures, there may be a decrease in the incubation period (the time between when a mosquito ingests a virus and when it is capable of transmitting the virus to humans) of the viruses in local vector species. This will mean that a potentially greater proportion of mosquitoes can transmit RRV or BFV in the local area. In addition, the warmer weather may not increase the magnitude of population increases but it may extend the period of mosquito activity, increasing nuisance-biting and potential public health risks into the spring and late autumn.

While there is no specific prediction of rainfall change in the Byron Shire associated with climate change, there is the prediction that there may be a greater frequency of extreme weather events and increases in rainfall intensity. These factors may contribute to increased mosquito productivity from the coastal swamp habitats in the Byron Shire. Currently, the abundance and distribution of these coastal swamp mosquitoes are strongly influenced by rainfall patterns between November and April each year with years recording above average rainfall generally resulting in more abundant mosquito populations. While major outbreaks of mosquito-borne disease do not necessarily follow increased mosquito populations, abundant mosquito populations are typically associated with a rise in local disease cases.

It is important to remember that the risks of mosquito-borne disease are influenced by a range of factors, not only mosquito populations. The activity of vertebrate reservoir hosts (e.g. birds, macropods) is an important factor and how these populations are influenced by changes in rainfall, temperature and sea level rise (as well as urban development) will influence mosquito-borne disease risks into the future.

Assessing the impact of climate change is a complex process (with much debate surrounding the potential magnitude of temperature, rainfall and sea level change) but the pest and public health impacts of mosquitoes in the future may be determined as much by urbanisation, wetland management strategies and mosquito control programs as any change to the climate in the Byron Shire.

There have been a number of publications in recent years discussing the possible impact of predicted climate change on the Australian mosquito fauna and activity of local and exotic mosquito-borne disease. For an informative overview of the issue, see Russell (2009) Mosquito-borne disease and climate change in Australia: time for a reality check in *Australian Journal of Entomology*, 48: 1-7.

14. SUMMARY OF MATTERS CONSIDERED IN THE FORMULATING OF THE ACTION PLAN FOR BYRON SHIRE COUNCIL

14.1 Why is mosquito management required?

14.1.1 Byron Shire provides suitable habitat for over 60 species of mosquito.

14.1.2 The major pest species are those associated with coastal swamp and estuarine wetland environments.

14.1.3 Mosquitoes associated with backyard habitats make a substantial contribution to mosquito risk is residential areas.

14.1.4 Although the abundance of mosquitoes in Byron Shire are generally lower than other regions in coastal NSW, populations are still sufficiently abundant to cause nuisance-biting and public health concerns.

14.1.5 Notwithstanding potentially significant nuisance-biting impacts, disease-causing pathogens such as RRV and BFV are associated with local mosquito populations in the Byron Shire and are a concern for the local community.

14.1.6 Byron Shire experiences some of the highest rates of human disease caused by RRV and BFV in NSW compared to nearby coastal regions.

14.1.7 Byron Shire supports a growing residential population and is a major tourist destination.

14.2 Mosquito risk zones

14.2.1 Based on mosquito population data collected during onsite surveys, as well as data provided by the NSW Arbovirus Surveillance and Mosquito Monitoring Program, vegetation community mapping provided by council and known dispersal ranges of pest mosquito species, mosquito risk maps were generated for the Byron Shire (Figure 13).

14.2.2 These maps represent areas were exposure to nuisance-biting mosquito populations, and consequently, potential RRV or BFV transmission may occur. However, the abundance of mosquito populations across the Byron Shire is expected to be variable with the abundance of mosquitoes highly dependent on seasonal rainfall.

14.2.3 These maps provide a guide to council, the community, local stakeholders and developers regarding the areas where greatest mosquito risk occurs.

14.2.4 In the areas beyond these zones, mosquito impacts are predicted to be relatively low. However, under favourable conditions (e.g. above average rainfall), localised pest impacts may be experienced and due care should be taken to avoid mosquito bites when mosquitoes are active, regardless of location.

14.3 Mosquito monitoring

14.3.1 Mosquito monitoring alone will not reduce mosquito-borne disease risk but the provision of reliable mosquito monitoring data, combined with information on the activity of mosquito-borne diseases, provides the basis for effective mosquito management.

14.3.2 Mosquito monitoring provides a quantitative measure of mosquito activity and is a more reliable measure of actual and potential pest impacts, and their associations with prevailing environmental conditions, than nuisance-biting complaints to council.

14.3.3 Continuation of Byron Shire Council's involvement in the NSW Arbovirus Surveillance Program will provide a foundation for the design and implementation of mosquito management into the future.

14.4 Community awareness

14.4.1 Byron Shire Council should develop an active “mosquito awareness” program to assist in communicating the risks of nuisance-biting, mosquito-borne disease risks and personal protection strategies that individuals and families can employ to reduce their exposure to mosquitoes.

14.4.2 On the Byron Shire Council website, an additional section on “mosquitoes and biting midges” should be added to the “Weeds and Pests” section. On this page there can be links to the mosquito management plan as well as high resolution maps of mosquito risk zones and fact sheets on a range of key topics including “mosquitoes and mosquito-borne disease in Byron Shire”, “protect yourself from mosquito bites” and “reducing mosquitoes around your home”. In addition, fact sheets on controlling mosquitoes in farm dams, the ecological role of mosquitoes and links to state and national health agencies can be included.

14.4.3 To assist the dissemination of “mosquito awareness” information, Byron Shire Council could look to integrate their community awareness program into other council activities, in particular, environmental, sustainability, wildlife care and bushcare groups as well as primary and secondary schools.

14.4.4 Byron Shire Council should establish a protocol for dealing with enquiries from the public regarding mosquitoes or biting midges. Individuals responsible for answering enquiries should be familiar with the current mosquito issues and a database of enquiries/complaints should be kept so that over time, any patterns in possible nuisance-biting impacts can be identified.

14.4.5 In conjunction with the Northern NSW Local Health District, Byron Shire Council should determine a strategy of “mosquito awareness” alert levels that are linked to climatic conditions that may cause increases in local mosquito populations, collection of increased mosquito populations in monitoring programs and notifications of mosquito-borne disease.

14.4.6 Byron Shire Council should be aware of major events within the local area that may occur during periods of mosquito-borne disease activity. School holiday periods over Christmas and Easter, together with major music festivals or other events that may include onsite camping close to coastal swamp or estuarine mosquito habitats and, together with Northern NSW Local Health District determine if specific health warnings or site-specific mosquito control activities may be required.

14.5 Urban planning

14.5.1 Byron Shire Council should consider amending Draft DCP – Chapter B7 Mosquito and Biting Midge Controls to ensure conformance with the current management plan. Such a planning instrument would allow Byron Shire Council to highlight problems of mosquitoes and biting midges in the local area and provide guidelines for new developments to minimise exposure to mosquito risk and reduce any onsite mosquito production that may result from water sensitive urban design or constructed wetlands.

14.5.2 For proposed developments within the predetermined mosquito risk zones (Figure 13), Byron Shire Council should require developers to engage a suitably qualified consultant to provide a site-specific mosquito risk assessment. Mosquito risk assessments may require site-specific mosquito sampling or a review of data available via the NSW Arbovirus Surveillance and Mosquito Monitoring Program but there should be sufficient evidence supplied to Council to demonstrate that the mosquito risk has been assessed and addressed in the design of the proposed developments.

14.5.3 As well as general “mosquito awareness” requirements of new developments, specific attention should applied to those developments within the predetermined mosquito risk zones (Figure 13). Consideration should be given to the overall site plan of the proposed development including buffer zones where appropriate, building design (i.e. screened openings), provision of screened outdoor recreation areas, vegetation plantings, stormwater structures (i.e. bioretention swales, wetlands, GPTs) and constructed wetlands.

14.5.4 For new developments that incorporate constructed wetlands into their design, consideration should be given to a specific environmental levy that will provide ongoing funding for wetland maintenance (i.e. vegetation management, sedimentation management, GPT clearance etc) without additional financial burden on Council's resources.

14.5.5 Investigate including information on mosquito risks in the Byron Shire in planning certificates for new developments.

14.6 Mosquito control

14.6.1 Broadscale mosquito control activities are not currently recommended for Byron Shire. While there is strong evidence that mosquito control programs can reduce adult mosquito populations and, consequently, the risks of mosquito-borne disease, mosquito control in coastal swamp environments can be operationally difficult due to the extensive habitats, the heterogeneous distribution of immature mosquito habitats within these environments and the unpredictability of rainfall (as well as occasionally tidal) flooding of these habitats.

14.6.2 As extensive areas of coastal swamp mosquito and estuarine mosquito habitat is located within areas currently managed by NPWS/OE&H, Council would be unable to undertake mosquito control activities in these areas. If these habitats remained untreated, it is unlikely that a sufficient reduction in mosquito populations could be achieved by treated Council managed wetlands alone.

14.6.3 While broadscale mosquito control may not currently be appropriate, smaller scale targeted control activities may provide assistance during extreme nuisance-biting activity or mosquito-borne disease epidemics and should be considered by Byron Shire Council. It is important that there is consideration given to the most suitable strategy of mosquito control well before a decision to implement control is required as during mosquito-borne disease epidemics, there may not be sufficient time to review options and decide on a strategy so that effective control can be undertaken to reduce public health risks.

14.6.4 Mosquito control in coastal swamp environments may be achieved through the targeting of immature mosquito populations with applications of larvicides or insect growth regulators. However, it is important that the community be extensively consulted should mosquito control be proposed.

14.6.5 Barrier treatments are often proposed as an effective strategy for reducing mosquito risk in new or existing developments close to mosquito habitats. The sustainability (from both a financial and ecological perspective) of such treatments should be carefully reviewed.

14.6.6 Consideration should be given to the response of Byron Shire Council should either *Ae. aegypti* or *Ae. albopictus* be detected in the local area.

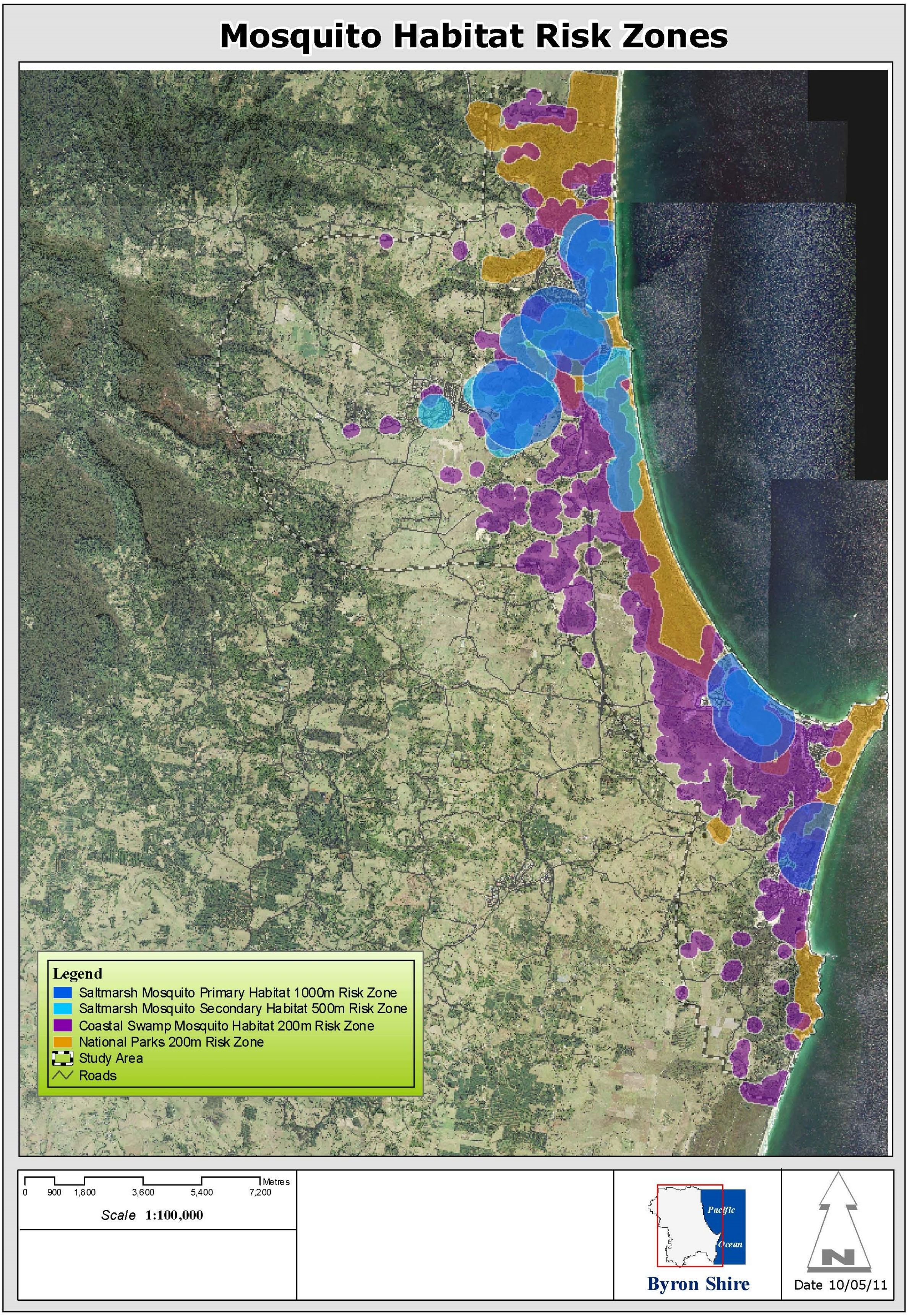

Figure 13. Mosquito risk maps for Byron Shire based on the dispersal patterns of estuarine and coastal swamp mosquitoes from known habitats. Within these zones, nuisance-biting should be expected during the warmer months with the severity to pest impacts dependent on local rainfall.

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16. APPENDIX 1: COLLECTING MOSQUITO DATA

16.1 Scientific and common names of mosquitoes

While some common names have been assigned to the more important mosquito species of pest or public health concern, or of notable appearance, mosquitoes are generally only referred to by their scientific names.

For mosquito species found in the Byron Shire, in some of the scientific publications cited in this document there may be variations in the scientific names used. In recent years there has been some debate over the taxonomic status of mosquito species in the genus *Aedes*. The sub-genus had been elevated to genus status for many species (for example, *Aedes vigilax* is now called *Ochlerotatus vigilax*).

Following a meeting of the Mosquito Control Association of Australia in 2006, it was decided to retain the scientific names in place prior to taxonomic revisions for use in technical reports, reflecting the editorial policy of the major international scientific journals (e.g. American Journal of Tropical Medicine and Hygiene). As a consequence, for the purpose of this document, the genus name Aedes was retained.

16.2 NSW Arbovirus Surveillance & Mosquito Monitoring Program

The NSW Arbovirus Surveillance and Mosquito Monitoring Program was established in 1984 to collect information on the activity of pest mosquitoes and arboviruses throughout NSW and provide an early warning system of mosquito-borne disease epidemics. Local governments in coastal and inland regions of NSW collect mosquitoes on a weekly basis (using dry-ice baited light traps) during the warmer months and send specimens to the Department of Medical Entomology, Westmead Hospital for the identification of mosquito species and isolation of arboviruses.

The far north coast of NSW has been represented in the program for many years by the Ballina and Tweed Shire regions with annual collections in these areas since the late 1980s. While collections were made at Byron Bay during 1988/1989 and 1989/1990, trapping was relatively infrequent with collections made only on a few occasions. It was not until the 2008/09 monitoring period that more frequent collections and testing of mosquitoes was undertaken in Byron Bay.

Data provided by the NSW Arbovirus Surveillance and Mosquito Monitoring Program was analysed to identify potential pest species and, based on mosquito populations in the nearby Ballina and Tweed regions, make an assessment of relative risk of nuisance-biting and mosquito-borne disease transmission. Data from the two traps sites, Byron Bay and Ocean Shores, were used in this analysis.

16.3 Mosquito habitat and population surveys

Mosquito habitat and adult mosquito population surveys were conducted over two periods, March 2011 and April 2011. Although data on mosquito populations was available via the NSW Arbovirus Surveillance and Mosquito Monitoring Program, there were still major gaps in our knowledge of mosquito populations across the Byron Shire region.

Actual and potential mosquito habitats were identified through a review of aerial photographs and topographic maps of the Byron Shire. Potential mosquito habitats were identified in conjunction with the provision of vegetation maps provided by Byron Shire Council. Representative habitats identified as potential mosquito habitats were inspected during the two site visits and all habitats that contained standing water were sampled using a standard 300ml dipper and any larvae collected were returned to the laboratory for identification.

Adult mosquito sampling was undertaken using dry ice baited Encephalitis Virus Surveillance (EVS) traps. These traps use carbon dioxide (dry ice) to attract host-seeking mosquitoes but do not collect large numbers of nontarget insects (e.g. moths, beetles etc) that would typically be collected in traditional light traps. Traps were operated at up to nine fixed trap sites on three consecutive nights during each of the sampling trips. The adult sampling sites were selected to provide protection from wind and rain and to maximize collections to enable an identification of the greatest diversity of mosquito species. A list of adult mosquito trap site locations is provided in Table 11 and Figure 14.

Table 11. List of adult mosquito trap sites where sampling was undertaken during March and/or April 2011.

Trap site name	Coordinates	
Bangalow 1	-28.688	153.527
Bangalow 2	-28.697	153.509
Federal 1	-28.651	153.456
Federal 2	-28.652	153.457
Main Arm 1	-28.510	153.436
Main Arm 2	-28.505	153.433
Suffolk Park 1	-28.692	153.608
Suffolk Park 2	-28.688	153.603
Suffolk Park 3	-28.682	153.613
Tallow Beach 1	-28.657	153.624
Tallow Beach 2	-28.661	153.619
Byron Bay 1	-28.660	153.608
Byron Bay 2	-28.660	153.610
Byron Bay 3	-28.644	153.616
West Byron 1	-28.642	153.583
West Byron 2	-28.650	153.597
Tyagarah	-28.608	153.565
Brunswick Heads 1	-28.557	153.550
Brunswick Heads 2	-28.543	153.555
Brunswick Heads 3	-28.535	153.541
Ocean Shores 1	-28.519	153.536
Ocean Shores 2	-28.519	153.550
Ocean Shores 3	-28.503	153.534
Ocean Shores 4	-28.509	153.545
South Golden Beach 1	-28.502	153.544
South Golden Beach 2	-28.493	153.549
South Golden Beach 3	-28.490	153.541
Mullumbimby 1	-28.562	153.520
Mullumbimby 2	-28.547	153.500
Mullumbimby 3	-28.552	153.493

16.4 Mosquito-borne disease notifications

The number of human notifications of human disease caused by RRV and BFV in Byron Shire and the far north coast of NSW was provided by NSW Health.

Figure 14. Location of adult mosquito trap sites in the Byron Shire operated in March and April 2011.

17. APPENDIX 2: MOSQUITO SAMPLING RESULTS

Table 11: Total mosquito species collected from trap sites operated at Byron Shire, March 2011

Mosquito species	*Ae. aculeatus*	*Ae. alternans*	*Ae. burpengaryensis*	*Ae. gahnicola*	*Ae. kochi*	*Ae. multiplex*	*Ae. notoscriptus*	*Ae. palmarum*	*Ae. procax*	*Ae. vigilax*	*Ae. vittiger*	*An. annulipes*	*An. atratipes*	*An. bancroftii*	*Cq. linealis*	*Cq. variegata*	*Cq. xanthogaster*	*Cs. antipodea*	*Cx. annulirostris*	*Cx. australicus*	*Cx. bitaeniorhynchus*	*Cx. orbostiensis*	*Cx. postspiraculosus*	*Cx. quinquefasciatus*	*Cx. sitiens*	*Cx. squamosus*	*Cx. sp. Marks No. 32*	*Ma. uniformis*	*Ur. pygmaea*	*Ve. funerea*	*Ve. sp. Marks No. 52*	Total mosquitoes
Bangalow 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bangalow 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brunswick Heads 1	0	0	0	0	2	0	22	0	0	3	0	0	0	0	0	0	13	0	1	0	0	3	0	0	9	0	0	0	0	4	0	57
Brunswick Heads 2	0	0	0	0	0	0	9	0	0	1	0	0	0	0	0	1	4	0	0	0	0	0	0	0	3	0	0	0	0	3	0	21
Brunswick Heads 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Byron 1	0	0	0	0	8	0	73	2	0	1	0	0	0	0	272	0	94	0	13	0	0	83	0	1	0	0	0	7	0	1	0	555
Byron 2	0	0	0	0	4	0	61	1	0	0	0	0	0	0	188	3	66	0	3	0	0	41	0	2	0	0	0	3	0	2	0	374
Byron 3	0	0	0	0	0	0	19	0	0	0	0	0	0	0	21	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	42
Federal 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Federal 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Main Arm 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Main Arm 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mullumbimby 1	0	0	0	0	0	0	43	1	0	3	0	0	0	0	1	0	0	0	3	0	0	1	0	0	1	0	0	0	0	0	0	53
Mullumbimby 2	0	0	0	0	0	0	10	0	0	0	7	0	0	0	0	0	0	0	3	0	0	0	0	0	6	0	0	0	0	0	0	26
Mullumbimby 3	0	0	0	0	0	0	10	0	0	1	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	15
Ocean Shores 1	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	4	0	3	0	0	0	0	0	0	0	0	3	0	0	0	21
Ocean Shores 2	0	0	0	0	2	0	4	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	9	0	0	0	0	3	0	20
Ocean Shores 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0	1	0	19
Ocean Shores 4	0	0	0	0	4	0	72	0	17	0	0	0	0	0	22	0	8	0	6	0	0	33	0	0	3	0	1	1	0	0	0	167
South Golden Beach 1	0	0	0	0	4	0	39	4	0	0	0	0	0	0	1	0	8	0	8	0	0	0	0	0	6	0	0	7	0	0	0	77
South Golden Beach 2	0	0	0	0	1	0	6	0	4	0	0	0	0	0	3	1	0	0	1	0	0	0	0	0	3	0	0	1	0	0	0	20
South Golden Beach 3	0	0	0	0	21	11	29	0	3	0	0	0	0	0	36	0	121	0	6	0	1	50	0	0	0	12	0	8	0	0	3	301
Suffolk Park 1	0	0	0	0	5	0	11	0	0	0	0	0	0	0	1	1	3	0	8	0	0	0	0	0	0	0	0	3	0	0	0	32
Suffolk Park 2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	6
Suffolk Park 3	0	0	0	0	0	0	9	0	0	0	0	0	0	0	36	108	2	0	4	0	0	1	0	0	2	0	0	2	0	2	0	166
Tallow 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	12	0	0	0	0	0	0	0	0	0	0	12	0	0	0	42
Tallow 2	0	0	0	0	2	0	10	1	0	0	0	0	0	0	12	0	13	1	5	0	0	0	0	0	1	0	0	0	0	0	0	45

Tyagarah 1	0	0	0	1	2	2	0	0	0	0	0	0	0	0	0	270	88	1	3	0	0	0	2	0	1	0	0	7	0	0	0	377
West Byron 1	0	0	0	0	0	0	7	0	0	1	0	0	0	0	6	0	14	0	20	0	0	0	0	0	0	0	0	0	0	0	0	48
West Byron 2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	10	0	13	0	7	0	0	0	0	0	0	4	0	2	0	0	0	39
Total mosquitoes	0	0	0	1	55	16	446	9	24	11	7	0	0	0	628	386	463	2	98	1	1	214	2	3	62	16	1	58	0	16	3	2523

Table 12: Total mosquito species collected from trap sites operated at Byron Shire, April 2011

Mosquito species	*Ae. aculeatus*	*Ae. alternans*	*Ae. burpengaryensis*	*Ae. gahnicola*	*Ae. kochi*	*Ae. multiplex*	*Ae. notoscriptus*	*Ae. palmarum*	*Ae. procax*	*Ae. vigilax*	*Ae. vittiger*	*An. annulipes*	*An. atratipes*	*An. bancroftii*	*Cq. linealis*	*Cq. variegata*	*Cq. xanthogaster*	*Cs. antipodea*	*Cx. annulirostris*	*Cx. australicus*	*Cx. bitaeniorhynchus*	*Cx. orbostiensis*	*Cx. postspiraculosus*	*Cx. quinquefasciatus*	*Cx. sitiens*	*Cx. squamosus*	*Cx. sp. Marks No.32*	*Ma. uniformis*	*Ur. pygmaea*	*Ve. funerea*	*Ve. sp. Marks No. 52*	Total mosquitoes
Bangalow 1	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	2	0	3	0	0	1	0	3	0	0	0	0	0	0	0	13
Bangalow 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	1	0	0	0	0	0	0	15
Brunswick Heads 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	28	0	1	2	2	0	0	0	2	0	0	0	0	0	0	36
Brunswick Heads 2	0	0	0	0	0	4	7	0	6	8	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	9	1	36
Brunswick Heads 3	0	0	0	0	1	13	5	0	7	5	0	8	0	2	11	4	21	0	15	1	0	0	0	0	19	0	0	5	0	18	38	173
Byron 1	2	0	1	0	25	18	39	0	0	2	0	0	0	1	238	2	51	0	19	0	0	23	0	0	0	0	0	38	0	1	29	489
Byron 2	0	0	0	0	3	2	1	0	17	0	0	0	0	0	10	0	69	0	7	2	1	1	0	0	1	0	0	4	0	3	56	177
Byron 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Federal 1	0	0	0	0	0	0	9	0	3	0	0	0	0	1	0	0	0	0	1	0	0	1	0	3	0	0	0	0	0	0	0	18
Federal 2	0	0	0	0	0	1	6	0	1	0	0	0	0	0	0	0	0	0	4	0	0	0	0	1	0	0	0	0	0	0	0	13
Main Arm 1	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	8	3	0	2	0	0	1	0	0	0	0	0	0	20
Main Arm 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	10	0	0	0	0	0	0	0	0	0	0	0	0	11
Mullumbimby 1	0	1	0	0	0	0	7	0	1	8	0	0	0	0	0	0	1	0	1	0	0	1	0	1	113	1	0	1	0	8	1	145
Mullumbimby 2	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	1	4	0	0	0	0	0	0	25
Ocean Shores 1	0	0	0	0	0	6	0	0	10	0	0	0	0	0	2	1	6	0	26	0	0	3	0	0	6	0	0	2	0	4	47	113
Ocean Shores 2	0	0	0	0	2	0	0	0	5	3	0	0	0	0	0	0	16	0	1	0	0	0	0	0	3	0	0	0	0	1	1	32
Ocean Shores 3	0	0	0	2	13	19	27	1	21	0	0	0	0	0	19	6	270	0	14	1	0	4	0	1	11	0	0	2	0	3	56	470
Ocean Shores 4	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3	0	5	1	0	0	0	0	97	0	0	2	0	0	0	111
South Golden Beach 1	0	0	0	0	6	13	39	0	52	0	0	0	0	0	8	0	51	0	18	2	0	4	0	0	0	0	0	0	0	2	41	236
South Golden Beach 2	0	0	0	0	0	0	26	1	1	0	0	0	0	0	0	0	38	0	6	0	0	0	0	0	0	0	0	7	0	0	3	82
South Golden Beach 3	0	0	0	0	43	17	12	1	2	0	0	0	0	0	7	3	286	0	7	0	0	3	0	0	3	0	0	6	0	1	29	420
Suffolk Park 1	0	0	0	0	0	0	16	0	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80
Suffolk Park 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Suffolk Park 3	0	0	0	0	5	0	31	1	19	0	0	0	0	0	0	0	3	0	11	0	0	0	0	0	0	0	0	1	0	0	1	72
Tallow 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tallow 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tyagarah 1	0	0	0	0	5	0	0	0	8	0	0	0	2	1	51	75	168	1	1	4	0	2	0	0	0	0	0	43	1	1	2	365
West Byron 1	1	1	0	0	0	13	14	0	21	0	0	0	0	0	0	0	33	0	2	0	0	1	0	0	0	0	0	0	0	0	0	86
West Byron 2	0	0	0	4	13	8	2	0	6	0	0	3	0	0	11	0	19	0	6	0	0	9	0	0	0	3	0	52	0	0	23	159
Total Mosquitoes	3	2	1	6	116	114	267	4	244	29	0	11	2	5	357	92	1067	1	184	16	3	55	0	10	261	4	0	163	1	51	328	3397

18. APPENDIX 3: PROPOSED FACT SHEET CONTENT

The following text is designed to be included in fact sheets hosted on the Byron Shire Council website. It is proposed that Fact Sheet #1 (Mosquitoes and Byron Shire Council) be produced in a printed format (A4, double sided, three panel) for distribution in the local community.

There is some duplication of information between these proposed fact sheets as it should not be assumed that an individual will read all fact sheets when seeking out information. Key points are included in all fact sheets.

18.1 FACTSHEET #1: MOSQUITOES AND BYRON SHIRE COUNCIL

Mosquitoes in the Byron Shire?

- There are over 60 different species of mosquito in the Byron Shire but only a small number cause nuisance-biting problems or spread disease-causing pathogens.
- Mosquitoes are a natural part of the local environment and provide food for a range of fish, frogs, birds, bats and other insects.
- Mosquito problems in Byron Shire are generally greater close to the coast as this is where the most productive mosquito habitats occur in association with estuarine wetlands and coastal swamp forests.
- As well as breeding in natural environments, some pest mosquitoes breed in backyard habitats.

Are mosquitoes a health concern?

- The two most common mosquito-borne diseases in the local areas are caused by Ross River virus and Barmah Forest virus.
- The diseases caused by Ross River virus (RRV) and Barmah Forest virus (BFV) are not fatal but can cause symptoms including joint pain, muscle tiredness, fatigue, fever and rash that may last from a few days to months.
- If you suspect that you may have the symptoms associated with RRV or BFV, you should consult your local health professional.
- Mosquitoes in the Byron Shire do not transmit dengue or malaria.
- Mosquitoes do not transmit HIV, Influenza, Hepatitis or any other disease-causing pathogen between people in the Byron Shire.

How can I protect myself from mosquito bites?

- There are three ways to protect yourself from mosquito bites:
    i. Avoid mosquitoes when and where they are most active
    ii. Use registered insect repellents
    iii. Responsible use of insecticides in and around the home.
- Mosquitoes are most active at dawn and dusk and are generally more abundant in areas close to estuarine wetlands (e.g. saltmarshes and mangroves) and coastal swamp forests (e.g. tea-tree and paperbark swamps) but they can also be active in backyards too.
- When outdoors, wear light-coloured and loose fitting clothing
- While mosquitoes will be active during the warmer months, their abundance will dramatically increase following rainfall. The peaks in mosquito activity generally occur within two weeks after major rainfall.
- There is a range of mosquito repellents available but the most effective products are those that contain diethyltoluamide (DEET) or picaridin.
- Botanical based repellents (such as those containing Melaleuca, Citronella or Eucalyptus oils) provide only limited protection and need to reapplied much more frequently than DEET or picaridin based products.

- The judicious use of insecticides around the home will assist in reducing the risk of mosquito bite. Knockdown sprays and plug-in units that contain a synthetic pyrethroid are most effective.

Avoidance of mosquitoes around the home

- Ensuring that windows, doorways and balconies are appropriately screened will provide protection from mosquitoes.
- Bed nets, particularly those treated with insecticides (e.g. synthetic pyrethroids), can provide effective protection.
- The operation of ceiling or floor fans can assist in reducing mosquito activity.
- Ensuring that any opportunities for mosquito breeding immediately outside the home are eliminated can greatly reduce local mosquito populations. This includes emptying contains of water after rainfall, clearing blocked drains and roof guttering, ensuring that rainwater tanks are adequately screened and that any opportunities for pooling surface water after rainfall is minimised.
- Ponds can be stocked with native fish to assist in keeping mosquito numbers down but be sure to only use native fish species.

What is Byron Shire Council doing about the mosquito problem?

- Byron Shire Council works together with nearby councils and NSW Health to better understand the local risks associated with mosquitoes and mosquito-borne disease.
- Byron Shire Council is actively involved in mosquito monitoring during the warmer months and data collected is provided to NSW Health to assist in managing mosquito-borne disease risk.
- Given the extensive and diverse nature of mosquito habitats in Byron Shire, and as many mosquito habitats are within national parks and nature reserves, broadscale mosquito control is not considered a sustainable strategy in the local areas.
- Byron Shire Council is working with developers to ensure that new residential areas are designed to minimise the exposure of residents to mosquitoes.
- Byron Shire Council can provide information to residents and visitors on strategies to reduce the risk of mosquito bites as well as providing advice to residents and businesses on how to reduce mosquitoes and their impacts around homes and workplaces.

18.2 FACTSHEET #2: PUBLIC HEALTH RISKS AND MOSQUITOES

Why do mosquitoes bite?

- Only female mosquitoes bite, they need the protein in a blood meal to help develop their eggs. Both male and female mosquitoes also feed on plant juices.
- Most mosquitoes in the Byron Shire take blood from a range of animals including wild marsupials and birds, domestic animals and humans.
- Mosquitoes locate the animals by detecting the carbon dioxide those animals (including humans) breathe out in combination with attractants that include heat, smell and colour.
- While there is always interest in why mosquitoes appear to bite some individuals more than others, the reality is that everyone is susceptible to mosquito bites and it only takes one bite for the potential transmission of disease-causing pathogens.

What are Ross River virus and Barmah Forest virus?

- Ross River virus and Barmah Forest virus circulate naturally between native animals and local mosquitoes. Mosquitoes are not “born” infected with either virus, they must acquire the virus from an infected animal.

- The diseases caused by Ross River virus and Barmah Forest virus are not fatal but can cause symptoms including joint pain, muscle tiredness, fatigue, fever and rash that may last from a few days to months.
- Diagnoses requires a blood test and both diseases are notifiable to health authorities in NSW.
- There are no vaccines for RRV or BFV disease. Medical treatment is aimed at easing symptoms, rather than curing the specific disease.

Do mosquitoes spread any other diseases?

- Mosquitoes in the Byron Shire do not transmit dengue, malaria or any other tropical mosquito-borne disease.
- There is no evidence that local activity of Murray Valley encephalitis virus and Kunjin virus is active in the local area.
- Mosquitoes do not transmit HIV, Influenza, Hepatitis or any other disease-causing pathogen between people in the Byron Shire.

How can I protect myself from mosquito bites?

- There are three ways to protect yourself from mosquito bites:
    - iv. Avoid mosquitoes when and where they are most active
    - v. Use registered insect repellents
    - vi. Responsible use of insecticides in and around the home.
- Mosquitoes are most active at dawn and dusk and are generally more abundant in areas close to estuarine wetlands (e.g. saltmarshes and mangroves) and coastal swamp forests (e.g. tea-tree and paperbark swamps) but they can also be active in backyards too.
- When outdoors, wear light-coloured and loose fitting clothing.
- While mosquitoes will be active during the warmer months, their abundance will dramatically increase following rainfall. The peaks in mosquito activity generally occur within two weeks after major rainfall.
- There is a range of mosquito repellents available but the most effective products are those that contain diethyltoluamide (DEET) or picaridin.
- The judicious use of insecticides around the home will assist in reducing the risk of mosquito bite. Knockdown sprays and plug in units that contain a synthetic pyrethroid are most effective.

Treatment of mosquito bites

- The classic “mozzie bite” is an itching, inflamed lump on the skin is an allergic reaction to the saliva injected by the mosquito during blood feeding.
- The severity of the reaction is highly variable between individuals and can often be determined by a person’s sensitivity as well as prior exposure to mosquito bites.
- Clean and dry the bite with warm soapy water and a clean cloth.
- Application of a cool compress (i.e. icepack wrapped in cloth) can reduce inflammation.
- The application of a medication lotion (e.g. anti-inflammatory, anti-puritic) or soothing substance (e.g. aloe vera) may reduce itchiness and the use of an antiseptic cream will prevent secondary infection. If secondary infection occurs, antibiotics may be required but consult a medical professional for specific advice.
- Severe reactions may need to be treated with topical or oral antihistamines but consult a medical professional for specific advice on the most suitable medication.
- Many home remedies exist for the treatment of mosquito bites. The application of a paste comprised of a mixture of baking/bi carb soda and water is thought to offer some relief from itching.
- Care should be taken if applying essential oils (e.g. lavender or eucalyptus) directly to the skin as these products may result in secondary skin irritation.

18.3 FACTSHEET #3: SAFE AND EFFECTIVE USE OF INSECT REPELLENTS

How can I protect myself from mosquito bites?

- Mosquitoes in Byron Shire have the potential to spread disease-causing pathogens such as Ross River virus and Barmah Forest virus that can cause symptoms including joint pain, muscle tiredness, fatigue, fever and rash that may last from a few days to months.
- There are three ways to protect yourself from mosquito bites:

  vii. Avoid mosquitoes when and where they are most active
  viii. Use registered insect repellents
  ix. Responsible use of insecticides in and around the home.
- Mosquitoes are most active at dawn and dusk and are generally more abundant in areas close to estuarine wetlands (e.g. saltmarshes and mangroves) and coastal swamp forests (e.g. tea-tree and paperbark swamps) but they can also be active in backyards too.
- When outdoors, wear light-coloured and loose fitting clothing.
- While mosquitoes will be active during the warmer months, their abundance will dramatically increase following rainfall. The peaks in mosquito activity generally occur within two weeks after major rainfall.
- There is a range of mosquito repellents available but the most effective products are those that contain diethyltoluamide (DEET) or picaridin.
- The judicious use of insecticides around the home will assist in reducing the risk of mosquito bite. Knockdown sprays and plug in units that contain a synthetic pyrethroid are most effective.

Which repellent is best? Are they safe to use?

- All mosquito repellents sold in Australia are required to be registered with the Australian Pesticides and Veterinary Medicines Authority (APVMA).
- The most effective repellents contain DEET or picaridin and products containing at least 10% of these active ingredients will provide effective protection for at least two hours.
- The concentration of active ingredients in each repellent formulation determines the period of time an individual is protected from mosquito bites, not the number of mosquitoes that are kept away.
- Botanical based products that contain essential oils and plant extracts are less effective and to provide the same level of production as chemical repellents, must be reapplied far more frequently.
- There is often a perception that synthetic repellents such as DEET or picaridin can be toxic to humans. However, despite the widespread use of such products in Australia, very few cases of adverse reactions have ever been documented.
- Repellents are most effective when there is a thin, even coverage of the product on exposed skin, a spray “here and there” or only clothes will not provide effective protection.
- It is important to note that some essential oil and plant-based products can also cause skin irritation if used incorrectly.
- Never allow children to apply repellent themselves, a parent or carer should apply repellent to their hands and then to the children.
- The failure to use repellents in some locations will almost certainly result in insect bites and the possibility of acquiring an infectious disease.

How should repellents be applied?

- Repellents are most effective if there is an even application to all areas of exposed skin, mosquitoes can detect, and bite, areas where no repellent has been applied.
- Applying large amounts of repellent does not result in longer periods of protection against bites.

- When using pump spray or roll-on formulations, it is important to evenly cover the skin and this may be best done by first applying the repellent from the container and then spreading over skin using your hands.
- Repellent sprays will not work effectively if they are applied sparingly or patchily. A quick spray "here and there" will generally not be sufficient to prevent mosquito bites.

Guidelines for insect repellent use on children

- Some insect repellents will contain warnings regarding age limitations for use on children. However, it is generally not recommended to use topical repellents on children under three months.
- Topical repellents should be avoided where possible for babies, and physical barriers such as netting of prams and play areas is preferred.
- Repellents containing <10% DEET or picaridin are considered safe if applied according to label instructions. Most importantly, children should not be allowed to apply their own repellents and carers should be cautious not to apply excessive amounts of repellent.
- Although they are often perceived to be safer, it is important to remember that repellents containing botanical extracts may still cause skin irritation and should be applied according to label instructions.