Mosquito Management Plan: Northern Beaches Council, NSW.

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Report Preparation

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EXECUTIVE SUMMARY

- There are over 60 different mosquito species found across metropolitan Sydney and some mosquitoes associated with wetlands and other habitats within the Northern Beaches Council local government area have the potential to pose pest and public health risks.
- In preparation of this management plan, reference was made to existing data on mosquito populations and mosquito-borne disease within the local area. There has been very limited mosquito monitoring conducted in the Northern Beaches Council area and to assist in the development of this plan, Medical Entomology (NSW Health Pathology) was engaged to undertake mosquito sampling at a number of prioritised locations including McCarrs Creek Reserve, Winnererremy Bay, Careel Bay, Warriewood Wetlands, and Narrabeen Lagoon (Deep Creek).
- A total of 37 mosquito species were recorded in the monitoring program with the most important mosquitoes from a pest and public health concern identified as those associated with freshwater-brackish water habitats (e.g. *Aedes multiplex*, *Aedes procax*, *Verrallina* Marks 52), freshwater wetlands (e.g. *Culex annulirostris*, *Coquillettidia linealis*) and backyard habitats (e.g. *Aedes notoscriptus*). Many coastal regions in NSW are impacted by saltmarsh mosquitoes, especially *Aedes vigilax*, but monitoring indicated with these habitats within the Northern Beaches region are not highly productive for this species.
- Mosquito abundance was highly variable across the monitoring period and between locations. Dry conditions during December 2019 and January 2020 resulted in very low mosquito abundance. Significant rainfall in early February 2020 caused mosquito abundance to increase substantially. However, these increases were concentrated around Warriewood Wetlands and Narrabeen Lagoon while other locations continued to record generally low abundances of mosquitoes. With favourable climatic conditions continuing through March and April 2020, substantial mosquito activity was recorded at Warriewood Wetlands and Narrabeen Lagoon through to early May 2020.
- A number of arboviruses was identified from mosquitoes collected in this study. Ross River virus (RRV) was detected from Narrabeen Lagoon on 5 occasions and Warriewood Wetlands on 3 occasions; Barmah Forest virus (BFV) was detected from Narrabeen Lagoon on 3 occasions; Stratford virus (STRV) was detected from Narrabeen Lagoon on 4 occasions, Warriewood Wetlands on 1 occasion and Careel Bay on 1 occasion; Edge Hill virus (EHV) was detected from Narrabeen Lagoon on 1 occasion. This is the first time mosquito-borne pathogens of human health importance (i.e. RRV and BFV) have been identified in mosquito populations on the Northern Beaches of Sydney.
- This investigation has clearly identified both pest and public health concerns associated with mosquitoes on the Northern Beaches of Sydney. Nuisance-biting pest species were abundant on occasion and the detection of arboviruses raises public health concern. Based on the findings of this investigation, high risk areas are those where wetlands and bushland habitats provide opportunities for mosquitoes, wildlife representing locally important reservoirs of arboviruses (e.g. swamp wallabies), and are either popular recreational areas or in close proximity to residential developments.
- A suite of strategies to manage mosquitoes and their pest and public health impacts is included in the action plan of this report. High priority activities are the participation in the NSW Arbovirus Surveillance and Mosquito Monitoring Program, development of a locally relevant public education program to raise awareness of mosquito risk and promote personal protection measures consistent with NSW Health guidelines, and consider implementation of judicious mosquito control in high risk areas.

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INTRODUCTION

The pest and public health threats associated with mosquitoes are of growing concern to local authorities across Sydney. Notwithstanding the public health risks associated with mosquito-borne pathogens, the potentially severe nuisance-biting impacts of mosquitoes have the potential to substantially impact the comfort and experiences of those living, or undertaking recreational activities, in close proximity to wetlands or bushland areas.

There are over 60 different species of mosquito found in the greater Sydney metropolitan area. While mosquitoes associated with a range of habitats have the potential to impact the local community, the majority of mosquitoes pose little or no risk due to their inherent low abundance or preference to bite animals over people. There are, however, a small number of mosquitoes that pose a potentially significant threat. Mosquitoes associated with the major estuaries of Sydney (e.g. *Aedes vigilax*) hold the greatest potential pest impacts due to their exceptional abundance, wide dispersal from habitats, propensity to bite people, and demonstrated role in pathogen transmission. Mosquitoes found in freshwater wetlands (e.g. *Culex annulirostris*), may also a pose a pest and public health threat. However, there may be unique environmental drivers of mosquito abundance and mosquito-borne disease risk in different parts of Sydney and to define those risk, a better understanding of local mosquito populations is required.

Notwithstanding the mosquitoes associated with wetland and bushland habitats, those found in close association with backyard habitats can also be problematic. Mosquitoes, especially *Aedes notoscriptus*, are widespread across residential areas of Sydney, are nuisance-biting pests, and can be involved in the transmission of mosquito-borne pathogens. These mosquitoes can also be active in urban parklands and these impacts must be differentiated from those resulting from mosquitoes found in bushland or wetland habitats to better assist local authorities management of potential pest impacts.

There is a paucity of knowledge regarding mosquitoes within the Northern Beaches Council local government area. There have been some limited investigations but generally, it was considered that mosquito abundance and diversity was generally low and that pest and public health risks were minimal. However, the public health risks, due to the transmission of arboviruses (e.g. Ross River virus (RRV) and Barmah Forest virus (BFV)) by mosquitoes, have started to be better understood across Sydney and that there may be elevated risks in some regions when favourable environmental and climatic conditions occur.

Urban development in many regions of Sydney has increased exposure of the human population to mosquitoes and, potentially, mosquito-borne pathogens. Concomitant with these urban developments has come an enhancement of recreational areas that encourage passive and active recreation, together with environmental education, leading to people spending more time in areas within or adjacent bushland and wetland habitats. In addition, many regions of Sydney are rehabilitating bushland and wetland habitats that may influence the activity of mosquitoes and the wildlife that represent potential reservoirs of mosquito-borne pathogens.

Prompted by concerns regarding nuisance-biting mosquitoes, Northern Beaches Council engaged Medical Entomology (NSW Health Pathology) to develop a mosquito management plan for the local area. The objective of this plan is to provide framework for Northern Beaches Council to better manage the pest and public health risks associated with the local area in a sustainable way that allows for future collaboration with local stakeholders and the community. To assist the development of this plan, mosquito monitoring was undertaken during the 2019-2020 season at a number of locations prioritised through discussions with Environmental Health, Northern Beaches Council, and the Northern Sydney Public Health Unit (NSW Health). This mosquito monitoring was also complemented by testing of mosquitoes for the presence of key mosquito-borne pathogens in conjunction with the NSW Arbovirus Surveillance and Mosquito Monitoring Program (Environmental Health Protection, NSW Health).

MOSQUITO BIOLOGY

Mosquitoes are small blood sucking insects that belong to the family of flies called Culicidae (Order Diptera) and there are more than 300 different species in Australia with each species closely associated with particular habitats.

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 stage totally aquatic, and without access to free-standing water of some kind, the larvae cannot complete their development to the adult phase. Immature mosquitoes cannot complete their development in damp soil or moist vegetation.

A gravid adult female mosquito will typically lay eggs either on the water surface (usually with eggs in the form of a floating raft) or on a frequently inundated substrate (usually singularly or in small groups). The 'oviposition sites' may include frequently inundated soil or vegetation at the edge of a wetland, soil or leaf litter where temporary pools form after rainfall or inside water holding containers (e.g. buckets, bird baths, tyres etc).

While some mosquito eggs (such as those laid by *Aedes* or *Verrallina* species) can be desiccation resistant and remain unhatched for many months before being inundated by tides or rainfall, most eggs (particularly those laid by *Culex* and *Anopheles* species) will hatch within 2-3 days. On hatching, the young larvae (commonly called wrigglers) feed continuously on aquatic particulate matter and grow through four different instars or moults. The larvae of some mosquito species have developed specialised mouthparts and are predatory, feeding on other mosquito larvae and aquatic invertebrates. The final larval stage (4^{th} instar) develops into a pupa (commonly called tumbler) from which the adult mosquito emerges approximately 2 days later. During warm weather, it generally takes seven to ten days from the hatching of larvae to the emergence of adults. This relatively consistent life cycle enables estimations of mosquito population increases based on the environmental conditions of temperature, humidity, rainfall, and tides.

On average, a female mosquito may live approximately 2-3 weeks but the male's lifespan is much shorter. Adult mosquitoes are most active from dusk until dawn, seeking refuge during the day in cool and humid habitats such as well-vegetated areas or under houses. Some pest species, however, can be active during the day and disperse many kilometres from larval habitats. These day active mosquitoes can often be particularly active in shaded areas around wetlands protected from wind by dense vegetation. Mosquitoes will also be active in these shaded areas when mosquito abundance is high.

Within their lifetime, both adult male and female mosquitoes will feed on nectar and plant fluids, but it is only the female that will seek a blood meal required to provide protein for egg development. While many mosquitoes are generalist feeders, some specialise in feeding on humans, mammals, birds or amphibians. It is this propensity to feed on wildlife that create a risk for the transmission of pathogens. Mosquitoes must bite an infected animal to pick up a virus (e.g. RRV) before transmitting it to a person. For this reason, the local public health risks within a region are determined, not only by mosquitoes and their habitats but wildlife also.

There is a paucity of knowledge regarding the ecological role of mosquitoes. Both the adult and immature stages are food for a range of insectivorous animals including birds, bats, fish, frogs, and a range of invertebrates. Some mosquitoes are also thought to play a role in the pollination of plants. However, there is no evidence that any plant or animal in Australia is completely reliant on mosquitoes. Even for those insectivorous animals, mosquitoes may comprise only a small percentage of their diet compared to other prey.

MOSQUITOES AND HEALTH RISKS

Nuisance-biting impacts

Across the Sydney region, there is a number of mosquitoes that may cause nuisance-biting concerns, these mosquitoes have all been identified from current or previous investigations on the Northern Beaches. The most common mosquitoes and their pest and public health concerns are summarised in Table 1.

It is difficult to quantify the impact of nuisance biting mosquitoes due to differences in mosquito abundance and diversity. Some mosquitoes are more likely to bite people and some mosquitoes are more likely to be found in high abundance. However, the tolerance level of individuals varies substantially and is often dependent on the current mosquito populations and previous personal experiences. There are strong indicators that nuisance biting alone can have negative impacts on a homeowner’s standard of living as well as economic impacts on residential and recreational developments.

While determining the levels of pest impacts can be difficult, there are some general guidelines available based on adult mosquito monitoring. The NSW Arbovirus Surveillance and Mosquito Monitoring Program considers average trap densities of adult mosquitoes greater than 100 per trap as high with over 1,000 per trap as very high to extreme when exceeding 10,000 per trap. Generally, when the abundance of adult mosquitoes, especially known human-biting pests, exceed 100 per trap in residential areas, nuisance biting impacts would be highly likely with considerable disruption to quality of life reported when collections exceed 1,000 per trap.

It can be difficult to extrapolate the pest impacts of mosquitoes across a local area based on a small number of traps given there will be mosquito-specific considerations required regarding their dispersal ranges from immature habitats (i.e. some mosquitoes fly many kilometres, other less than 100m). In some circumstances, nuisance-biting impacts will be generally limited to areas within and immediately surrounding wetland and connected bushland areas while in others, impacts will be experienced across adjacent suburban areas.

A reliance on complaints to local authorities can be an unreliable method to gauge local mosquito impacts. For some people, a small number of aggressive “backyard mosquitoes” may be more disruptive than “swarms” of mosquitoes biting near wetland or bushland areas where exposure may be for only short periods or may even be expected given local conditions. Local authorities can record complaints regarding mosquitoes and this information can assist the identification of areas where “hot spots” of mosquito activity occur. However, it is important to be able to differentiate complaints arising from genuine mosquito impacts as opposed to perceived problems associated with neglected swimming pools or stormwater infrastructure. The only reliable way to measure changes in the abundance of local mosquitoes is through a routine monitoring mosquito program.

Mosquito-borne disease

Mosquito-borne disease is reported on an almost annual basis around Sydney. The most commonly reported mosquito-borne disease is caused by either Ross River virus (RRV) or Barmah Forest virus (BFV). However, there are also a number of other viruses regularly detected from mosquitoes in Sydney and, although themselves may not represent a significant threat to human health, may prove valuable indicators of activity of the more important pathogens.

There are almost, 6,000 cases of disease resulting from RRV or BFV infection combined per year across Australia with the majority of these, on average around 5,000 cases, are caused by RRV. While not fatal, the diseases caused by these viruses can be seriously debilitating. The symptoms can vary greatly between individuals and include fever and rash, infection with either of these viruses may result in 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. Under the NSW Public Health Act 2010, both viruses are classified as a notifiable infectious disease and require a blood test to confirm infection.

In the almost 30 years to June 2020, there was a total of 514 cases of RRV infection reported to the Northern Sydney Local Health District as recorded by the NSW Health Notifiable Conditions Information Management System (NCIMS), Communicable Diseases Branch and Centre for Epidemiology and Evidence, NSW Health (Figure 1). Over this time, there was an annual average of 16.5 formal notifications of RRV infections but fewer cases of BFV infection with only 2.2 formal notifications reported to Northern Sydney Local Health District. Across these seasons, the peak in notifications of these two diseases typically occurs between February and April.

While the total number of cases is relatively low compared to regional areas outside metropolitan Sydney, it is important to note that there may be underdiagnoses of the disease due to a lack of awareness among health professionals and many visitors to the region may be exposed but not diagnosed when returning to the residential suburbs elsewhere in Sydney. There has also been the expectation that the vast majority of these cases of disease notification resulted from infections acquired outside the Sydney metropolitan region as there had been little evidence indicating a threat of mosquito-borne disease in the Northern Beaches region historically.

The risk of mosquito-borne disease is driven by a combination of factors including mosquito abundance and diversity as well as populations of wildlife. The reservoir hosts of RRV are thought to most importantly be kangaroos and wallabies. Mosquitoes must first bite these animals to pick up and become infected themselves before then transmitting the virus to people. As a consequence, local transmission of RRV in metropolitan Sydney has always been associated with areas where kangaroos (e.g. Western Sydney, Hills District, Hawkesbury) or wallabies (e.g. Georges River) have been present. While it is suspected that other native animals, such as the common brushtail possum, ring-tailed possum, or grey-headed flying fox may play a role in transmission of RRV and other arboviruses, there may be ecological barriers that limit the contact between suitable mosquitoes and infected individuals of these animals. Similarly, birds are often considered important reservoirs of some mosquito-borne flaviviruses and there is evidence that mosquitoes in Sydney readily feed on birds and that some birds have been reported with serological evidence of prior arbovirus infection but their contribution to local transmission of arboviruses is some unclear. There remains a need for further research into the role of wildlife in urban arbovirus transmission cycles.

It is noteworthy that recent efforts to rehabilitate bushland and control wildlife predators (e.g. foxes) has resulted in an increase of swamp wallaby activity in many parts of Sydney, including the Ku-ring-gai and Northern Beaches regions. However, while there may be areas of the local government area where kangaroos and/or wallabies may be present, in the absence of regularly abundant mosquito populations, the risk of mosquito-borne disease is likely to be very low. There remains substantial gaps in our understanding of the role native wildlife play in transmission cycles of RRV, BFV, and other arboviruses. Notwithstanding the potential for other animals to contribute to transmission, there is a paucity of information on the importance of wildlife dynamics and movement across a region in driving public health risks. Horses may also be a reservoir of arboviruses in peri-urban areas but domestic pets (e.g. cats and dogs) are not considered a source of arboviruses.

There are also a number of other arboviruses that could be present in the Northern Beaches region and may pose minor health risks. Edge Hill virus (EHV) and Stratford virus (STRV) are often detected in mosquitoes collected across Sydney but there are few documented cases of symptomatic patients infected with these arboviruses. In NSW more generally, there is a number of other pathogens transmitted by mosquitoes that are important (e.g. Murray Valley encephalitis virus (MVEV), Kunjin virus (KUNV)) but there is a negligible risk of their activity in the Northern Beaches.

Concern is often raised in the community regarding the mosquito-borne disease of international significance. Fortunately, Australia is relatively free of the mosquitoes and their pathogens that cause a substantial burden of disease in many parts of the world.

Historically, there were cases of locally acquired malaria reported from the Northern Beaches with reports from 1926 of a case from Narrabeen. However, Australia was declared malaria free in the 1980s and any locally reported cases of infection are acquired overseas. While there are mosquitoes (e.g. *Anopheles annulipes*) present in the local area capable of transmitting the parasites that cause malaria, there is an extremely low risk that international travellers would trigger local outbreaks given that symptomatic individuals are likely to be treated quickly and highly unlikely to come into contact with local mosquitoes.

Potentially life threatening mosquito-borne disease, caused by viruses including dengue (DENV), chikungunya (CHIKV) and Zika (ZIKV) viruses, are present in many parts of the world and Australian travellers often return home infected with these pathogens. Individuals may occasionally test positive to these infections on return to the Northern Beaches but there is minimal risk that these travellers would trigger local activity of these mosquito-borne pathogens.

Dengue is of greatest concern given it is currently considered one of the most important mosquito-borne diseases internationally with South America, SE Asia and the Pacific have suffered significant outbreaks in recent years. Notwithstanding the direct health risks to local travellers, the potential movement of exotic mosquitoes (e.g. *Aedes aegypti* and *Aedes albopictus*) in their belongings may bring increased health threats to the local region. There are no mosquitoes currently known to exist in NSW that are capable of transmitting DENV, CHIKV, or ZIKV but, historically, *Aedes aegypti* was present in the Northern Beaches region suggesting that the climate, during the warmer months, is suitable for the mosquito.

A summary of the key mosquito-borne pathogens and their relative importance within the Northern Beaches region is provided in Table 2.

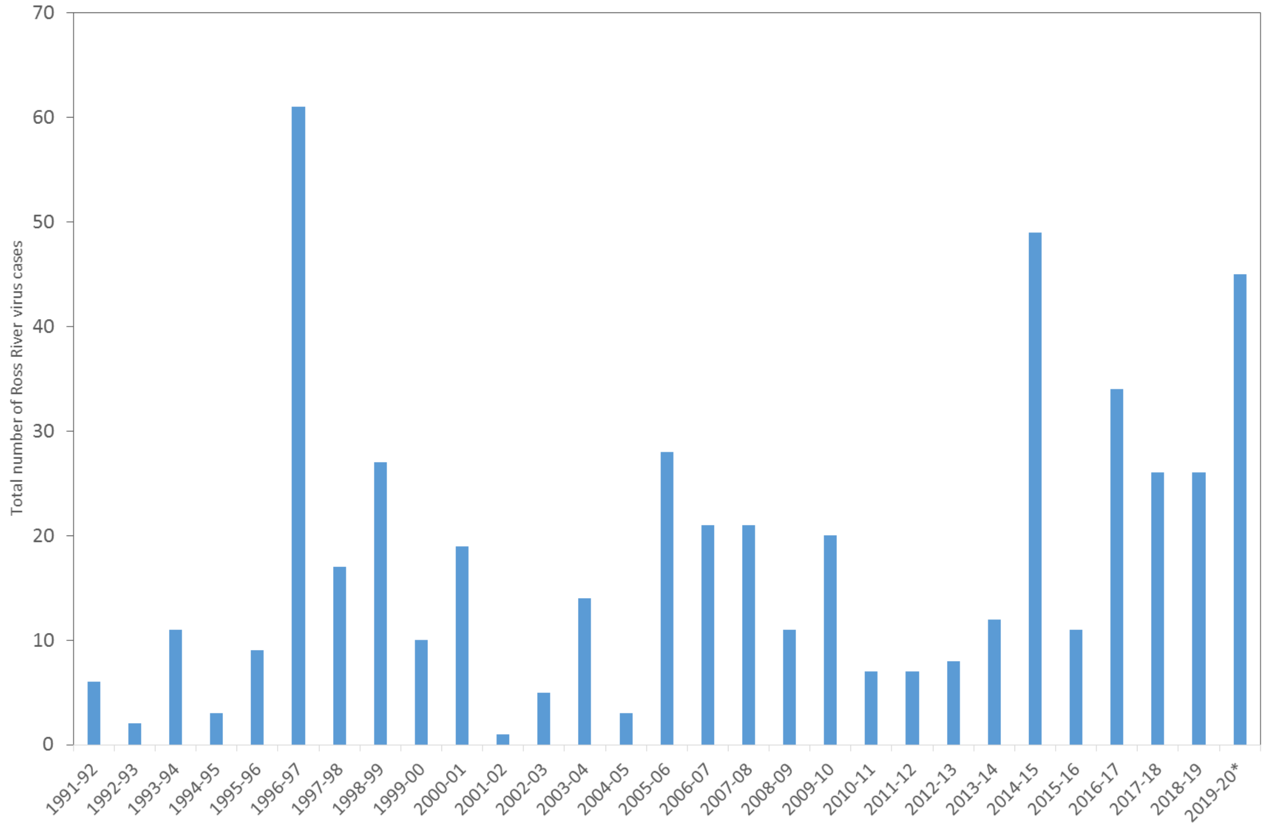

Figure 1. Annual Ross River virus disease notifications in Northern Sydney Local Health District residents, January 1991 to June 2020, presented for the period July through June. (Source: NSW Health Notifiable Conditions Information Management System (NCIMS), Communicable Diseases Branch and Centre for Epidemiology and Evidence, NSW Health). *At the time of reporting, data on RRV cases were only available between July 2019 and April 2020.

Table 1. Summary of common mosquitoes known to occur in the Northern Beaches region, their habitat associations, potential pest and public health concerns.

Mosquito species	Habitat associations	Potential pest and public health threat[1]
Aedes alternans	Estuarine and freshwater wetlands; mostly ephemeral in nature	Minor nuisance-biting pest; Low risk vector of mosquito-borne pathogens
Aedes multiplex	Freshwater wetlands; mostly ephemeral in nature	Moderate nuisance-biting pest (close to wetland habitats); Importance as vector of RRV and BFV unclear
Aedes notoscriptus	Freshwater container habitats in urban areas; especially domestic backyards	Moderate nuisance-biting pest (particularly in backyards); Moderate vector RRV and BFV
Aedes procax	Freshwater wetlands; mostly ephemeral in nature	Moderate nuisance-biting pest (close to wetland habitats); Moderate vector of RRV and BFV
Aedes vigilax	Estuarine wetlands	Major nuisance-biting pest; Major vector of RRV and BFV
Anopheles annulipes	Brackish water and freshwater wetlands	Minor nuisance-biting pest; Low risk vector of mosquito-borne pathogens
Coquillettidia linealis	Freshwater wetlands	Moderate nuisance-biting pest; Minor vector of mosquito-borne pathogens
Culex annulirostris	Freshwater wetlands	Moderate nuisance-biting pest; Moderate vector of RRV and BFV
Culex molestus	Urban stormwater and waste-water infrastructure; occasionally freshwater wetlands	Moderate nuisance-biting pest (properties with septic tanks); Importance as vector of RRV and BFV unclear
Culex quinquefasciatus	Freshwater wetlands, commonly polluted urban habitats	Moderate nuisance pest but generally prefers to bite birds; Minor vector of mosquito-borne pathogens
Culex sitiens	Estuarine wetlands; mostly permanently inundated	Rarely a nuisance-biting pest (prefers to bite birds)
Mansonia uniformis	Freshwater wetlands; mostly permanent with abundant floating aquatic plants	Moderate nuisance-biting pest; Importance as vector of RRV and BFV unclear
Verrallina funerea	Brackish water wetlands; mostly ephemeral in nature	Moderate nuisance-biting pest (close to wetland habitats); Minor vector of RRV and BFV
Verrallina Marks 52	Freshwater wetlands; mostly ephemeral in nature	Moderate nuisance-biting pest (close to wetland habitats); Importance as vector of RRV and BFV unclear

[1]Based on current understandings resulting from field observation, results of NSW Arbovirus Surveillance and Mosquito Monitoring Program, and published laboratory studies

Table 2. Summary of mosquito-borne pathogens of concern within the Northern Beaches and those from outside the region that may be a risk to travellers.

Pathogen	Symptoms and associated risk
Ross River virus	Transmission has been recorded in the local region. Symptoms can vary greatly between individuals and may include fever, rash and a condition known as polyarthritis with arthritic pain in the ankles, fingers, knees and wrists. Generally, the arthritic pain is greater with RRV infection compared to BFV. The primary animal hosts of RRV are macropods (i.e. kangaroos and wallabies).
Barmah Forest virus	Transmission has been recorded in the local region but far less common than RRV. Symptoms can vary greatly between individuals and may include fever, rash and a condition known as polyarthritis with arthritic pain in the ankles, fingers, knees and wrists. Generally, the rash tends to be more florid with BFV infection but the arthritic pain is greater with RRV infection. The primary animal hosts of BFV unconfirmed but are thought to be birds with mammals also potentially playing an important role.
Edge Hill virus	A pathogen occasionally detected in mosquitoes across Sydney but there has only been a single case illness reported in Australia. Symptoms described as including muscle ache, joint pain and fatigue.
Stratford virus	A pathogen regularly detected in mosquitoes across Sydney but there have been very few cases of illness reported in Australia. Symptoms described as including fever, joint pain and fatigue.
Kunjin virus	No cases of human disease reported in the local area and risk considered extremely low. The primary animal hosts of KUNV are thought to be birds and serologically positive birds have been found in western Sydney. Significant veterinary impacts (i.e. horse illness) reported in 2011 outside Sydney metropolitan region.
Dengue viruses	Not known from local region. Travellers returning from overseas may be diagnosed by local health authorities. There is currently no risk of local transmission due to the absence of mosquitoes capable of spreading the pathogen (e.g. *Aedes aegypti* or *Aedes albopictus*). There is no risk of local transmission.
Chikungunya virus	Not known from local region. Travellers returning from overseas may be diagnosed by local health authorities. There is currently no risk of local transmission due to the absence of mosquitoes capable of spreading the pathogen (e.g. *Aedes aegypti* or *Aedes albopictus*). There is no risk of local transmission.
Zika virus	Not known from local region. Travellers returning from overseas may be diagnosed by local health authorities. There is currently no risk of local transmission due to the absence of mosquitoes capable of spreading the pathogen (e.g. *Aedes aegypti* or *Aedes albopictus*). There is no risk of local transmission.
Malaria	Australia has been declared malaria free by the World Health Organisation in 1980s. Local cases reported in early 1900s from Northern Beaches. Travellers returning from overseas may be diagnosed by local health authorities. There is minimal risk of local transmission.

MOSQUITOES AND THE NORTHERN BEACHES

Previous mosquito investigations

Adult mosquito monitoring on the Northern Beaches had previously been undertaken as part of the NSW Arbovirus Surveillance and Mosquito Monitoring Program in the seasons 1997-98 and 1998-99. This included sites at North Avalon, Bilgola Plateau, McCarrs Creek, Church Point, and Narrabeen (Mullet Creek). This mosquito monitoring was most likely in response to a spike in RRV infections reported during the previous season (1996-1997) when over 60 cases were reported. Mosquito populations across these sites over these two seasons were not considered abundant, rarely more than 30 mosquitoes per trap. There was, however, a single detection of an arbovirus, Edge Hill virus (EHV), in 1998 from a specimen of *Aedes notoscriptus* collected at Bilgola Plateau. The most common mosquitoes collected at the time were *Aedes notoscriptus*, *Aedes multiplex*, *Anopheles annulipes*, *Culex annulirostris*, and *Culex quinquefasciatus*; mosquitoes commonly collected throughout the Sydney metropolitan region.

In addition to the formal mosquito monitoring undertaken as part of the NSW Arbovirus Surveillance and Mosquito Monitoring Program, mosquito sampling had also been undertaken around Warriewood Wetlands and Winnererremy Bay as part of contracted (NSW Health Pathology unpublished reports) mosquito risk assessments associated with new residential developments, wetland construction as part of water sensitive urban design programs, and estuarine wetland rehabilitation projects. Research projects (University of Sydney) had also been undertaken in the southern regions of the Council area around Middle Harbour. Data collected as part of these projects were relatively limited given short periods of sampling but generally reflected similar mosquito populations to those reported in formal surveillance.

Current mosquito investigations

Mosquito and arbovirus monitoring

Adult mosquito populations were monitored on 12 occasions between December 2019 and May 2020 at five locations across the region, McCarrs Creek Reserve, Winnererremy Bay, Careel Bay, Warriewood Wetlands, and Narrabeen Lagoon (Deep Creek) (Figure 2). Traps were not set at all locations on each trapping occasion due to prioritising sampling at Warriewood Wetlands, and Narrabeen Lagoon (Deep Creek) during later stages of investigation. In addition to the standard trapping sites, mosquitoes were also collected from a small number of *ad hoc* sampling locations including bushland around Oxford Falls (Middle Creek) and Irrawong Reserve (Mullet Creek).

At each location, 2-3 Encephalitis Virus Surveillance (EVS) traps (Figure 3) were operated per night. The EVS traps use carbon dioxide to attract host-seeking female mosquitoes and are considered the gold standard for monitoring mosquito populations of pest and public health concern in most areas of Australia. The frequency of trapping was primarily determined by prevailing climatic conditions with the intention of sampling mosquito populations following environmental conditions likely to trigger change in mosquito populations (e.g. rainfall, high tides). While originally planned to be conducted between the months of December and March, sampling continued beyond the original anticipated monitoring period due to the detection of arboviruses. On each sampling occasion, mosquito traps were set in the mid to late afternoon and collected the following morning shortly after sunrise.

Mosquito specimens were returned to the laboratory for identification and processing to determine the presence of arboviruses. Mosquitoes were identified according to the taxonomic keys of Russell (1998) and pictorial guides of Webb et al (2016). Mosquito specimens from multiple trap sites were pooled according to trap location and dates and processed to determine the presence of arboviruses using methods consistent with the NSW Arbovirus Surveillance and Mosquito Monitoring Program. In summary, molecular techniques are employed to identify the genetic evidence of arboviruses within pooled mosquitoes. The detailed methodology of arboviruses detection and identification is provided in annual reports of the NSW Arbovirus Surveillance and Mosquito Monitoring Program (see Doggett et al 2019).

Figure 2. Overview of study locations, Careel Bay (A), Winnererremy Bay (B), McCarrs Creek Reserve (C), Warriewood Wetlands (D), and Deep Creek (Narrabeen Lagoon) (E), and individual mosquito trap sites (○) within Northern Beaches local government area, December 2019 through May 2020. (Images © NSW Government Spatial Services 2019, Creative Commons Attribution 4.0 Australia Licence)

Figure 3. An example of the carbon dioxide-baited "Encephalitis Virus Surveillance" traps used to survey adult mosquito populations at five locations within the Northern Beaches local government area, December 2019 through May 2020.

Table 3. Summary of climatic conditions during the 2019-2020 Northern Beaches mosquito monitoring period compared to long-term average conditions. (Bureau of Meteorology, Observatory Hill, Sydney)

Month	2019-2020			Long-term Average		
	Mean Monthly Minimum Temperature (°C)	Mean Monthly Maximum Temperature (°C)	Total Monthly Rainfall (mm)	Mean Monthly Minimum Temperature (°C)	Mean Monthly Maximum Temperature (°C)	Mean Total Monthly Rainfall (mm)
November	16.9	26.6	26.2	15.7	23.7	83.8
December	18.9	26.8	1.6	17.6	25.2	77.1
January	20.9	28.1	71.4	18.8	26.0	101.2
February	20.3	27.1	441.6	18.9	25.8	119.3
March	17.6	25.3	160.4	17.6	24.8	131.6
April	15.8	24.4	27.6	14.8	22.5	126.5
May	11.7	20.0	118.8	11.6	19.5	117.4

Climatic and environmental conditions

The climatic and environmental conditions recorded during the investigation varied markedly. December 2019 and January 2020 recorded minimal rainfall and above average temperatures that created adverse condition for mosquitoes (Table 3). While there was tidal inundation of estuarine wetlands (i.e. saltmarsh and mangroves) at Careel Bay and Winnererremy Bay, the extent of inundation and persistence of ground pools was below average and did not provide suitable conditions for mosquitoes such as *Aedes vigilax*. Similarly, the hot and dry conditions were not suitable for many freshwater or brackish water mosquitoes and very few mosquitoes were collected during these months. In early February, there was an exceptional rainfall event in which over 400mm of rainfall was recorded across Sydney and this event was then followed by rainfall generally consistent with long-term averages over following months. Combined with mean maximum and minimum daily temperatures remaining above average over this period also, environmental conditions were enhanced for a wide range of mosquito species.

It is important to note these exceptional environmental and climatic conditions when interpreting the results of adult mosquito monitoring and arbovirus surveillance. The conditions during February through early May 2020 are substantially different to those associated with the long-term average for the region. As a consequence, the results, and recommendations, presented here should consider these unusual circumstances.

Mosquito populations

A total of 13,480 mosquitoes were collected representing nine genera and 37 species (Table 4). The most commonly collected mosquitoes were *Aedes procax* (27.1% of total mosquitoes collected), *Verrallina* Marks 52 (19.4% of total mosquitoes collected), *Aedes multiplex* (17.7% of total mosquitoes collected), and *Anopheles annulipes* (6.3% of total mosquitoes collected). It is interesting to note that the three mosquitoes most commonly associated with pest and public health concerns across much of Sydney were all recorded at relatively low abundances, *Aedes notoscriptus* (4.9% of total mosquitoes collected), *Aedes vigilax* (2.5% of total mosquitoes collected), and *Culex annulirostris* (4.3% of total mosquitoes collected). A full breakdown of individual trap night collections is provided in Attachment 1.

Adult mosquito collections at Oxford Falls (Middle Creek) and Irrawong Reserve (Mullet Creek) did not identify substantially different abundance or diversity of mosquitoes compared to Warriewood Wetlands or Narrabeen Lagoon. At Oxford Falls (Middle Creek), collections included specimens of *Aedes notoscriptus, Aedes multiplex*, *Aedes procax*, *Anopheles annulipes*, *Coquillettidia linealis*, *Culex annulirostris,* and *Culex quinquefasciatus.* At Irrawong Reserve, the diversity of specimens collected reflected those of the nearby Warriewood Wetlands, collections included specimens of *Aedes flavifrons, Aedes multiplex*, *Aedes notoscriptus, Aedes multiplex*, *Aedes procax*, *Anopheles annulipes*, *Coquillettidia linealis*, *Culex annulirostris, Culex molestus, Culex orbostiensis, Culex quinquefasciatus, Culex sitiens,* and *Verrallina* Marks 52*.*

The collection of such a diverse range of mosquitoes was surprising and it was unusual to collect so many species over a relatively short period. The high degree of mosquito diversity reflects the diverse environments across the region (Figure 4) that includes estuarine, brackish water, and freshwater habitats that are either permanent or ephemeral while including water-holding containers that are either natural or artificial. The substantial rainfall during late summer also played an important role in providing enhanced conditions for many mosquitoes across all habitats.

The most important mosquitoes identified in this investigation can broadly be classified as "floodwater mosquitoes". These mosquitoes are found in ephemeral, or the margins of permanent, water bodies in a range of wetland, woodland, and bushland areas. While there may be more than a dozen mosquito species that could be grouped into this classification, the key species identified through this investigation are *Aedes procax*, *Aedes multiplex*, and *Verralina* Marks 52. These mosquitoes lay their eggs in and around ground pools that either fill following rainfall or are at the margins of larger marshland areas that are inundated as water levels rise with rainfall or surface runoff. These mosquitoes are common pests in many coastal regions, especially where urban development and recreational facilities are provided in close proximity to coastal swamp forests.

These mosquitoes are generally only found in freshwater habitats but they are tolerant of very mildly brackishwater conditions. In the local region, the habitats best suited for these mosquitoes are associated with Warriewood Wetlands and the surrounding habitats of Narrabeen Lagoon. While they will also be present in higher elevations of bushland areas (e.g. ephemeral ground pools in bushland or freshwater sandstone rock pools) they are less like to be as abundant as in those low-lying areas. These mosquitoes do not generally travel far from habitats and there is some evidence they do not travel in substantial numbers beyond 100m from woodland/forest habitats unless there is substantial vegetation cover that facilitates movement into nearby residential areas.

There are also some mosquitoes associated with permanent freshwater wetlands (e.g. Warriewood Wetlands). A suite of mosquitoes were recorded but those most likely to bring pest and/or public health concern are *Culex annulirostris*, *Coquillettidia linealis,* and *Mansonia uniformis*. However, it is interesting to note that these mosquitoes were not considered particularly abundant in any location. Warriewood Wetlands and Narrabeen Lagoon recorded the largest numbers but compared with some other areas of Sydney, the abundance of these mosquitoes was considered relatively low considering the substantial rainfall recorded. It is likely that there is an absence of suitable habitats for these mosquitoes across the region. It is important to note that where stormwater infrastructure is increasing, these mosquitoes may become more problematic. Stormwater infrastructure and associated elements of water sensitive urban design (including drains, bioretention basins, swales, gross pollutant traps, septic tanks) can be a potential source of pest mosquitoes. Water bodies that are either deep or contain regular water movement are generally less suitable for mosquitoes, where there is an abundance of aquatic vegetation, either emergent macrophytes (e.g. *Typha* or *Phragmites* spp.) or floating aquatic plants (e.g. duckweed, water hyacinth) populations of these three mosquitoes can increase.

The mosquito of greatest concern in many areas of Sydney where estuarine wetlands are present is *Aedes vigilax*. Conditions that are most suitable for this mosquito are moderately ephemeral ground pools within tidally inundated saltmarsh, mangrove, or sedgeland environments. In some regions, the mosquito is also found in brackish to saline conditions in coastal swamp forests and she-oak woodlands. However, in these two habitats, rainfall is the driving factor creating favourable conditions more so than tidal inundation.

The most productive habitats for *Aedes vigilax* are those dominated by saltmarsh vegetation, especially *Sarcocornia quinqueflora* and *Sporobolus virginicus*. *Aedes vigilax* lays desiccation resistant eggs on substrates and vegetation, these eggs may persist for many years before hatching following favourable conditions. Regularly flushed mangrove habitats are generally not suitable for mosquito production given the water movement and abundance of predatory fish. Recent studies from NSW and SE QLD indicate that degraded mangrove habitats are more likely to support productive conditions for mosquitoes. There are small areas of saltmarsh and sedgelands fringing many of the creeks and lagoons within the area but these areas are not sufficiently large (e.g. saltmarsh at Winnererremy Bay) to represent a source of substantial mosquito populations. The most substantial wetlands of this nature are in Carrel Bay but during this investigation, the wetlands effectively drained following rainfall or tidal inundation and the habitats were not considered to be conducive for producing large numbers of *Aedes vigilax*. This was confirmed in that relatively few mosquitoes of this species were collected at either Careel Bay or Winnererremy Bay.

It is noteworthy that there was a section of Careel Creek (adjacent to tennis centre) that retained water in large but shallow pools after the February rainfall. While not assessed as being a significant source of pest mosquitoes during this investigation, consideration could be given to remediation of this area so that water drains from these pools back into the main creekline. Relatively minor earthworks would be required but would dramatically reduce the potential for this area to be a source of pest mosquitoes.

In residential and industrial areas, especially residential backyards, mosquitoes associated with water-holding containers may be problematic. *Aedes notoscriptus* is one of the most widespread nuisance-biting mosquitoes in Australia and it was collected at all locations in this study where residential areas were in close proximity to trap sites. This mosquito will lay eggs in association with small water holding containers such as tins, pot-plant saucers, discarded tyres and children's toys, ornamental ponds, roof guttering, unscreened rainwater tanks, and water-holding tarpaulins covering boats or trailers, as well as water holding plants (e.g. bromeliads) and tree holes. The mosquito is a nuisance-biting pest and potential vector of RRV and BFV as well as potentially spreading dog heartworm parasites. This mosquito does not fly far from backyard habitats, perhaps less than 200m, so may be present in parklands adjacent to wetlands or bushland areas. As a consequence, nuisance-biting reported to council should be investigated as this mosquito, as opposed to mosquitoes associated with wetland and bushland areas, may be responsible. It is interesting to note that the overall lowest abundances of these mosquitoes were in sites furthest from residential dwellings (e.g. McCarrs Creek Reserve and Deep Creek (Narrabeen Lagoon)). Studies in QLD, NSW, and WA have identified that strategies for reducing opportunities for these mosquitoes is heavily reliant on community education programs.

There are other mosquitoes found in urban habitats that may cause nuisance problems. *Culex quinquefasciatus* and *Culex molestus* were both recorded in this investigation and, although the numbers were collected were low, they may be a source of pest problems under some circumstances. Neither species is considered important in the transmission of RRV or BFV but as they are found in various stormwater and waste-water infrastructure in urban areas they may occasionally be abundant. *Culex molestus* is almost exclusively found in subterranean habitats, especially septic tanks.

It is noteworthy that there are three mosquito species known to exist in the region but were not recorded in this monitoring. Those species are *Aedes australis* (a mosquito associated with saline rock pools along the coast and estuarine waterways), *Aedes rupestris* (a mosquito associated with ephemeral waterbodies in bushland areas), and *Toxorhynchites speciosus* (a mosquito associated with natural and artificial water-holding containers but not readily collected in the style of traps used in this study given this mosquito does not feed on animals). There are also likely to be other mosquito species present in the area that are either associated with highly specific habitats or are not readily collected in traps used in the current study (e.g. the frog-feeding *Uranoteania* spp.).

Arbovirus activity

Arboviruses were detected in mosquitoes on 18 occasions between 19 March and 4 May 2020 (Table 5). This included RRV detected from Deep Creek (Narrabeen Lagoon) on 5 occasions and Warriewood Wetlands on 3 occasions; BFV was detected from Deep Creek (Narrabeen Lagoon) on 3 occasions; STRV was detected from Narrabeen Lagoon on 4 occasions, Warriewood Wetlands on 1 occasion and Careel Bay on 1 occasion; Edge Hill virus (EHV) was detected from Deep Creek (Narrabeen Lagoon) on 1 occasion. This is the first time mosquito-borne pathogens of human health importance (i.e. RRV and BFV) have been identified in mosquito populations on the Northern Beaches of Sydney.

It is worth noting that in the season 1996-1997, in which over 60 cases of RRV infection were reported in Northern Sydney LHD, there was a similarly timed substantial rainfall event with over 300mm of rain recorded between 29 January and 13 February 1997 (BOM; Sydney (Observatory Hill) meteorological station). Notwithstanding the environmental differences around Warriewood Wetlands and Narrabeen Lagoon at that time compared to current conditions, and possible differences in wildlife abundance and distribution, it is highly likely that substantial increases in mosquito populations, including the range of species recorded during the current investigation, are likely to have occurred at that time.

Response of authorities to arbovirus detection

In response to elevated mosquito abundance and the detection of RRV and BFV in local mosquitoes, Northern Beaches Council, with consultation with Northern Sydney Public Health Unit and Medical Entomology, NSW Health Pathology, issued a public health warning on 30 April 2020 (see Attachment 2). This was followed by the installation of warning signs at the entrances to Warriewood Wetlands and the Narrabeen Lagoon Trail (see Attachment 3) to raise awareness of the health risks associated with local mosquitoes and promote the use of personal protection measures.

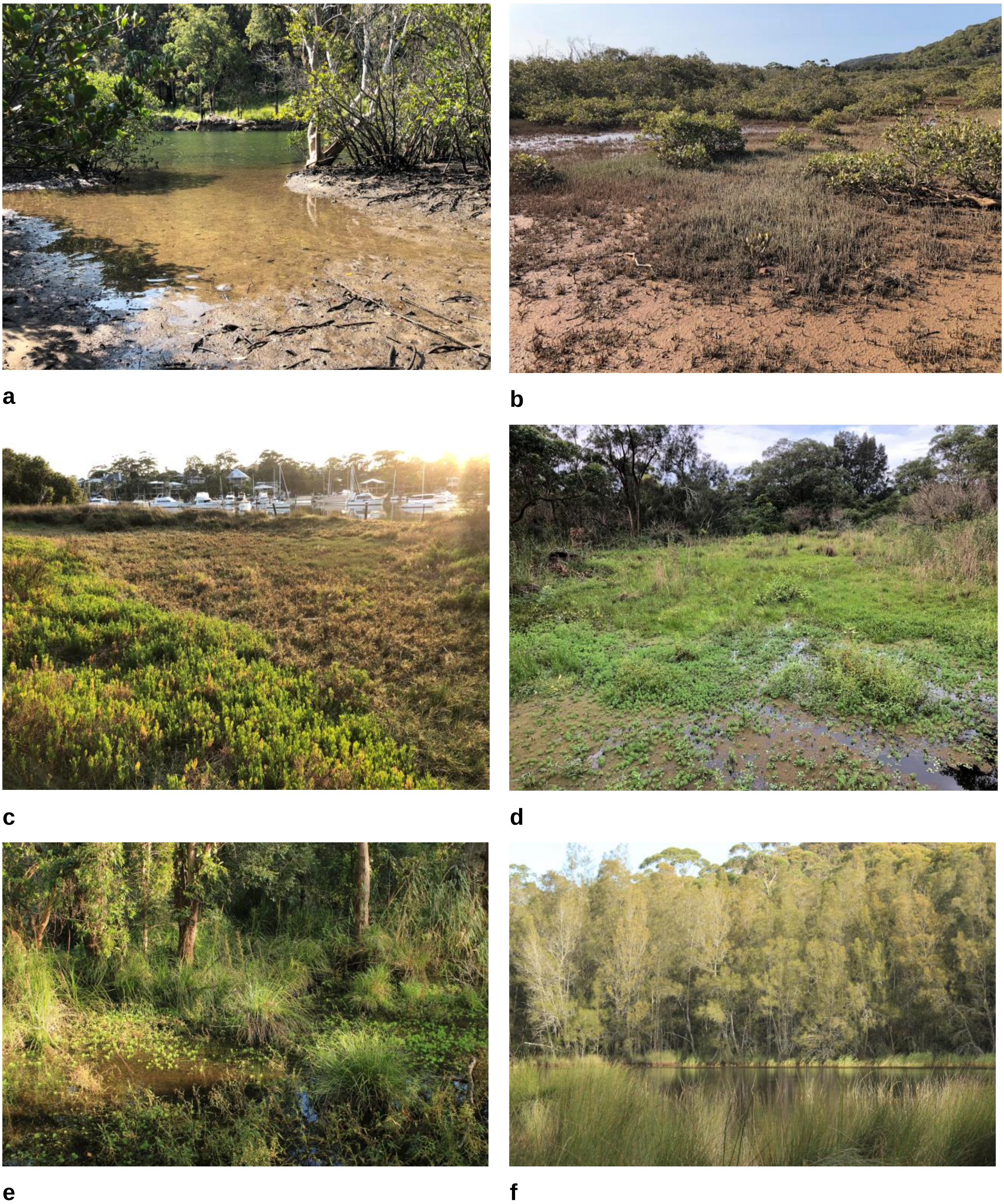

Figure 4. Examples of actual and potential mosquito habitat within Northern Beaches Council including the estuarine wetlands of MaCarrs Creek (a), Careel Bay (b) and Winnererramy Bay (c) and the freshwater wetlands and ephemeral habitats of Warriewood Wetlands (d and e) and Deep Creek (Narrabeen Lagoon) (f), Northern Beaches, 2019-2020.

Table 4. Total abundance of mosquito species collected at five sampling locations across the Northern Beach Council region, 2019-2020.

Mosquito species	McCarrs Creek Reserve	Winnereremy Bay	Careel Bay	Warriewood Wetlands	Narrabeen Lagoon	Total
Adeomyia venustipes	0	0	0	1	0	1
Aedes aculeatus	0	0	3	9	54	66
Aedes alboannulatus	0	0	0	0	1	1
Aedes alternans	0	0	11	3	5	19
Aedes burpengaryensis	0	0	0	0	1	1
Aedes flavifrons	2	3	0	127	206	338
Aedes kochi	7	0	0	0	0	7
Aedes mallochi	1	0	0	2	0	3
Aedes multiplex	4	0	1	1,593	788	2,386
Aedes notoscriptus	32	160	164	257	42	655
Aedes procax	38	14	30	727	2,837	3,646
Aedes quasirubrithorax	0	0	0	3	1	4
Aedes rubrithorax	3	0	0	0	0	3
Aedes theobaldi	0	0	0	2	0	2
Aedes vigilax	77	62	116	28	59	342
Aedes vittiger	0	4	0	0	1	5
Aedes Marks 51	6	3	0	60	170	239
Anopheles annulipes	2	7	5	482	346	842
Anopheles atratipes	0	0	0	17	62	79
Coquillittidia linealis	2	0	0	11	25	38
Coquillittidia xanthogaster	0	0	5	45	34	84
Culex annulirostris	67	49	92	136	232	576
Culex australicus	1	0	2	3	0	6
Culex bitaeniorhynchus	0	0	0	2	1	3
Culex halifaxii	0	0	0	1	2	3
Culex molestus	18	2	6	41	39	106
Culex orbostiensis	0	0	0	180	108	288
Culex postspiraculosus	0	0	0	1	2	3
Culex quiquefasciatus	7	16	75	23	13	134
Culex sitiens	14	45	321	21	9	410
Culex squamosus	0	0	0	6	0	6
Culex Marks 32	0	1	0	62	4	67
Mansonia uniformis	0	0	0	54	2	56
Mimomyia elegans	0	0	0	3	0	3
Tripteroides marksae	0	0	1	1	0	2
Verrallina funerea	0	1	4	84	354	443
Verrallina Marks 52	0	0	98	1,109	1,406	2,613
Total	**281**	**367**	**934**	**5,094**	**6,804**	**13,480**

Table 5. Number of detections of Ross River virus (RRV), Barmah Forest virus (BFV), Stratford virus (STRV), and Edge Hill virus (EHV) from mosquitoes collected at three locations on the Northern Beaches of Sydney, December 2019-May 2020.

Site	Date Set	RRV	BFV	STRV	EHV	Total
Narrabeen Lagoon (Deep Creek)	19/03/2020	0	0	1	0	1
Narrabeen Lagoon (Deep Creek)	30/03/2020	1	0	0	0	1
Warriewood Wetlands	06/04/2020	1	0	0	0	1
Narrabeen Lagoon (Deep Creek)	06/04/2020	1	1	1	0	3
Narrabeen Lagoon (Deep Creek)	20/04/2020	1	1	1	0	3
Warriewood Wetlands	20/04/2020	0	0	1	0	1
Warriewood Wetlands	26/04/2020	1	0	0	0	1
Narrabeen Lagoon (Deep Creek)	26/04/2020	1	1	1	1	4
Narrabeen Lagoon (Deep Creek)	04/05/2020	1	0	0	0	1
Warriewood Wetlands	04/05/2020	1	0	0	0	1
Careel Bay	04/05/2020	0	0	1	0	1
Total		**8**	**3**	**6**	**1**	**18**

MOSQUITO MANAGEMENT STRATEGIES

Environmentally sustainable mosquito management

Managing the pest and public health risks of the local mosquito populations does not have to adversely impact the environment or place undue operational and/or financial burdens on local authorities or community. Many of the mosquitoes present in the local region are native species and an intrinsic part of the local ecosystem. The objective of mosquito management should be reducing the contact between people and mosquitoes to reduce the associated pest and public health risks, without adversely impacting the local ecosystem.

While the control of mosquito populations within and around wetlands has been effectively employed by local authorities around Australia, there is a paucity of evidence that mosquito control, other than extensive pre-emptive programs, significantly reduces the rate of mosquito-borne disease. There is clear evidence that mosquito populations can be suppressed in ecologically sustainable ways and that this results in a reduction of nuisance-biting impacts but given the wide variety of mosquito species associated with pathogen transmission, it is just not possible to reduce the abundance of all mosquitoes across all habitats. Mosquito control alone is not the only solution, there are a range of additional approaches that need to be incorporated into an integrated, site-specific strategy by local authorities.

A summary of mosquito management strategies employed across Australia, their advantages and disadvantages are summarised in Table 6.

Mosquito and mosquito-borne pathogen surveillance

Mosquito and mosquito-borne pathogen surveillance should form the basis of local mosquito management strategies in the region. The provision of reliable information on mosquito populations, as well as mosquito-borne disease activity, will be crucial in shaping mosquito management strategies. Without data on changes in mosquito abundance and diversity within and between seasons, strategic cost-effective modifications to mosquito control and surveillance programs will not be possible.

Elements of a strategic surveillance program include monitoring mosquito abundance and diversity with respect to local environmental conditions, monitoring mosquito-borne pathogen activity within local mosquito populations, and monitor notifications of mosquito-borne disease in human population. Each of these surveillance strategies brings a specific set of information to local authorities and there must be clear guidelines on this information will vary the response to local mosquito threats.

For the Northern Beaches local government area, it is important to consider the role of prevailing climatic conditions in driving the abundance and diversity of mosquitoes. Based on this investigation, even though there are estuarine wetlands present in the area, high abundances of key mosquitoes of pest and public health importance will primarily be driven by rainfall events (as opposed to tide cycles in other coastal regions of Sydney and, more generally, coastal NSW). It should be expected that increases in mosquito abundance will occur following substantial rainfall events during the period December through March each season. However, during periods of below average rainfall over this same period, mosquito populations would be expected to be substantially lower.

Based on this current investigation, considering the abundant mosquito populations and activity of arboviruses of human health concern, there would be great benefit to Northern Beaches Council participating the NSW Arbovirus Surveillance and Mosquito Monitoring Program. This is a state-wide program that includes a number of local governments and public health units in metropolitan Sydney. Mosquito sampling is typically undertaken between December and April with weekly collection and processing of adult mosquitoes. Adult mosquitoes are collected with carbon dioxide baited light traps (as used in this investigation) are effective at collecting the mosquitoes of pest and public health concern. These traps are typically only operated once a week, set in the late afternoon and collected the following morning. This is generally done early in the week to allow processing of collections and notifications to stakeholders by the end of the working week.

While local government is responsible for the setting and collection of mosquito traps, the NSW Arbovirus Surveillance and Mosquito Monitoring Program (Medical Entomology, NSW Health Pathology and Health Protection NSW) facilitates the identification of mosquito specimens, testing specimens for the presence of mosquito-borne pathogens, and the provision of weekly reports. These reports provide a summary of results, implications for pest and public health risks, and commentary regarding prevailing season climatic conditions and implications for the remainder of the season and potential mosquito impacts.

The costs to council would include purchase of EVS traps (approximately $290 each) and consumables associated with trapping (i.e. batteries and dry-ice). There is also an opportunity for mosquito traps to be loaned to local governments from Medical Entomology, NSW Health Pathology, but availability cannot always be guaranteed. Consumable costs are variable but estimated at approximately $3/week for batteries (approximately $70 per season) and approximately $30/week for dry-ice (approximately $360 per season). These costs are offset by funds provided by Health Protection NSW to participant local government agencies of $25/trap/week (approximately $600 per season). The major cost to participant agencies is the staffing time of council employees to set and collect traps (estimated at less than 4h per week) as well as arrange transport of specimens to Medical Entomology laboratories at Westmead Hospital. There are various options for this including the use of a courier service or council staff physical drop off of traps to Westmead Hospital.

The information gathered by mosquito monitoring can be used to strengthen public health messages and other public health education initiatives of Northern Beaches Council and North Sydney Public Health Unit. Seasonal warnings of mosquito activity can be accompanied by data from surveillance programs. For example, using data on mosquito activity, health warnings may include comments on increased mosquito activity such as “current mosquito populations are well above the long-term average” or “there are currently three times as many mosquitoes being collected compared to this time last month”. By including this data in public health messages, it would be expected to strengthen impact and engagement giving the message immediacy that seasonal routine messages may not.

Quantified mosquito population sampling can also assist with the response to community complaints about mosquitoes. It is commonly stated that “this season is the worst ever for mosquitoes” when, in reality there may not be many more than the usual number of mosquitoes. Individuals vary in their sensitivity to mosquito bites and the level at which nuisance becomes serious. There will also be great variability in the awareness and willingness of the community to contact local authorities to complain. Having access to reliable mosquito population data assists in responding to these enquires from the community.

Based on the results of this investigation, the extensive trapping network employed here would not necessarily be replicated within the NSW Arbovirus Surveillance and Mosquito Monitoring Program. Given the relatively low mosquito populations recorded at Careel Bay, Winnererreny Bay, and McCarrs Creek Reserve, trap sites at these locations are not a high priority. The two priority areas are Warriewood Wetlands and Deep Creek (Narrabeen Lagoon). These two areas recorded the highest numbers of mosquitoes, activity of arboviruses, and are generally locations either close to residential areas (Warriewood Wetlands) or near locations of high recreation activity (Warriewood Wetlands and Narrabeen Lagoon). A single trap site at each of these locations should be considered a priority.

It is also important to note that while these areas are a priority for mosquito and arbovirus surveillance, this does not mean that detection of arboviruses in mosquitoes collected from these locations does not indicate potential public health risks across wider areas of the Northern Beaches Council region. There is likely to be concomitant risks in other areas, especially where wetlands and bushland reserves are close to residential and recreational areas.

With consideration given to the unusual climatic and environmental conditions experienced during the 2019-2020 investigation, the need for annual involvement in the program can be reviewed following the 2020-2021 monitoring period. There is a potential that conditions favourable for elevated pest and public health concern are associated with significant rainfall events and that "normal" circumstances pose a minimal risk. In these circumstances, it may be that strategic surveillance is required, prompted only by favourable environmental conditions or the detection of RRV or BFV elsewhere in the Sydney or Central Coast region.

Public education programs

It should be expected that mosquitoes will always be active during the warmer months, especially in and around wetland and bushland areas within the Northern Beaches Council area. Public education programs to raise awareness of the pest and public health threats associated with mosquitoes and promotion of strategies to protect the community from bites are critical.

Messaging across a range of Council communication channels should promote awareness of mosquito risk as well as strategies individuals and households can have on reducing exposure to mosquitoes. Personal protection measures can reduce the risks of mosquito-borne disease by preventing mosquito bites or by reducing the activity of mosquitoes in and around the home.

The use of personal insect repellents is the first line of protection against biting mosquitoes and, consequently, pest and public health risks. A wide range of formulations, including aerosols, creams, lotions, pump sprays and sticks are registered for use in Australia by the APVMA. However, regardless of the formulation, the most effective products are those that contain DEET (diethyltoluamide or N,N-diethyl-3-methylbenzamide) and Picaridin, two chemicals known to be effective insect repellents and widely available in commercial formulations. Both products have been proven to be effective against a range of Australian mosquitoes and very few adverse health impacts have been reported internationally when used as recommended. A third active ingredient listed on the label of registered products as "Oil of Lemon Eucalyptus" is also effective and is increasingly common in commercial insect repellent formulations.

Many 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 people will find they cause skin irritations. More importantly, however, they generally offer substantially lower protection times when compared to those containing DEET or picaridin and will therefore need to be reapplied more frequently to provide protection.

In addition to topical mosquito repellents, there is a range of products including coils, sticks and other 'burner' devices that purport to repel mosquitoes. Mosquito coils and sticks that contain insecticides generally provide better protection than those containing plant-derived products. There are also "smokeless" products increasingly available that are impregnated with an insecticide (usually a pyrethroid) that is released when heated, either by burning (coils and sticks), or by a small electrical unit (vaporising mat) or dispersed by a battery operated fan (clip-on devices). These products are generally designed for indoor or sheltered outdoor areas and should be used as directed.

An essential component of community education is to increase awareness of the importance of backyard mosquito habitats. Even in suburbs relatively close to wetland areas, the production of mosquitoes from backyard habitats, especially *Aedes notoscriptus*, can cause relatively greater nuisance-biting problems as the mosquitoes are in close proximity to dwellings and are persistent biters. Key habitats for this mosquito are artificial water-holding containers and the homeowner can greatly reduce opportunities for this mosquito in their backyards by throwing out, covering up, or storing inside any receptacles that could collect water after rain. Rainwater tanks are a common source of mosquitoes. While modern and well installed tanks actual pose minimal risk, in situations where screening is not adequately in place or that the tank is not satisfactorily installed or constructed (i.e. where gaps exist for mosquitoes to gain access inside), they can be a major source of pest mosquitoes.

Many local government agencies around Australia engage the community through various community events to assist promotion of awareness of mosquito risks and personal protection measures. This may include the incorporation of mosquito educational material with other human health or environmental/sustainability initiatives. Personal protection measures (e.g. selection of suitable insect repellents) can be readily incorporated into environmental awareness programs (e.g. bushwalks, bird watching etc) while reducing opportunities for mosquitoes in backyards can be incorporated into messaging around recycling, property clean up, or water recycling/storage.

In addition to routine messaging reminding residents and visitors of the risks associated with mosquitoes, there should also be targeted messages issued in response to local and Sydney/Central Coast metropolitan mosquito and arbovirus monitoring. Messages sent via Northern Beaches Council communication routes (e.g. newsletter, website, social media, media engagement) may be triggered by the environmental conditions likely to trigger an increase in mosquitoes (e.g. substantial rainfall), monitoring that reveals increased mosquito abundance, or the detection of arboviruses. The installation of temporary warning signs may be beneficial but more work is required to determine if this changes behaviour of residents and visitors. The critical issue for local authorities to consider is the timeliness of communication. Where an elevated risk to public health is identified, there should be rapid communication of public health and personal protection measures. These messages, and their timing, should be undertaken in consultation with the Northern Sydney Public Health Unit and any relevant experts (e.g. Medical Entomology, NSW Health Pathology). The detection of an arbovirus may not necessarily require the issuing of a public warning (e.g. detection late in season during cold conditions and/or at times that mosquito populations are very low) but, generally, warnings should be issued as soon as possible following the detection of RRV or BFV in locally collected mosquitoes.

In the case of arbovirus detection, the lead agency for public communications may be the Northern Sydney Public Health Unit or Environmental Health Protection NSW. The detection of arboviruses in mosquitoes collected around Sydney often prompts media releases from either the individual Public Health Unit or NSW Health. The response of often assessed on a case-by-case basis dependant on a range of factors including type of mosquito-borne pathogen detected, prevailing and forecast climactic conditions, school and public holidays, and known cases of human disease in local or broader region. It is important that there is communication between all agencies ahead of issuing such public health messages to ensure that all agencies are properly prepared for subsequent media or community enquiries.

Northern Sydney Public Health Unit and/or Environmental Health Protection NSW would almost certainly be the lead agency for communication around identified outbreaks of confirmed mosquito-borne disease on Northern Beaches. However, it is important to note that due to delays between likely exposure to infected mosquitoes and confirmation of locally acquired human disease, public health messages promoting avoidance of mosquitoes will generally be too late to limit exposure of the community to infected mosquitoes and mosquito-borne pathogens. For this reason, monitoring of environmental conditions, mosquito abundance and diversity, and activity of pathogens in mosquito populations are far more effective to inform public health interventions.

A framework for communicating issues regarding mosquito and mosquito-borne disease awareness, together with promotion of personal protection measures to be used against mosquitoes is provided in Table 6.

Table 6. Proposed Northern Beaches Council (NBC) communication plan framework, in partnership with Northern Sydney Public Health Unit (NSPHU) and NSW Health, to raise awareness of mosquitoes and mosquito-borne disease in combination with promotion of personal protection measures

Public message type	Timing and trigger	Notes
Routine	Issued at the start of the mosquito season (November/December)	NBC in partnership with NSPHU and NSW Health. Media release, newspaper and radio advertisements, social media, flyer distribution; standard messages regarding awareness of mosquitoes and their health impacts, personal protection recommendations.
Environmental-prompted	Substantial rainfall; extreme weather	NBC in partnership with NSPHU and NSW Health. Media release, social media. Reminders of possible mosquito population increase, backyard clean up to minimise opportunities for mosquitoes, and personal protection recommendations.
Surveillance-prompted (mosquitoes)	Increased mosquito abundance detected in surveillance program.	NBC in partnership with NSPHU and NSW Health. Media release, newspaper and radio advertisements, social media. Messages include specific mention of mosquito population change (e.g. twice as many mosquitoes as usual; dramatic increase compared to earlier in season).
Surveillance-prompted (arboviruses)	Detection of arboviruses (e.g. RRV, BFV) in local mosquitoes	NBC in partnership with NSPHU and NSW Health. Media release, newspaper and radio advertisements, social media. Messages reinforce recommended personal protection measures, temporary signage around "hot spots", background on specific mosquito-borne pathogen and clinical consequences and diagnosis.
Outbreak-prompted	Increase in human disease notifications; consultation with Northern Sydney Public Health Unit and NSW Health.	NSPHU and NSW Health lead agencies in partnership with NBC. Possible media conference, media release, newspaper and radio advertisements, social media. Messages reinforce recommended personal protection measures, temporary signage around "hot spots", background on specific mosquito-borne pathogen and clinical consequences and diagnosis.
Event-prompted	Seasonal events (e.g. school holidays, long weekends) or mass gathering events (e.g. music, market, sporting, or cultural events) near wetland or bushland areas.	NBC in partnership with NSPHU and NSW Health. Media release, newspaper and radio advertisements, social media. Engagement with local businesses, event organisers.

Mosquito management

Habitat management and modification

Studies elsewhere in Sydney have demonstrated that a high abundance of mosquitoes may be a symptom of poor health of estuarine wetlands and that the rehabilitation of these wetlands and associated habitats can reduce mosquito abundance. Based on the results of this investigation, the major saltmarsh and mangrove areas within the Northern Beaches Council area do not pose an immediate risk in providing suitable conditions for substantial mosquito populations. However, where new estuarine wetlands are proposed to be constructed or major rehabilitation works are planned, careful consideration is required to determine the potential risk of increasing local mosquito populations.

Based on this investigation, the main mosquito habitats within the local area are those associated with Warriewood Wetlands and areas around Narrabeen Lagoon (e.g. Deep Creek, Middle Creek, South Creek). It was beyond the scope of this investigation to provide a detailed plan of habitat modification to reduce the production of mosquitoes from these areas. This would be expensive, operationally difficult, and require careful consideration as to the potential adverse impacts on other aspects of the local ecosystem. The conditions within these two areas that provide suitable habitats for mosquitoes are also providing valuable resources to a range of native plants and animals. There may be areas where enhancing water flow or encouraging the establishment of populations of mosquito predators (e.g. fish) may assist in reducing mosquito abundance. However, given that the main mosquitoes of pest and public health concern are those associated with ephemeral habitats, these approaches may be less effective.

Beyond these substantial wetland habitats, the continued development of freshwater habitats within urban environments, especially stormwater systems (i.e. Water Sensitve Urban Design (WSUD)), must be considered. Constructed wetlands are becoming increasingly common components of WSUD and may bring with them side benefits for wildlife conservation, passive recreation, community education and aesthetic appeal. However, mosquitoes including *Culex annulirostris*, *Culex quinquefasciatus*, *Coquillettidia linealis*, and *Mansonia uniformis*, may also become established in these habitats. The results of this investigation have demonstrated that these mosquitoes are not currently a major concern, even in areas adjacent to Warriewood Wetlands where a number of waterbodies have been constructed to assist with stormwater management. However, consideration should be given to future developments as these mosquitoes can pose serious pest and public health concerns.

Mosquito risk is often overlooked in WSUD but reducing mosquito risk can be a substantial co-benefit of carefully considered strategies for the design, construction and maintenance of these habitats. Critical to the likelihood of these habitats creating opportunities for mosquitoes is the retention of water following rainfall. It is common that such structures are designed to facilitate infiltration of water within 72h or sooner. This is best achieved by ensuring ephemeral water bodies are free draining where possible while structures retaining water for longer periods (e.g. gross pollutant traps, and sumps) are routinely maintained to reduce their suitability for mosquitoes. With regard to bioretention swales, the rate of infiltration is achieved through careful consideration of construction and soil types. However, factors that change this infiltration rate can raise the potential for mosquito production. Sedimentation during the construction phases, or shortly after, can slow infiltration rates while the establishment of vegetation in the structures can assist sedimentation rates and accumulation of organic material that will also slow infiltration rates. These habitats can also be further modified through maintenance, especially where vegetation is managed through mowing. Similarly, where the community uses these structures for recreation (e.g. bike riding, pedestrian thoroughfare, etc.), compaction can occur, as well as the formation of wheel ruts, which may create opportunities for mosquitoes where persistent surface pools of water occur. These issues, and strategies to ensure mosquito risk is mitigated, can be addressed through Development Control Plans or other guidelines for development or stormwater management in Northern Beaches Council.

Mosquito control agents: Larvicides and insect growth regulators

The use of mosquito control agents targeting aquatic, immature stages of mosquitoes are widely considered to be much more ecologically sustainable.

The two most appropriate mosquito control agents targeting larval populations are *Bacillus thuringiensis israelensis* (e.g. trade name Vectobac®) or *s*-methoprene (e.g. trade name Altosid®). *Bacillus thuringiensis israelensis* is a bacterial based product that, when ingested, is fatal to mosquito larvae. The insect growth regulator, *s*-methoprene, stops adult mosquitoes emerging from pupae. Both *Bacillus thuringiensis israelensis* and *s*-methoprene have been shown to have no significant impact on non-target aquatic organisms (including fish, shrimps, copepods and amphibians) when applied at their recommended application rate. Neither product is a threat to human health.

These two control agents are registered for use in estuarine and freshwater wetlands against a range of mosquitoes of pest and public health concern by the Australian Pesticides and Veterinary Medicines Authority (APVMA) and are commonly used to management populations of this mosquitoes in Queensland, Victoria, Western Australia, Northern Territory, and New South Wales (including Sydney Olympic Park, Liverpool City Council, Tweed Shire Council). There are various formulations of both products and they can be applied in targeted mosquito control activities through ground application (i.e. backpack or vehicle mounted application equipment) or, over larger areas, aerially via helicopter. Remote piloted aircraft are also being investigated as cost-effective options for mosquito control agent application. However, there is still a paucity of evidence to demonstrate how effective they can be in local environments. There are various considerations required when assessing the most cost-effective approach of mosquito control agent application with careful consideration to relevant legislation. This is of particular concern where aerial application may be required in wetlands close to residential areas.

Irrespective of control agent applied to local habitats, assessing the effectiveness of mosquito control is required. All aspects of mosquito control should be recorded. Key mosquito habitats should be identified and data on mosquito surveys, mosquito abundance and diversity (e.g. density of immature mosquitoes, abundance of adult mosquitoes in nearby traps), designated “risk factor” that relates to likely productivity of habitats, preferred control agent and trigger points for treatment (e.g. following highest tides of the month, detection of immature mosquitoes etc).

A detailed record of control agents applied (including product name, active ingredient/s, application method and application rates) should be made, to track the influence on mosquito populations and avoid missed treatments or over application This will also assist the development of a baseline level on operational considerations for planning and training purposes. There is also legislation associated with the use of insecticides in public spaces that must be addressed.

Mosquito control agents: Biological control

The use of mosquito predators or competitors is often promoted as an alternative method to reduce mosquito abundance compared to the application of insecticides. These approaches are often encouraged by local communities but, unfortunately, there are few examples of where “biological control” has successfully be applied to mosquitoes associated with estuarine wetlands.

Fish are the most commonly promoted “biological control” agent of mosquitoes. It is clear that many fish will consume the aquatic immature stages of mosquitoes but there is great difficulty in ensuring appropriate fish species are released and have an effective impact on suppressing mosquito populations. Historically, poor decisions have been made with regard to the release of exotic animals to control mosquitoes and one key example is the plague minnow (*Gambusia holbrooki*) that was released into Australian waterways in the 1920s. A fish native to North

America, it is commonly known in this region as the "mosquito fish" and its distribution to natural and artificial waterbodies, including neglected swimming pools, is encouraged by local authorities. Here in Australia, the fish is considered a pest species and has adversely impacted the local environment, including direct impacts on tadpoles, fish, and native insects. This, or any other exotic fish species, should not be released into wetlands or waterways on the Northern beaches for the purpose of mosquito control. Native fish (e.g. pacific blue-eye or empire gudgeon are suitable alternatives but their survivorship in polluted urban waterways limits their effective use to control mosquito populations. The promotion of fish movement into the wetlands through increased water flows entering the wetlands will assist but the release of fish into these habitats will be of minimal benefit given the most productive habitats are those of a moderate to highly ephemeral nature.

Insectivorous bats are often cited as a potentially usefully component of integrated mosquito management but there is little evidence that any local microbat species consumes enough adult mosquitoes to reduce the associated pest and public health impacts. Studies in coastal wetlands elsewhere in NSW have demonstrated that while these bats do consume adult mosquitoes and that the foraging behaviour of bats is influenced by mosquito abundance and distribution, they are generally more frequently feeding on larger insects (e.g. moths) than mosquitoes. While the installation of "bat boxes" and other initiatives to improve local conditions for small bat species should be considered, there should not be an expectation that these bats will reduce the abundance of mosquitoes or their nuisance-biting impacts.

As with bats, many small birds will eat mosquitoes. However, they too are unlikely to reduce local mosquito populations to such an extent that there is a noticeable reduction in the abundance of mosquitoes or their nuisance-biting impacts.

Mosquito control agents: Adulticides

The application of adulticides (e.g. pyrethroids), typically in the form of a fog, ultra-low volume mist, or as residual liquid applied to terrestrial plants or buildings can assist in reducing mosquito abundance but is generally not employed as a routine strategy in NSW. While insecticides are registered by the APVMA for use against mosquitoes, there is far greater likelihood of non-target impacts and this group of insecticides can be highly toxic to aquatic life and so are not recommended for use in close proximity to wetlands.

Given the high likelihood of non-target impacts, the use of adulticides is not recommended at this stage. Should this option be pursued, a detailed plan of management would need to be developed in collaboration with pest control operators to ensure that a suitable product formulation is selected and application schedule is decided on. Additional considerations will need to be given to the use of these products in public spaces and in areas of potentially significant environmental quality.

There is also likely to be strong objections to the employment of insecticides in and around wetland and bushland areas by some sectors of the community. Should such a strategy need to be employed during a period of highly abundant mosquito populations or elevated public health concern, careful consideration will be required to be given to public awareness and education communications.

A summary of mosquito management strategies that may be considered for the Northern Beaches is provided in Table 7.

Table 7. Summary of advantages and disadvantages of environmental, chemical and biological mosquito control strategies to be considered by Northern Beaches Council

Option	**Advantages**	**Disadvantages**
Adulticides (thermal fogging, ULV, and residual formulations)	▪ Rapid, flexible and relatively cost-effective strategy via vehicle mounted or backpack application ▪ Large areas can be covered quickly ▪ Useful in emergency response to disease outbreaks ▪ Potentially long periods of mosquito control in some situations (e.g. residual application in domestic settings)	▪ Potentially highly visual activity that may not be considered appropriate by community ▪ Difficult to achieve effective long term control ▪ Effectiveness highly dependent on environmental/climatic conditions ▪ Potentially significant direct non-target impacts
Larval control (*Bti* and *s*-methoprene)	▪ Proven effective for mosquito control in a range of estuarine and freshwater habitats ▪ Relatively cost effective ▪ Minimal direct non-target impacts ▪ Simple to assess treatment effectiveness	▪ Reapplication regularly required throughout season as no residual control provided ▪ Requires accurate mapping of larval mosquito habitats and monitoring larval populations ▪ Reduced efficacy in heavily polluted habitats or those containing high levels of organic material
Habitat modification (wetlands)	▪ Potential long term solution without reliance on routine application of control agents ▪ May assist the rehabilitation of degraded wetlands (e.g. restore tidal flushing, improve water quality)	▪ May not significantly reduce mosquito populations over large wetland areas ▪ May adversely impact environment or ecosystem if not suitably assessed ▪ Requires regular maintenance to remain effective
Biological control (fish, bats, birds)	▪ Potential long term solution without reliance on routine application of chemical control agents ▪ Introduction of native species complementary to other wetlands management objectives ▪ Enhances community engagement	▪ Not suitable for ephemeral and/or highly polluted habitats ▪ Only fish species endemic to the local area can be released

SUMMARY

Mosquitoes are a natural part of wetland and bushland habitats on the Northern Beaches of Sydney. However, when conditions are suitable, they can be abundance and their nuisance-biting can adversely impact the quality of life of residents and enjoyment of recreational activities. Mosquitoes can also pose a health risk by transmitting disease-causing pathogens.

In response to concerns raised by local residents regarding nuisance-biting mosquitoes associated with some of the wetlands in the local area, Northern Beaches Council engaged the Department of Medical Entomology, NSW Health Pathology to undertake a study of local mosquitoes, assess the pest and public health concerns they pose, and, in consultation with the Northern Sydney Public Health Unit, make recommendations to Council on how best to manage current and future mosquito risks.

Mosquitoes were collected at five locations within the local area (Careel Bay, Winnererremy Bay, McCarrs Creek Reserve, Warriewood Wetlands, Deep Creek (Narrabeen Lagoon)) using specialized mosquito traps. Over 30 different types of mosquitoes were collected and the most important of these were those associated with bushland and freshwater wetland habitats. Unlike other regions in Sydney, the estuarine wetlands (e.g. saltmarshes and mangroves) on the Northern Beaches were not found to be an important source of pest mosquitoes. Mosquitoes found in coastal swamp forests, she-oak woodlands, and freshwater wetlands (e.g. Warriewood Wetlands, Narrabeen Lagoon) were found to produce the most mosquitoes. However, the high numbers of mosquitoes recorded was most likely due to the exceptionally wet conditions experienced following substantial rainfall in mid February 2020.

The mosquitoes of greatest concern are known to bite people but they do not fly far from local habitats. For that reason, nuisance-biting impacts are likely to be much greater within the wetlands and bushland areas themselves and will not extend far into adjacent residential areas. In additional to these mosquitoes, there are also mosquitoes found in residential backyards that can also cause problems. These mosquitoes are not found in wetlands or bushland; they prefer water-filled containers in backyards (e.g. pot-plant saucers, bird baths, roof gutters, rainwater tanks) or water-holding plants (e.g. bromeliads).

For the first time, a range of mosquito-borne pathogens were detected in mosquitoes collected on the Northern Beaches. The two pathogens of greatest concern were Ross River virus and Barmah Forest virus. These two viruses can cause non-fatal but potentially debilitating illness with symptoms including fever, rash, joint pain, and fatigue. The viruses were detected in wetland and bushland areas (i.e. Warriewood Wetlands and Narrabeen Lagoon) where there were abundant mosquitoes but also the wildlife that are known to carry the pathogens (e.g. wallabies). Mosquitoes pick up the pathogens by biting wallabies and other native animals and then passing them on when subsequently biting people.

The results indicate that during favourable conditions, mosquitoes on the Northern Beaches can be abundant, resulting in nuisance-biting problems close to wetland and bushland areas as well as the potential transmission of mosquito-borne pathogens. It is likely that the health risks posed by mosquitoes are not consistent from year to year but will fluctuate due to prevailing climatic and environmental factors.

A series of recommendations have been made to Northern Beaches Council regarding management of mosquito risk. The actions include enhanced mosquito surveillance in conjunction with NSW Health, community awareness and education programs, modification of some degraded habitats where mosquitoes are abundant, and the consideration of judicious insecticide use in “hot spots” of mosquito activity.

MOSQUITO MANAGEMENT ACTION PLAN

Strategies	Strategic actions and benefits	Partner Stakeholders	Schedule
Participation with NSW Arbovirus Surveillance and Mosquito Monitoring Program	▪ Seasonal adult mosquito surveillance (December through to April) at a minimum of two locations (Warriewood Wetlands and Narrabeen Lagoon) during 2020-2021 ▪ Purchase 2 Encephalitis Virus Surveillance (EVS) traps from Australian Entomological Supplies [http://www.entosupplies.com.au/]; alternatively arrange for a loan of equipment from MEDENT ▪ Liaise with HPNSW, NSPHU, and MEDENT to assist with the final selection of appropriate trapping locations and arrange transport of mosquitoes to MEDENT ▪ Trapping would provide additional understanding of local mosquito populations and arboviruses under "normal" climatic conditions while also allowing access to additional resources to assist mosquito management and public health communications (e.g. workshops, online material) as provided by HPNSW	HPNSW; NSPHU; MEDENT	Commence December 2020
Review arrangements with NSPHU and EEU regarding public health warnings	▪ Clear communication and decision making is required to ensure timely public health messages are issued following the detection of arboviruses in local mosquito populations ▪ Agreement should be reached with NSPHU regarding lead agency on mosquito-related public health messaging. ▪ Recommendation that routine and mosquito abundance triggered message NBC; arbovirus detection NSPHU or HPNSW, human disease notifications NSPHU or HPNSW	NBC; HPNSW; NSPHU	To be completed December 2020
Review local public education material	▪ Review mosquito information provided on NSW Health website to ensure consistency with NBC content and the appropriateness of use through various NCB communication channels ▪ Revise mosquito awareness information and recommendations on personal protection measures with more specific information on the safe and effective use of insect repellents with a local perspective ▪ Review local public education material would ensure appropriate material is readily available to use in response to elevated mosquito abundance or detection of arboviruses in local mosquitoes	HPNSW; NSPHU	To be completed December 2020

Targeted mosquito control activities	▪ Mosquito control is not recommended as a routine strategy to manage mosquitoes but may need to be considered in future given potential mosquito-borne disease risk; assessing the appropriateness, operational requirements, and costs will ensure NBC can make an informed decision on future actions ▪ Consideration should be given to operational requirements for the judicious use of mosquito control agents (larvicides or insect growth regulator) following favourable environmental conditions, or short-term adulticide use, to suppress abundance of pest mosquitoes in key locations, Warriewood Wetlands a priority. ▪ Review safe work practice and legislative requirements for mosquito control (and surveillance) methodology	NBC; Private contractors	To be completed December 2020
Storm water and natural resource management	▪ Liaise with NBC departments with regard to construction and maintenance of storm water infrastructure (e.g. Water Sensitive Urban Design, green infrastructure) to ensure that actual and potential mosquito risk is considered ▪ Liaise with NBC departments with regard to wetland, bushland, and parkland management to ensure that actual and potential mosquito risk is considered, especially wetland construction and/or rehabilitation projects	Various	Commence 2021 and beyond
Mosquito research projects	▪ The Northern Beaches region provides a unique opportunity to study mosquitoes, wildlife, wetlands, and associated mosquito-borne disease risk ▪ Investigate partnerships with local institutes to undertake research into matters relating to mosquito biology, surveillance, and control with a view to outcomes informing local mosquito management	Various	Commence 2021 and beyond

NBC: Northern Beaches Council; HPNSW: Health Protection NSW; NSPHU: Northern Sydney Local Health District Public Health Unit; MEDENT: Medical Entomology, NSW Health Pathology

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APPENDIX 1: MOSQUITO DATA

Total mosquitoes collected, Nth Beaches, 2019-2020 **Date: 17 December 2019**

Species/Trap Site	McCarrsCk-1	McCarrsCk-2	WinBay-1	WinBay-2	CareelBay-1	CareelBay-2	CareelBay-3	WarrieWet-1	WarrieWet-2	WarrieWet-3	DeepCk(NL)-1	DeepCk(NL)-2	DeepCk(NL)-3	Total
Ad.venustipes														**0**
Ae. aculeatus														**0**
Ae.alboannulatus														**0**
Ae.alternans														**0**
Ae. burpengaryensis														**0**
Ae.flavifrons														**0**
Ae. kochi														**0**
Ae.mallochi														**0**
Ae.multiplex								3	8		1			**12**
Ae.notoscriptus	2	1	3	1	1	1	2	4	6	15	2			**38**
Ae.procax														**0**
Ae.quasirubrithorax														**0**
Ae.rubrithorax														**0**
Ae.theobaldi														**0**
Ae.vigilax														**0**
Ae.vittiger														**0**
Ae. Marks #51														**0**
An.annulipes								3	10	3	3			**19**
An. atratipes														**0**
Cq.linealis		1												**1**
Cq.xanthogaster														**0**
Cx.annulirostris								1	1	1	1			**4**
Cx.australicus														**0**
Cx.bitaeniorhynchus														**0**
Cx.halifaxii														**0**
Cx.molestus		1												**1**
Cx.orbostiensis									8		2			**10**
Cx. postspiraculosus														**0**
Cx.quiquefasciatus					1		1		1					**3**
Cx.sitiens														**0**
Cx.squamosus														**0**
Cx. Marks 32														**0**
Ma.uniformis									1	1				**2**
Mi. elegans														**0**
Tp. marksae														**0**
Ve. funerea														**0**
Ve. Marks 52														**0**
Total	**2**	**3**	**3**	**1**	**2**	**1**	**3**	**11**	**35**	**20**	**9**	**0**	**0**	**90**
												DNT	DNT	

Total mosquitoes collected, Nth Beaches, 2019-2020 **Date: 2 January 2020**

Species/Trap Site	McCarrsCk-1	McCarrsCk-2	WinBay-1	WinBay-2	CareelBay-1	CareelBay-2	CareelBay-3	WarrieWet-1	WarrieWet-2	WarrieWet-3	DeepCk(NL)-1	DeepCk(NL)-2	DeepCk(NL)-3	Total
Ad.venustipes														**0**
Ae. aculeatus														**0**
Ae.alboannulatus														**0**
Ae.alternans														**0**
Ae. burpengaryensis														**0**
Ae.flavifrons														**0**
Ae. kochi														**0**
Ae.mallochi														**0**
Ae.multiplex								1	4		1			**6**
Ae.notoscriptus	3	2	1	1	1	1	1	3	1	5	1	2	1	**23**
Ae.procax														**0**
Ae.quasirubrithorax														**0**
Ae.rubrithorax														**0**
Ae.theobaldi														**0**
Ae.vigilax														**0**
Ae.vittiger														**0**
Ae. Marks #51														**0**
An.annulipes								1	9	3	2	1	1	**17**
An. atratipes														**0**
Cq.linealis		1							1				1	**3**
Cq.xanthogaster												1	1	**2**
Cx.annulirostris								1	1	1	1	1	1	**6**
Cx.australicus														**0**
Cx.bitaeniorhynchus														**0**
Cx.halifaxii														**0**
Cx.molestus		1							1					**2**
Cx.orbostiensis									4		4	1	2	**11**
Cx. postspiraculosus														**0**
Cx.quiquefasciatus					1		1		2					**4**
Cx.sitiens														**0**
Cx.squamosus														**0**
Cx. Marks 32														**0**
Ma.uniformis									1	1			1	**3**
Mi. elegans														**0**
Tp. marksae														**0**
Ve. funerea														**0**
Ve. Marks 52														**0**
Total	**3**	**4**	**1**	**1**	**2**	**1**	**2**	**6**	**24**	**10**	**9**	**6**	**8**	**77**

Total mosquitoes collected, Nth Beaches, 2019-2020 **Date: 23 January 2020**

Species/Trap Site	McCarrsCk-1	McCarrsCk-2	WinBay-1	WinBay-2	CareelBay-1	CareelBay-2	CareelBay-3	WarrieWet-1	WarrieWet-2	WarrieWet-3	DeepCk(NL)-1	DeepCk(NL)-2	DeepCk(NL)-3	Total
Ad.venustipes														**0**
Ae. aculeatus														**0**
Ae.alboannulatus														**0**
Ae.alternans														**0**
Ae. burpengaryensis														**0**
Ae.flavifrons														**0**
Ae. kochi														**0**
Ae.mallochi														**0**
Ae.multiplex												1	1	**2**
Ae.notoscriptus	5	1	18	22	11	31	6	6	4	1	1	4	2	**112**
Ae.procax								1				1	1	**3**
Ae.quasirubrithorax														**0**
Ae.rubrithorax														**0**
Ae.theobaldi														**0**
Ae.vigilax	58	2	13	18	7	22	4		2	2	1	12	2	**143**
Ae.vittiger														**0**
Ae. Marks #51														**0**
An.annulipes								2				3	4	**9**
An.atratipes														**0**
Cq.linealis												6	1	**7**
Cq.xanthogaster														**0**
Cx.annulirostris		2	1	1				1	6	2		6	8	**27**
Cx.australicus														**0**
Cx.bitaeniorhynchus														**0**
Cx.halifaxii														**0**
Cx.molestus	1					1								**2**
Cx.orbostiensis														**0**
Cx. postspiraculosus														**0**
Cx.quiquefasciatus			1	2	1	3					1	1	1	**10**
Cx.sitiens														**0**
Cx.squamosus														**0**
Cx. Marks 32								5						**5**
Ma.uniformis								1						**1**
Mi. elegans														**0**
Tp. marksae								1						**1**
Ve. funerea														**0**
Ve. Marks 52													1	**1**
Total	**64**	**5**	**33**	**43**	**19**	**57**	**10**	**17**	**12**	**5**	**3**	**34**	**21**	**323**

Total mosquitoes collected, Nth Beaches, 2019-2020 **Date: 24 February 2020**

Species/Trap Site	McCarrsCk-1	McCarrsCk-2	WinBay-1	WinBay-2	CareelBay-1	CareelBay-2	CareelBay-3	WarrieWet-1	WarrieWet-2	WarrieWet-3	DeepCk(NL)-1	DeepCk(NL)-2	DeepCk(NL)-3	Total
Ad.venustipes														**0**
Ae. aculeatus							1	2			28			**31**
Ae.alboannulatus														**0**
Ae.alternans							2							**2**
Ae. burpengaryensis											1			**1**
Ae.flavifrons				2				2			1			**5**
Ae. kochi		1												**1**
Ae.mallochi														**0**
Ae.multiplex						1		89			21			**111**
Ae.notoscriptus	4	6	56	39	11	10	1	14			12			**153**
Ae.procax	8	11	1	4		2	1	123			98			**248**
Ae.quasirubrithorax														**0**
Ae.rubrithorax														**0**
Ae.theobaldi														**0**
Ae.vigilax	10	5	9	17	19	26	35	6			9			**136**
Ae.vittiger			1	3							1			**5**
Ae. Marks #51	1	3	2	1				14			66			**87**
An.annulipes			1					3			8			**12**
An. atratipes														**0**
Cq.linealis														**0**
Cq.xanthogaster														**0**
Cx.annulirostris			2			4		9			11			**26**
Cx.australicus														**0**
Cx.bitaeniorhynchus														**0**
Cx.halifaxii														**0**
Cx.molestus	1													**1**
Cx.orbostiensis								19						**19**
Cx. postspiraculosus														**0**
Cx.quiquefasciatus	1		1		1	8		10						**21**
Cx.sitiens					2									**2**
Cx.squamosus														**0**
Cx. Marks 32								3						**3**
Ma.uniformis								4						**4**
Mi. elegans														**0**
Tp. marksae														**0**
Ve. funerea			1			1					1			**3**
Ve. Marks 52						1		22			13			**36**
Total	**25**	**26**	**74**	**66**	**33**	**53**	**40**	**320**	**0**	**0**	**270**	**0**	**0**	**907**
									DNT	DNT		DNT	DNT	

Total mosquitoes collected, Nth Beaches, 2019-2020 **Date: 13 March 2020**

Species/Trap Site	McCarrsCk-1	McCarrsCk-2	WinBay-1	WinBay-2	CareelBay-1	CareelBay-2	CareelBay-3	WarrieWet-1	WarrieWet-2	WarrieWet-3	DeepCk(NL)-1	DeepCk(NL)-2	DeepCk(NL)-3	Total
Ad.venustipes														**0**
Ae. aculeatus											6	2	1	**9**
Ae.alboannulatus														**0**
Ae.alternans													1	**1**
Ae. burpengaryensis														**0**
Ae.flavifrons			1					43	12	8	2	1	1	**68**
Ae. kochi		2												**2**
Ae.mallochi	1							1		1				**3**
Ae.multiplex	4							308	140	109	47	39	21	**668**
Ae.notoscriptus		2	6	4	3	1	2	21	13	9	3			**64**
Ae.procax	2	6						17	89	44	283	123	65	**629**
Ae.quasirubrithorax										1				**1**
Ae.rubrithorax	1													**1**
Ae.theobaldi														**0**
Ae.vigilax	1		2	1			1	1		1	4	11	5	**27**
Ae.vittiger														**0**
Ae. Marks #51	2								8	1	36	29	5	**81**
An.annulipes			1					16	14	9	17	7	4	**68**
An.atratipes														**0**
Cq.linealis								2	1	1	1	2	1	**8**
Cq.xanthogaster														**0**
Cx.annulirostris	3	4	2	2		1	1	29	9	8	21	2	6	**88**
Cx.australicus		1						1						**2**
Cx.bitaeniorhynchus														**0**
Cx.halifaxii												1	1	**2**
Cx.molestus		1	1		1	1							1	**5**
Cx.orbostiensis								27	31	16	19	18	5	**116**
Cx. postspiraculosus														**0**
Cx.quiquefasciatus														**0**
Cx.sitiens		1	1	2	4	1		2		2	1		3	**17**
Cx.squamosus														**0**
Cx. Marks 32								19	8	2				**29**
Ma.uniformis								9	3	2			1	**15**
Mi. elegans								1						**1**
Tp. marksae														**0**
Ve. funerea										1			1	**2**
Ve. Marks 52								33	21	61	29	13	11	**168**
Total	**14**	**17**	**14**	**9**	**8**	**4**	**4**	**530**	**349**	**276**	**469**	**248**	**133**	**2075**

Total mosquitoes collected, Nth Beaches, 2019-2020 **Date: 19 March 2020**

Species/Trap Site	McCarrsCk-1	McCarrsCk-2	WinBay-1	WinBay-2	CareelBay-1	CareelBay-2	CareelBay-3	WarrieWet-1	WarrieWet-2	WarrieWet-3	DeepCk(NL)-1	DeepCk(NL)-2	DeepCk(NL)-3	Total
Ad.venustipes														**0**
Ae. aculeatus									2		4	1	9	**16**
Ae.alboannulatus														**0**
Ae.alternans													1	**1**
Ae. burpengaryensis														**0**
Ae.flavifrons								13	7	2	3	3	3	**31**
Ae. kochi														**0**
Ae.mallochi														**0**
Ae.multiplex								251	193	23	93	31	29	**620**
Ae.notoscriptus								3	2	1	3		2	**11**
Ae.procax								67	47	9	68	49	220	**460**
Ae.quasirubrithorax														**0**
Ae.rubrithorax														**0**
Ae.theobaldi														**0**
Ae.vigilax									2	1	2		3	**8**
Ae.vittiger														**0**
Ae. Marks #51								9			2		5	**16**
An.annulipes								7	8	3	13	8	7	**46**
An.atratipes														**0**
Cq.linealis								3			3	3		**9**
Cq.xanthogaster														**0**
Cx.annulirostris								4	4	3	9	8	37	**65**
Cx.australicus								1						**1**
Cx.bitaeniorhynchus														**0**
Cx.halifaxii														**0**
Cx.molestus														**0**
Cx.orbostiensis								11	27	11	7	6	19	**81**
Cx. postspiraculosus														**0**
Cx.quiquefasciatus								2						**2**
Cx.sitiens												2		**2**
Cx.squamosus														**0**
Cx. Marks 32								2		1				**3**
Ma.uniformis									7	4				**11**
Mi. elegans									1					**1**
Tp. marksae														**0**
Ve. funerea														**0**
Ve. Marks 52								19	32	21	2	10	17	**101**
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**392**	**332**	**79**	**209**	**121**	**352**	**1485**
	DNT	DNT	DNT	DNT	DNT	DNT	DNT							

Total mosquitoes collected, Nth Beaches, 2019-2020 **Date: 30 March 2020**

Species/Trap Site	McCarrsCk-1	McCarrsCk-2	WinBay-1	WinBay-2	CareelBay-1	CareelBay-2	CareelBay-3	WarrieWet-1	WarrieWet-2	WarrieWet-3	DeepCk(NL)-1	DeepCk(NL)-2	DeepCk(NL)-3	Total
Ad.venustipes								1						**1**
Ae. aculeatus						1	1	1		4				**7**
Ae.alboannulatus												1		**1**
Ae.alternans											1	1	1	**3**
Ae. burpengaryensis														**0**
Ae.flavifrons	1	1									2	8	1	**13**
Ae. kochi	3	1												**4**
Ae.mallochi														**0**
Ae.multiplex								56	114	7	83	43	57	**360**
Ae.notoscriptus	2	3	2	3	1	6	3	81	6	2	2	1	1	**113**
Ae.procax	3	8	6	2	2		14	37	69	7	267	177	329	**921**
Ae.quasirubrithorax								1						**1**
Ae.rubrithorax		2												**2**
Ae.theobaldi														**0**
Ae.vigilax		1	1		2			6	2	2				**14**
Ae.vittiger														**0**
Ae. Marks #51								14	7	2	8	2	13	**46**
An.annulipes			1	1		1		23	3	29	1	4	1	**64**
An. atratipes														**0**
Cq.linealis									1	2				**3**
Cq.xanthogaster														**0**
Cx.annulirostris	35	23	29	11	43	9	21	9	8	13	6	31	54	**292**
Cx.australicus														**0**
Cx.bitaeniorhynchus														**0**
Cx.halifaxii														**0**
Cx.molestus	3	6			2						3		1	**15**
Cx.orbostiensis								4	19	2	4	13	5	**47**
Cx. postspiraculosus									1					**1**
Cx.quiquefasciatus	3	3	8	4	3		5	1	1	3	3	2	4	**40**
Cx.sitiens	5	7	17	23	39	7	19		1	2	1		1	**122**
Cx.squamosus									1					**1**
Cx. Marks 32								1	1					**2**
Ma.uniformis								1		1				**2**
Mi. elegans									1					**1**
Tp. marksae														**0**
Ve. funerea					1		1			1	1		1	**5**
Ve. Marks 52					1			119	73	9	32	18	29	**281**
Total	**55**	**55**	**64**	**44**	**94**	**24**	**64**	**355**	**308**	**86**	**414**	**301**	**498**	**2362**

Total mosquitoes collected, Nth Beaches, 2019-2020 **Date: 6 April 2020**

Species/Trap Site	McCarrsCk-1	McCarrsCk-2	WinBay-1	WinBay-2	CareelBay-1	CareelBay-2	CareelBay-3	WarrieWet-1	WarrieWet-2	WarrieWet-3	DeepCk(NL)-1	DeepCk(NL)-2	DeepCk(NL)-3	Total
Ad.venustipes														**0**
Ae. aculeatus												2		**2**
Ae.alboannulatus														**0**
Ae.alternans								3						**3**
Ae. burpengaryensis														**0**
Ae.flavifrons								19		4	23	31	11	**88**
Ae. kochi														**0**
Ae.mallochi														**0**
Ae.multiplex								53	4	4	19	67	57	**204**
Ae.notoscriptus					1	2	3		3	3		2		**14**
Ae.procax					1		1	88	9	9	47	142	50	**347**
Ae.quasirubrithorax														**0**
Ae.rubrithorax														**0**
Ae.theobaldi														**0**
Ae.vigilax								1			2		1	**4**
Ae.vittiger														**0**
Ae. Marks #51								4		1			3	**8**
An.annulipes						1	1	43	14	18	13	36	29	**155**
Cq.linealis								13	2	2	39	14	8	**78**
Cq.xanthogaster														**0**
Cx.annulirostris					2	2	1	23	11	11	9	17	6	**82**
Cx.australicus														**0**
Cx.bitaeniorhynchus														**0**
Cx.halifaxii										1				**1**
Cx.molestus														**0**
Cx.orbostiensis								11	12	9		11	17	**60**
Cx. postspiraculosus														**0**
Cx.quiquefasciatus													2	**2**
Cx.sitiens					13	2	20		1	2				**38**
Cx.squamosus														**0**
Cx. Marks 32								1	1	1				**3**
Ma.uniformis								2	8	8		3	1	**22**
Mi. elegans														**0**
Tp. marksae														**0**
Ve. funerea							1							**1**
Ve. Marks 52							1	49	16	16	51	165	128	**426**
Total	**0**	**0**	**0**	**0**	**17**	**7**	**28**	**310**	**81**	**89**	**203**	**490**	**313**	**1538**
	DNT	DNT	DNT	DNT										

Total mosquitoes collected, Nth Beaches, 2019-2020 **Date: 20 April 2020**

Species/Trap Site	McCarrsCk-1	McCarrsCk-2	WinBay-1	WinBay-2	CareelBay-1	CareelBay-2	CareelBay-3	WarrieWet-1	WarrieWet-2	WarrieWet-3	DeepCk(NL)-1	DeepCk(NL)-2	DeepCk(NL)-3	Total
Ad.venustipes														**0**
Ae. aculeatus														**0**
Ae.alboannulatus														**0**
Ae.alternans					4	3	1							**8**
Ae. burpengaryensis														**0**
Ae.flavifrons									9	3	14	19	43	**88**
Ae. kochi														**0**
Ae.mallochi														**0**
Ae.multiplex								34	36	8	41	26	17	**162**
Ae.notoscriptus					3	8	12	4	3				2	**32**
Ae.procax					2		1	20	29	6	106	192	257	**613**
Ae.quasirubrithorax								1					1	**2**
Ae.rubrithorax														**0**
Ae.theobaldi								1	1					
Ae.vigilax														**0**
Ae.vittiger														**0**
Ae. Marks #51														**0**
An.annulipes								11	13	3	45	20	10	**102**
An. atratipes														**0**
Cq.linealis													3	**3**
Cq.xanthogaster														**0**
Cx.annulirostris					4	2	3	3	2	1		4	2	**21**
Cx.australicus														**0**
Cx.bitaeniorhynchus									1					**1**
Cx.halifaxii														**0**
Cx.molestus								1						**1**
Cx.orbostiensis											1			**1**
Cx. postspiraculosus														**0**
Cx.quiquefasciatus														**0**
Cx.sitiens					10	40	134		3	6				**193**
Cx.squamosus								1	1					
Cx. Marks 32								1						**1**
Ma.uniformis								10	4					**14**
Mi. elegans														**0**
Tp. marksae														**0**
Ve. funerea													3	**3**
Ve. Marks 52								19	23	3	39	17	14	**115**
Total	**0**	**0**	**0**	**0**	**23**	**53**	**151**	**106**	**125**	**30**	**246**	**278**	**352**	**1364**
	DNT	DNT	DNT	DNT										

Total mosquitoes collected, Nth Beaches, 2019-2020 **Date: 26 April 2020**

Species/Trap Site	McCarrsCk-1	McCarrsCk-2	WinBay-1	WinBay-2	CareelBay-1	CareelBay-2	CareelBay-3	WarrieWet-1	WarrieWet-2	WarrieWet-3	DeepCk(NL)-1	DeepCk(NL)-2	DeepCk(NL)-3	Total
Ad.venustipes														**0**
Ae. aculeatus													1	**1**
Ae.alboannulatus														**0**
Ae.alternans					1									**1**
Ae. burpengaryensis														**0**
Ae.flavifrons										1	9	13	13	**36**
Ae. kochi														**0**
Ae.mallochi														**0**
Ae.multiplex								3	1	59	17	19	22	**121**
Ae.notoscriptus							2	2	28	2				**34**
Ae.procax					1		1	13	8	21	45	68	115	**272**
Ae.quasirubrithorax														**0**
Ae.rubrithorax														**0**
Ae.theobaldi														**0**
Ae.vigilax											1		2	**3**
Ae.vittiger														**0**
Ae. Marks #51														**0**
An.annulipes								9	46	19	4	22	10	**110**
An. atratipes														**0**
Cq.linealis											1		3	**4**
Cq.xanthogaster														**0**
Cx.annulirostris					1	2	1	2	11	4	2	2	19	**44**
Cx.australicus								1						**1**
Cx.bitaeniorhynchus												1		**1**
Cx.halifaxii														**0**
Cx.molestus					1			1		1		2	1	**6**
Cx.orbostiensis								1				1	1	**3**
Cx. postspiraculosus														**0**
Cx.quiquefasciatus					1									**1**
Cx.sitiens					8	9	41	2	2			1		**63**
Cx.squamosus														**0**
Cx. Marks 32								1						**1**
Ma.uniformis									1	3				**4**
Mi. elegans														**0**
Tp. marksae														**0**
Ve. funerea												1		**1**
Ve. Marks 52								4	9	17	5	3	19	**57**
Total	**0**	**0**	**0**	**0**	**13**	**11**	**45**	**39**	**106**	**127**	**84**	**133**	**206**	**764**
	DNT	DNT	DNT	DNT										

Total mosquitoes collected, Nth Beaches, 2019-2020 **Date: 4 May 2020**

Species/Trap Site	McCarrsCk-1	McCarrsCk-2	WinBay-1	WinBay-2	CareelBay-1	CareelBay-2	CareelBay-3	WarrieWet-1	WarrieWet-2	WarrieWet-3	DeepCk(NL)-1	DeepCk(NL)-2	DeepCk(NL)-3	Total
Ad.venustipes														**0**
Ae. aculeatus														**0**
Ae.alboannulatus														**0**
Ae.alternans														**0**
Ae. burpengaryensis														**0**
Ae.flavifrons									1		1		1	**3**
Ae. kochi														**0**
Ae.mallochi														**0**
Ae.multiplex								3	52	9	5	13	6	**88**
Ae.notoscriptus	1		2	2	3	4	4	1	7					**24**
Ae.procax				1	1	1			8	1	32	22	16	**82**
Ae.quasirubrithorax														**0**
Ae.rubrithorax														**0**
Ae.theobaldi														**0**
Ae.vigilax				1					1	1			2	**5**
Ae.vittiger														**0**
Ae. Marks #51											1			**1**
An.annulipes	1	1	1	2	1		1	15	71	12	1	13	41	**160**
An. atratipes												1		**1**
Cq.linealis														**0**
Cq.xanthogaster														**0**
Cx.annulirostris				1					1	1				**3**
Cx.australicus					1	1								**2**
Cx.bitaeniorhynchus														**0**
Cx.halifaxii														**0**
Cx.molestus	2	2		1						1		1	2	**9**
Cx.orbostiensis														**0**
Cx. postspiraculosus														**0**
Cx.quiquefasciatus					1						1			**2**
Cx.sitiens		1		2	4	2	1			1				**11**
Cx.squamosus														**0**
Cx. Marks 32				1										**1**
Ma.uniformis														**0**
Mi. elegans														**0**
Tp. marksae														**0**
Ve. funerea														**0**
Ve. Marks 52								11	22	7	1	5	21	**67**
Total	**4**	**4**	**3**	**11**	**11**	**8**	**6**	**30**	**163**	**33**	**42**	**55**	**89**	**459**

Total mosquitoes collected, Nth Beaches, 2019-2020 **Date: 13 May 2020**

Species/Trap Site	McCarrsCk-1	McCarrsCk-2	WinBay-1	WinBay-2	CareelBay-1	CareelBay-2	CareelBay-3	WarrieWet-1	WarrieWet-2	WarrieWet-3	DeepCk(NL)-1	DeepCk(NL)-2	DeepCk(NL)-3	Total
Ad.venustipes														**0**
Ae. aculeatus														**0**
Ae.alboannulatus														**0**
Ae.alternans														**0**
Ae. burpengaryensis														**0**
Ae.flavifrons								2		1	1		2	**6**
Ae. kochi														**0**
Ae.mallochi														**0**
Ae.multiplex								6	3	12	3	2	6	**32**
Ae.notoscriptus					19	4	6	2	2	3			1	**37**
Ae.procax					1		1	2		3	6	10	48	**71**
Ae.quasirubrithorax														**0**
Ae.rubrithorax														**0**
Ae.theobaldi														**0**
Ae.vigilax											1		1	**2**
Ae.vittiger														**0**
Ae. Marks #51														**0**
An.annulipes								19	12	31	3	4	11	**80**
Cq.linealis														**0**
Cq.xanthogaster														**0**
Cx.annulirostris														**0**
Cx.australicus														**0**
Cx.bitaeniorhynchus														**0**
Cx.halifaxii														**0**
Cx.molestus										1				**1**
Cx.orbostiensis								1	2	1				**4**
Cx. postspiraculosus														**0**
Cx.quiquefasciatus														**0**
Cx.sitiens					1	2	10							**13**
Cx.squamosus														**0**
Cx. Marks 32														**0**
Ma.uniformis														**0**
Mi. elegans														**0**
Tp. marksae														**0**
Ve. funerea														**0**
Ve. Marks 52										1			2	**3**
Total	**0**	**0**	**0**	**0**	**21**	**6**	**17**	**32**	**19**	**53**	**14**	**16**	**71**	**249**
	DNT	DNT	DNT	DNT	DNT									

APPENDIX 2: MEDIA RELEASE 30 APRIL 2020

Take precautions to reduce Ross River fever risk

Published online [https://www.northernbeaches.nsw.gov.au/council/news/precautions-needs-to-reduce-risk-ross-river-fever] Thursday, 30 April 2020

Northern Beaches Council advises people around the Narrabeen Lagoon and Warriewood Wetlands areas to take extra precautions against exposure to mosquitoes after Ross River virus and Barmah Forest virus were detected in mosquitoes collected at Deep Creek in late March. Ross River virus was also detected in mosquitoes collected in the Warriewood Wetlands in early April.

Council together with NSW Health have been proactively trapping mosquitoes in the Northern Beaches region since December 2019 in six potentially high risk locations. The program is aimed at monitoring local mosquito activity to identify if arboviruses are present and what measures can be taken to reduce risk.

Ross River virus and Barmah Forest virus, spread by mosquitoes to humans, are commonly found in marsupials such as kangaroos and wallabies. Detection in mosquitoes at Deep Creek and in the Warriewood Wetlands areas indicate the viruses are present in wildlife around these areas. Mosquitoes pick up the virus by feeding on an infected animal and can then pass it onto humans.

Mosquito populations will decline with cooler weather but people should remain vigilant by taking measures to avoid mosquito bites. The risk to the general community is considered low but the risk is greater in areas with a high number of mosquitoes and marsupials present such as bushland and wetland areas.

The community is advised to follow these steps to avoid mosquito bites:

1. Wear loose-fitting long sleeved shirts and long pants when outside especially around dusk and dawn when mosquitoes are most active. Take special care during peak mosquito biting hours, especially around dawn and dusk;

2. Wear mosquito repellent to exposed skin using brands that contain either DEET or Picaridin.

3. Remove potential mosquito breeding sites from around the home by removing stagnant shallow water from saucers, buckets, etc. Mosquitoes like to breed in shallow stagnant water.

Please see the NSW Health factsheet [https://www.health.nsw.gov.au/Infectious/factsheets/Factsheets/mosquitoes-health-hazard.pdf] for further information

APPENDIX 3: MOSQUITO WARNING SIGN

An example of temporary warning signs installed at entrances to Warriewood Wetlands and Narrabeen Lagoon Trail, May 2020.