Weather extremes associated with increased Ross River virus and Barmah Forest virus notifications in NSW: learnings for public health response

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Abstract

Objective: To examine the sequence of environmental and entomological events prior to a substantial increase in Ross River virus (RRV) and Barmah Forest virus (BFV) notifications with a view to informing future public health response.

Methods: Rainfall, tidal, mosquito and human arboviral notification data were analysed to determine the temporality of events.

Results: Following two extremely dry years, there was a substantial increase in the abundance of mosquitoes along coastal New South Wales (NSW) two weeks after a significant rainfall event and high tides in February 2020. Subsequently, RRV and BFV notifications in north east NSW began to increase eight and nine weeks respectively after the high rainfall, with RRV notifications peaking 12 weeks after the high rainfall.

Conclusions: Mosquito bite avoidance messaging should be instigated within two weeks of high summer rainfall, especially after an extended dry period.

Implications for public health: Intense summertime rain events, which are expected to increase in frequency in south-east Australia with climate change, can lead to significant increases in arboviral disease. These events need to be recognised by public health practitioners to facilitate timely public health response. This has taken on added importance since the emergence of Japanese encephalitis virus in southeastern Australia in 2022.

Key words: environmental health, arbovirus, climate

The abundance and diversity of mosquitoes of pest and public health significance are dependent on suitable habitat and seasonal climatic conditions. Mosquitoes of public health significance are those capable of transmitting arboviruses known to cause human illness. There is a seasonal component to the incidence of mosquito-borne illness in New South Wales (NSW), with more cases generally reported during the warmer months and extending into late autumn and early winter from infections acquired sometime prior. In addition to this general pattern, from time to time there are local or regional epidemics.[1] These are difficult to predict.[2] It is important that opportunities are taken to examine the circumstances around episodes of increased mosquito-borne illness to enhance our understanding of why and when this occurs to inform future public health actions.

Under the *NSW Public Health Act 2010*, cases of human arboviral infection are required to be notified to public health authorities. From April to July 2020, very high numbers of cases of Ross River virus (RRV) and Barmah Forest virus (BFV) infection in residents of north eastern NSW were notified (herein called RRV and BFV notifications). The NSW Arbovirus Surveillance and Mosquito Monitoring Program,[3] which was established in 1984, provides data on mosquito abundance and arbovirus activity. Historically high numbers of mosquitoes have been collected along the NSW mid-north and north coast in late February and March 2020.

RRV and, to a lesser extent, BFV are the most common mosquito-borne pathogens notified to public health authorities in NSW.[4-6] While local outbreaks have occurred elsewhere,[1] during most years a high proportion of RRV and BFV notifications in NSW are for cases in residents of the north east of the state, (in the local health districts (LHDs) of Hunter New England, Mid North Coast and Northern NSW). A humid climate with many waterways and ephemeral water bodies, as well as an abundance of reservoir host animals of arboviruses in close proximity to human populations, are likely contributing factors to the higher number of notifications in this part of NSW.

The severity of RRV and BFV infections is highly variable.[7,8] Symptoms include fever, chills, headache, painful and swollen joints, muscle ache, rash, fatigue, weakness, and

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a general feeling of being unwell. Most symptoms resolve in a few weeks, but sometimes debilitating symptoms persist for many months.[9]

RRV and BFV are known to have many mosquito vectors but key vectors for both viruses are *Aedes vigilax*, a mosquito closely associated with tidally influenced coastal wetlands and *Culex annulirostris*, a mosquito closely associated with permanent and ephemeral freshwater habitats.[1,10] It is thought that RRV is maintained in nature through transmission by mosquito vectors within populations of susceptible endemic marsupials with macropods, such as kangaroos and wallabies, generally considered the most common reservoir hosts.[11] The most important host animals for BFV are less well defined, however genetic homogeneity in different regions of Australia is consistent with involvement of mobile hosts, most likely birds.[12]

The life cycle of mosquitoes is closely linked to environmental and climatic conditions. Increased rates of development and subsequent abundance of populations is closely associated with higher temperatures and humidity. The immature stages of mosquito development require an aquatic environment and, as a consequence, water provides suitable habitat for mosquitoes and generally promotes increased mosquito abundance during the warmer months of the year. While mosquito activity can increase after rain, on the coast, tidal inundation of estuarine wetlands (*e.g.* saltmarshes and mangroves) can also lead to increased abundance.[13] A combination of heavy rainfall and high tides has been identified as potentially important drivers of several historic outbreaks of RRV and BFV on the NSW coast.[14]

Models of RRV notifications in low-populated inland areas of southeastern Australia[15-18] and in Brisbane[19] have regressed envrionmental and entomological variables with RRV notifications to determine the predictive value of those variables for RRV outbreaks, on a monthly time scale. Rainfall, especially in Spring or Summer, and mosquito vector abundance have most consistently been predictive of RRV outbreaks. This study, of events prior to an exceptionally high number of RRV notifications in north east NSW in 2020 has the benefit of examining a weekly timeline that informs the optimal time for public health messaging following a series of extreme weather events.

Prior to 2020, NSW experienced an extended dry period, with rainfall totals across the state for the previous two years below the fifth percentile of historical two-year totals.[20,21] In early February 2020 there was substantial rainfall in NSW, especially along the coast where totals were greater than 200mm over the week ending 13 February 2020.[22] This rainfall coincided with high tides. In combination, this provided ideal conditions for mosquitoes given the extensive inundation across many different habitats.

This article documents the timeline of environmental and entomological events that led to an increase in RRV and BFV notifications in NSW in 2020, with a view to informing timely public messaging to protect health. The impact of climate change on environmental conditions conducive to mosquito proliferation is briefly discussed, as is the possible contribution of social restrictions implemented during the coronavirus disease 2019 (COVID-19) pandemic to the incidence of mosquito-borne illness.

Methods

Rainfall and tidal data

Daily rainfall totals were obtained from the Australian Bureau of Meteorology website (www.bom.gov.au/climate/data) for recording stations: Nobbys Signal Station AWS (Newcastle), Port Macquarie Airport AWS (Port Macquarie), Coffs Harbour Airport (Coffs Harbour) and Tweed Heads Golf Club (Tweed Heads). Daily tidal maxima were obtained from the Manly Hydraulics Laboratory, NSW Department of Planning, Industry and Environment for the tidal Station Number 213470, HMAS Penguin, Middle Head, Sydney Harbour.

Mosquito abundance monitoring and arbovirus surveillance

The NSW Arbovirus Surveillance and Mosquito Monitoring Program 'the program', collects mosquitoes from late Spring to Autumn each year. In 2019-2020, weekly collections of mosquitoes were made with the assistance of community, local councils, and public health units (PHUs) of NSW Health LHDs. Mosquitoes were collected overnight in carbon dioxide-baited Encephalitis Virus Surveillance (EVS) type traps. Collected mosquitoes were couriered live to the Department of Medical Entomology, NSW Health Pathology, Institute of Clinical Pathology and Medical Research (ICPMR), at Westmead Hospital, Sydney for species identification, counts, and arboviral detection. While the program has collection locations in inland regions of the state as well as metropolitan Sydney, here we report only the data from 10 coastal locations on the central, mid-north and north coast of NSW that are within the three LHDs of Hunter New England, Mid North Coast and Northern NSW. These locations were chosen for this analysis because most RRV and BFV notifications reported during the study period related to people who resided in these LHDs.

The abundance and diversity of mosquitoes collected in each of the mosquito traps was recorded weekly and for public reporting mosquito abundance was categorised: <50 mosquitoes trapped overnight "low", 50-100 "medium", 101-1,000 "high", 1,001-10,000 "very high" and >10,000 "extreme". Most mosquito collection locations have more than one mosquito trapping site and the reported abundance is based on the average number of mosquitoes collected in the traps at each location.

Identification of RRV and BFV in mosquitoes was via nucleic acid detection. Up to 1,000 mosquitoes from an overnight collection were ground mechanically with sterile glass beads in 2 to 10 ml of Tris-Ethylenediaminetetraacetic acid (EDTA) buffer, pH 8.0.[23] Viral RNA was extracted using the EZ1® Virus Mini Kit (Qiagen) and amplified via real-time RT-PCR with multiplexed fluorogenic TaqMan® probes (Thermo Fisher Scientific)[24,25] using a Corbett™ Rotor-Gene 6000 real-time cycler (Qiagen).

Notifications of RRV and BFV infection in humans

Under the *NSW Public Health Act 2010*, cases of human arboviral infection determined by clinical laboratory test are required to be notified to public health authorities. Both confirmed and probable cases of RRV and BFV infection are required to be entered into the NSW Notifiable Conditions Information Management System (NCIMS). A confirmed case requires laboratory definitive evidence in the form of either isolation of the virus, detection of the virus by nucleic acid testing, IgG seroconversion or a significant increase in IgG antibody level (fourfold or greater rise in titre) to the virus.[26,27] A probable case requires laboratory suggestive evidence in the form of detection of viral IgM and IgG antibodies except if viral IgG is known to have been detected in a specimen collected greater than three months earlier.

RRV and BFV notifications (confirmed and probable cases) were extracted from the

NCIMS by notification date using SAS® software. Notifications were grouped by epidemiological week (Sunday to Saturday) of the year for the date of notification, with the analysis encompassing the period 1 March to 25 July for 2020 and the equivalent epidemiological weeks of the year for the previous five years.

Results

High rainfall and coincident high tides in February 2020

In the week ending 13 February 2020, there was high rainfall (greater than 200mm) along the NSW coast with weekly totals greater than 400mm north of Port Macquarie. Figure 1 shows the daily rainfall totals at four major population centres on the central, mid-north and north coast of NSW for January to April 2020. These data indicate that the rainfall in the week ending 13 February 2020 was the most significant rainfall event in the first four months of 2020. The rainfall that week coincided with high tides along the NSW coast, indicated by the daily maximum tide height in Sydney (Figure 1). The tide height of 1.8 metres is designated because a high tide of this magnitude in Sydney has been associated with the hatching of *Aedes vigilax*.[28] Daily tide height maxima along the NSW coast north of Sydney (not shown) varied by less than 0.15 metres from that in Sydney.

Mosquito abundance and arbovirus detections

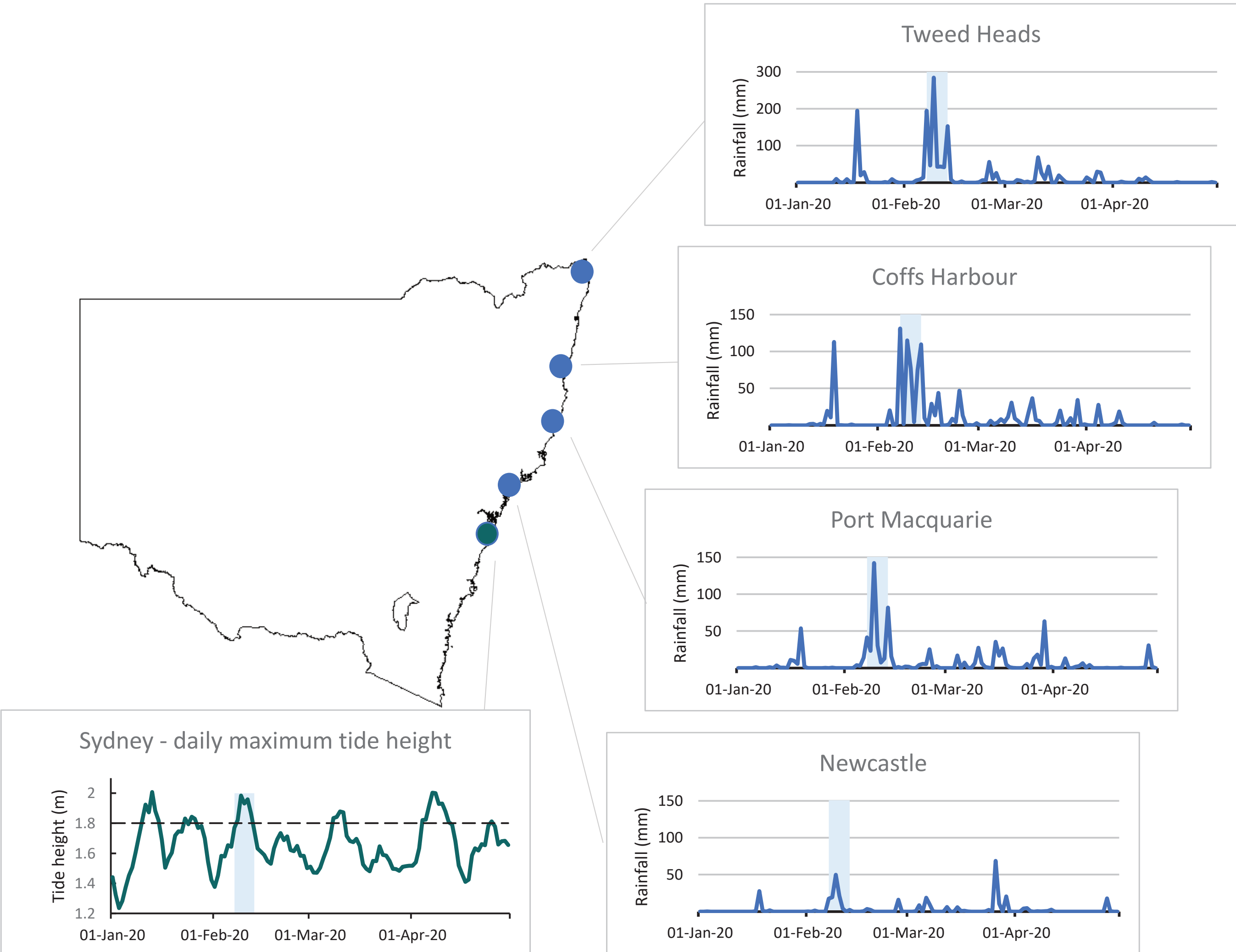
Very high numbers (>1,000) of mosquitoes were collected from at least one collection location on the NSW central, mid-north or north coast each week from the week ending 22 February 2020 to the week ending 28 March 2020 (Figure 2). This included high numbers of important arboviral vectors of concern, *Cx. annulirostris* and *Ae. vigilax*. *Cx. annulirostris* counts peaked the week ending 14 March 2020 while *Ae. vigilax* counts peaked the week ending 7 March 2020.

The first detections in 2020 of RRV in mosquitoes were from mosquitoes collected on 2 March 2020 at Kempsey and at Port Macquarie. BFV was first detected in mosquitoes collected on 9 March 2020 at Port Macquarie. Further detections of RRV and BFV came from mosquitoes collected later in March and in April 2020.

Human RRV and BFV notifications

From the week ending 7 March 2020 to the week ending 25 July 2020, the majority of RRV (76%) and BFV (81%) notifications in NSW

Figure 1: Daily rainfall totals 1 January 2020 to 30 April 2020 at four major population centres on the central, mid-north and north coast of NSW and daily maximum tide height at Sydney.

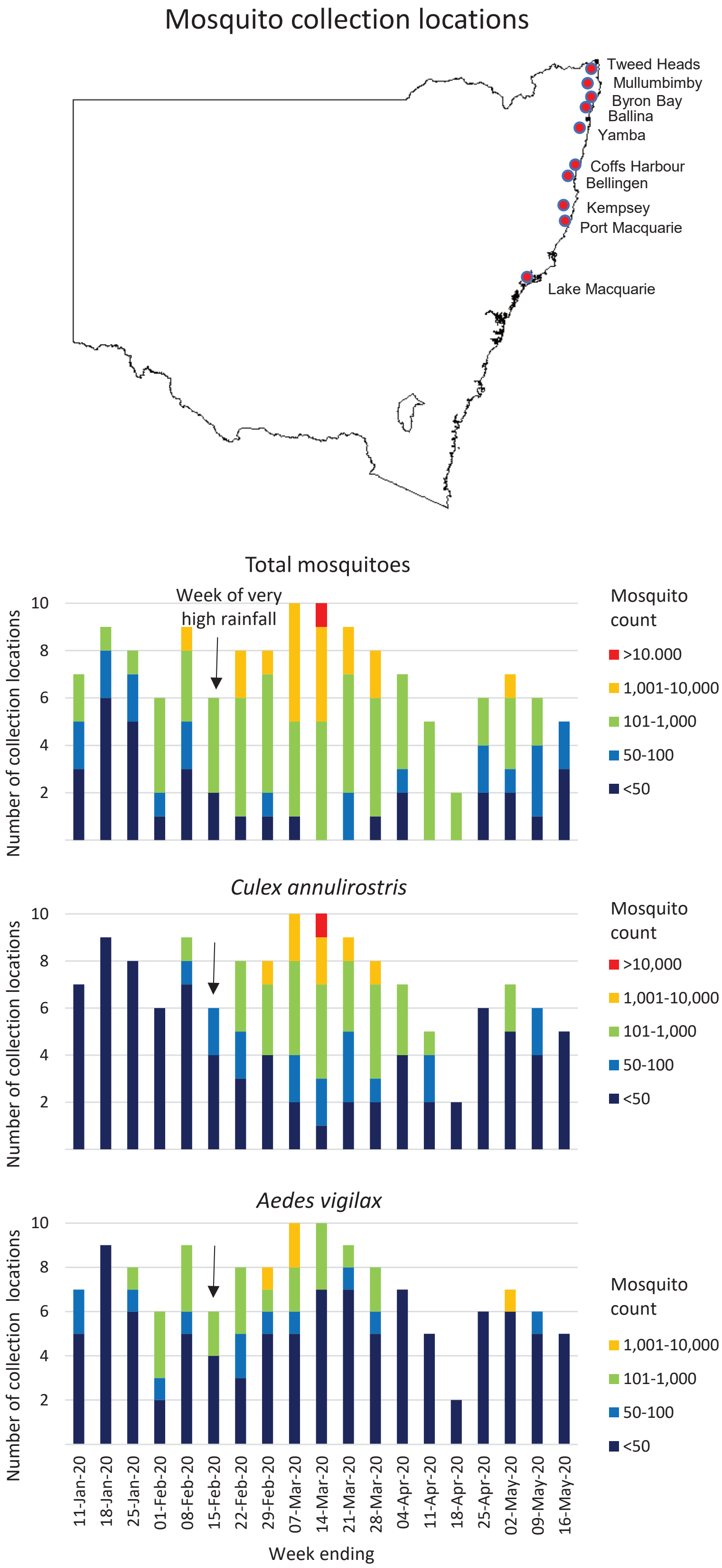


Notes:

Shaded columns identify the week ending 13 February 2020.

Data were sourced from the Bureau of Meteorology and the NSW Department of Planning, Industry and Environmental under Creative Commons Attribution Licence.

Figure 2: Categorical counts of mosquitoes collected from locations on the central, mid-north and north coast of NSW from the week ending 11 January 2020 to the week ending 16 May 2020.



Note:

There are 10 collection locations, but the number of categorical counts does not total 10 each week as mosquito collections were not able to be obtained from all locations each week. Arrows indicate the collection week when the high rainfall event occurred.

(data not shown) were for residents of north east NSW in an area (Figure 3) encompassed by the NSW LHDs of Hunter New England, Mid North Coast and Northern NSW.

Weekly RRV notifications in residents of north east NSW began to increase the week ending 11 April 2020, peaking in the week ending 9 May 2020 (Figure 3). From the week ending 11 April 2020 to the week ending 11 July 2020, weekly notifications were greater than the average over the previous five years (2015-2019). The total number of RRV notifications over this period in 2020 was 1,254, compared to an average of 165 for the equivalent period over the previous five years.

Weekly BFV notifications in residents of north east NSW began to increase the week ending 18 April 2020 (Figure 3). From the week ending 18 April 2020 to the week ending 25 July 2020, weekly notifications were greater than the average over the previous five years. The total number of BFV notifications over this period in 2020 was 115, compared to an average of 31 for the equivalent period over the previous five years.

Timeline of events from high rainfall to increase in RRV and BFV notifications

A timeline of events (Figure 4) shows that the substantial increase in the abundance of the arboviral vectors, *Ae. vigilax* and *Cx. annulirostris*, was observed two weeks after the high rainfall and high tides. Counts of those arboviral vectors peaked three and four weeks respectively after the high rainfall. RRV notifications began to increase eight weeks after the high rainfall (six weeks after mosquito abundance began to increase), peaked 12 weeks after the high rainfall, and remained higher than the previous five-year average to 21 weeks after the high rainfall.

BFV notifications began to increase nine weeks after the high rainfall and remained higher than the previous five-year average to 23 weeks after the high rainfall.

Discussion

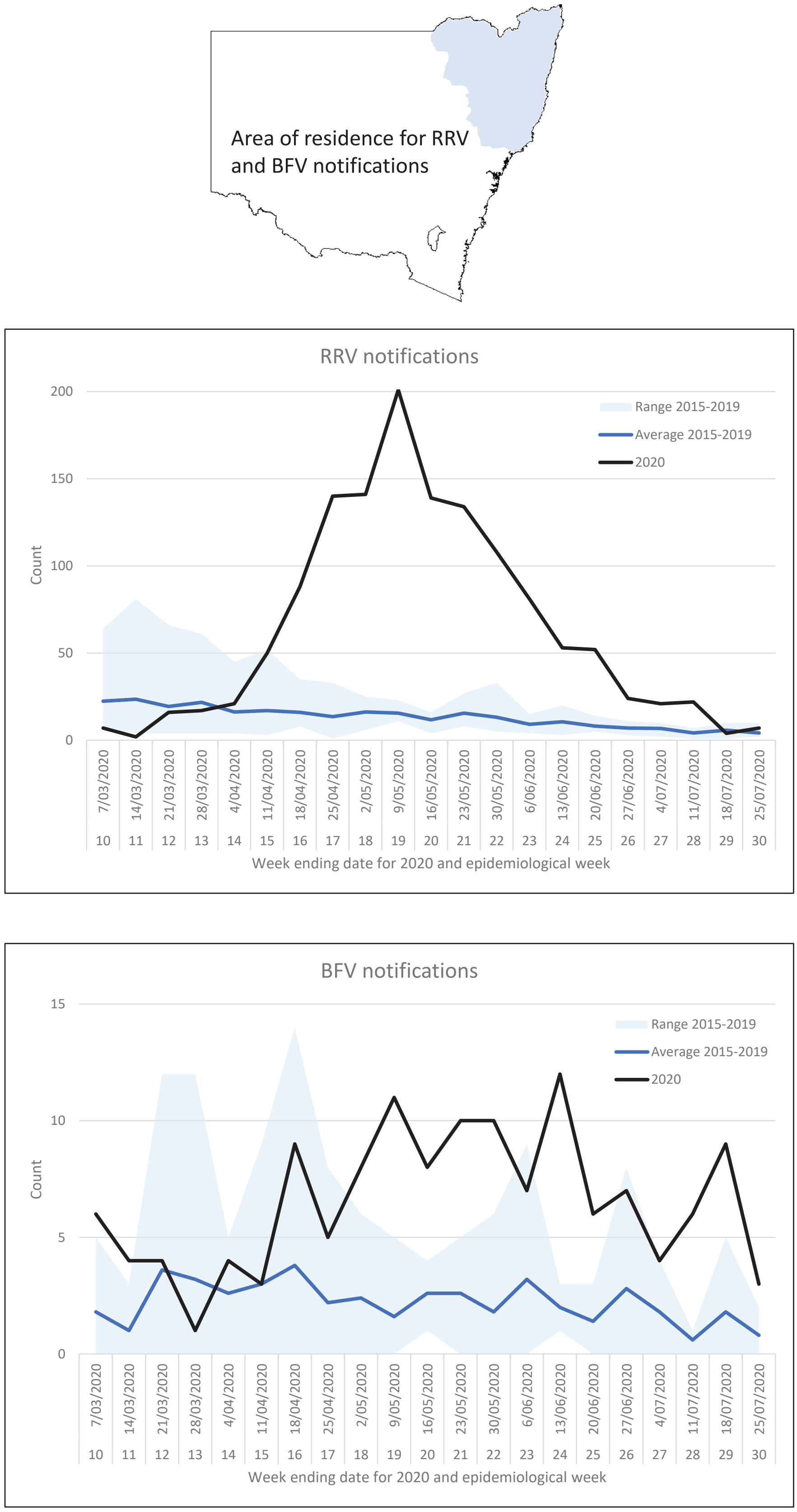
In late February and March 2020, increased abundance of mosquitoes, including vectors for RRV and BFV, was recorded on the central, mid-north and north coast of NSW. This increase was two weeks after substantial rainfall (and tidal events) that was preceded by two extremely dry years, demonstrating the role of habitat inundation in triggering mosquito proliferation. Our findings have taken on added importance since the emergence of Japanese encephalitis virus in southeastern Australia in 2022, and noting that *Cx. annulirostris*, a species abundant in NSW, is likely a key driver of transmission of this virus to humans.

Some species of mosquitoes, including *Ae. vigilax*, have eggs that are desiccation-resistant and can remain viable in the environment for long periods; periods of drying are actually preferable for breeding.[13,29] Thus dry years preceding 2020 would not have necessarily limited the rapid expansion in mosquito populations following the first significant rainfall, and may even have contributed to it. An important factor in the observed pattern of mosquito abundance and human arboviral infection notifications during this period is that when the rain came it was during summer and not winter. Warmer temperatures can increase the competency of arbovirus transmission through enhanced viral replication, acceleration of mosquito development and increased frequency of blood feeding.[30] In NSW, mosquito activity typically decreases during the cooler months from about April, with a decrease human arboviral infection notifications in later months.

If, as we postulate occurred in NSW in 2020, rainfall and tidal events substantially increased arboviral vector populations, it is possible to estimate when an increase in human infections might subsequently occur by considering the sequence of intermediary steps. The exact number of days from hatching to the emergence of adult mosquitoes from the aquatic environment varies depending on the species and ambient temperature but is around 10 days for the arboviral vectors *Ae. vigilax* and *Cx. annulirostris*. Newly emerged female mosquitoes seek out blood meals to obtain protein for egg production, and in doing so may acquire an arbovirus from an infected host animal.[31] To enable subsequent transmission to a human, the arbovirus must multiply through replication within the mosquito and disseminate into the mosquito's salivary glands.[32] This takes around five to seven days. Thus, the earliest that increased human infections might possibly occur would be between two to three weeks (around 10 days for mosquito development, plus 1-2 days of feeding activity, plus 5-7 days for arbovirus multiplication) after an environmental event induces mosquito hatching.

The timing post-infection of case notification to public health authorities is dependent on a

Figure 3: Weekly RRV and BFV notifications to public health authorities by date of notification for residents of north east NSW.



Note:
The number of notifications each week are shown from the week ending 7 March 2020 to the week ending 25 July 2020. Also shown are the average and range of weekly notifications for the previous five years, 2015-2019, for equivalent epidemiological weeks.

range of factors such as symptom severity, the propensity for an individual to seek medical attention, accessibility of medical services and the time taken for diagnosis and subsequent notification. The incubation period (time from infection to signs or symptoms) for RRV and BFV is usually around 7-9 days but can be up to 21 days for RRV.[8] Joint pain (also known as arthralgia or polyarthritis when multiple joints are involved) is one of the more common symptoms of RRV and BFV infection and is usually most severe at the time of diagnosis.[8,33] We observed increased RRV notifications 8-21 weeks after the high rainfall in February 2020. All of the reported RRV notifications after February 2020 will not have been a consequence of the February rain and subsequent increase in mosquito vectors. However, the numbers of mosquito vectors collected in late February and March 2020 were very high for the program and undoubtedly contributed to the later increase in RRV notifications. The long period of increased RRV notifications is not unexpected given the aforementioned factors that contribute to the timing of diagnosis, especially as the severity of RRV symptoms are highly variable and can be chronic. It could be many weeks, and longer than the incubation period of the infection before an infected individual presents to a medical practitioner. It is possible that in 2020, concern about symptoms and enhanced surveillance associated with the COVID-19 pandemic may have increased investigations and identification of the cause of some infections, but we have no evidence to support this.

While there are a range of strategies to reduce arboviral risk such as habitat modification in urban areas,[13] environmental release of laboratory-modified mosquitoes[34] and judicious pesticide use,[35] the most effective strategies to reduce the risk of acquiring a mosquito-borne pathogen are the steps that individuals can take to decrease the chance of mosquito bite[36] (see Box 1). To this end, public health messaging is a valuable policy instrument to raise awareness of health risks and reinforce the importance of mosquito bite avoidance.

There are two important considerations regarding public health messaging. Firstly, a principle of effective public health communications is timeliness.[37] Secondly, judicious use of messaging can avoid message fatigue, which leads to ineffective persuasive outcomes (in this case practising mosquito bite avoidance).[38]

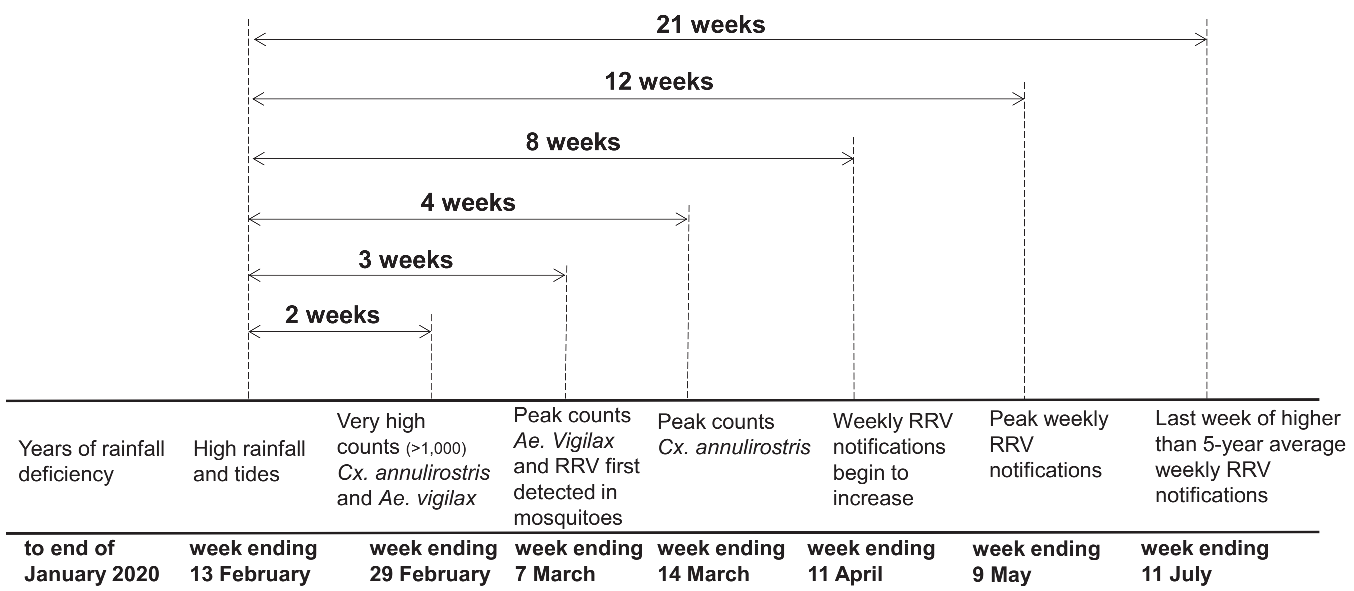
Conducting public health messaging when there is an expectation of heightened arboviral risk, such as holiday periods when people spend more time outdoors in wilderness areas, and periods when environmental conditions are conducive to mosquito proliferation, is likely to enhance messaging effectiveness due to recall of mosquito bite avoidance actions occurring when such activities can most protect health. This analysis of environmental and entomological events suggests that when a dry spell ends with intense summertime rainfall, public health messaging about mosquito bite avoidance is likely to be most timely if conducted within the two weeks following the rain. In our investigation, the two weeks following the rain was immediately prior to the largest collections of arboviral mosquito vectors and therefore just before the period of highest arboviral risk. The collections of vectors only remained high for several weeks and therefore in this scenario, waiting until high vector numbers have been reported before conducting messaging is likely to result in a missed opportunity to provide health protection messages at a time when they are most beneficial. However, any follow up messaging targeting specific populations and areas may be informed by the findings of arbovirus surveillance and mosquito monitoring programs.

It is clear from our findings that the increase in human notifications of arboviral illness, many weeks after a period of heightened arboviral risk, is not the optimal time to promote health protection messages. Other than a reminder of the reasons for practicing mosquito bite avoidance, public health messaging when notifications of illness are high may have little impact on the number of people infected as arboviral risk at that time may be low. As in 2020, this can be the case in NSW with notifications of illness high in late Autumn and early Winter when mosquito numbers are low. Increased numbers of

Box 1: Mosquito bite avoidance actions.

- Apply mosquito repellent to exposed skin
- Wear light-coloured clothing with long sleeves and pants
- Beware of the peak times for mosquito activity at dawn and dusk
- Have flyscreens on windows and doors
- Empty water-holding containers weekly around the home

Figure 4: Timeline of the sequence of events from the week of high rainfall to the last week of above average RRV notifications.



notifications of infections may bring arboviral illness to the attention of public health authorities however at such time the peak seasonal opportunity to promote health protection measures may have passed. During the cooler months populations of important mosquito vectors are low and people are less likely to be outdoors in clothing with exposed skin that is more liable to mosquito bite.

A drawback of initiating public health messaging based on environmental conditions is that not all high rainfall events will necessarily increase arbovirus-related risks and high rainfall and water flows may adversely impact local mosquitoes and reservoir host wildlife. This variability in health impacts has been identified in relation to post-flooding activity of RRV[18] and highlights the complexity in understanding the responses of mosquitoes and reservoir hosts to climatic events, and subsequent drivers of public health threats.[10] Recurrent public health messaging after every high rainfall event could reduce the effectiveness of these communications. Additionally, assessing specific environmental cues in relation to mosquitoes may not generally be a competency of public health practitioners.

Modelled climate projections for south-east Australia point to climate change resulting in longer dry spells but also increases in the magnitude and frequency of extreme precipitation days, including in the warmer months.[39] An overall warming climate will also increase the temporal frame in which extreme precipitation events may trigger increased mosquito abundance. Thus, the environmental events described here that led to a large increase in arboviral illness may become a more frequent occurrence.

While the high mosquito abundance in late February and March 2020 foreshadowed that there might be an increase in arbovirus illness, RRV notifications were exceptionally high in April and May 2020. A contributing factor may have been social restrictions implemented in response to the COVID-19 pandemic. In March 2020, legislated public health orders were enacted in NSW to close indoor recreation facilities, prohibit indoor fitness classes, and order people to stay home from work and education if it was possible to do these activities at home.[40] Anecdotally, these restrictions resulted in more people doing individual or household group outdoor exercise such as walking and running near their home. These activities, especially at dawn and dusk, would likely have increased people's exposure to mosquitoes, especially where urban parklands and bushland areas represented areas of elevated risk. It has been proposed that COVID-19 mitigation measures may have contributed to an atypical late season outbreak of RRV in Queensland.[41]

There are several limitations of this study and our interpretation of the link between environmental, entomological, and epidemiological events. Foremost of these limitations is that the number of surveillance locations in the NSW Arbovirus Surveillance and Mosquito Monitoring program is small relative to the geographical area, and that it is known that mosquito abundance can be highly variable within small areas.[42] Also, mosquitoes were not collected from every location each week. The program was dependent on the setting and retrieving of mosquito traps and this was not always possible in 2020,[43] especially as the COVID-19 pandemic progressed and restrictions were placed on people's activities or workers were impacted by other COVID-19-related issues. Arbovirus surveillance and counts of collected mosquitoes from the limited number of locations does not provide a measure of arboviral activity or mosquito abundance in all areas where people are at risk of arboviral infection. Without a more extensive data set and consistent sampling, we were able to do a graphical assessment of data overtime but were unable to undertake a quantitative analysis such as a time series analysis to provide a mathematical model to predict the impact of similar extreme weather events.

The program data can indicate expectations for the incidence of arboviral illness, but there are limitations to linking the program data to the human notification data. The location information in the NCIMS database from which the human notification data were extracted refers to the person's place of residence, not the location where the infection was necessarily acquired. However, social movement restrictions in place during the COVID-19 pandemic may have increased the likelihood that infections were acquired near to home. Additionally, we have analysed data from mosquito collection locations on the coast but have reported RRV and BFV notifications for people who resided within a wide area of north east NSW. Data from mosquito collection locations on the coast of NSW is not necessarily indicative of arboviral risk in areas many kilometres inland. However, as most of the population resides on the coast, the data from the program is highly relevant to population risk in the region.

Another important consideration is that cases recorded in the NCIMS are those identified as a result of health-seeking behaviour and subsequent testing. Asymptomatic infections are highly unlikely to be picked up via this surveillance system. The ratio of asymptomatic to symptomatic infections is unclear, but there are likely to be many more asymptomatic RRV infections[7] (and low severity infections) than the number of cases reported in the NCIMS. Therefore, RRV and BFV notifications likely represent a fraction of the true incidence of infection.

In theory, arboviral genetic change could have contributed to the increase in notifications of arboviral infections. There is evidence from Western Australia that roughly every ten years distinct genetic lineages of RRV emerge.[44] If genetic change in an arbovirus resulted in enhanced viraemia, this could have driven the increase in reported infections in 2020. However, genetic sequencing of RRV isolated from collected mosquitoes did not indicate that there had been any substantial genetic change in the RRV in NSW in 2020.

We have reported the human data by the date of notification in the NCIMS, which is different to the date of symptom onset. The lack of clinical information in the majority of notifications and the absence of a clinical component to the case definition in control guidelines[26,27] make the notification date a more consistent and appropriate choice for this study than an estimate of symptom onset. The absence of data on symptom onset, which would be a better indicator of date of infection, does not detract from our findings of an increase in mosquito vectors in the weeks following a high rainfall event and conclusion that public health messaging should occur when environmental conditions are favourable to an increase in mosquito vectors; prior to people becoming infected. Lastly, here we report on one environmental scenario and a subsequent sequence of events that suggest when may be the optimal time to conduct public health messaging. No two rainfall events are identical and examinations of entomology and cases of human disease following other summertime rainfall events will add to our knowledge about which environmental situations are likely to lead to an increase in arboviral risk and in doing so assist public health practitioners in decision-making to protect health.

Despite the study limitations, this analysis of events in the early months of 2020 substantiates the potential benefit of using environmental information to inform timely public health messaging when arboviral risk is likely to increase.

Conclusion

In a scenario that may become more frequent with climate change, messaging about mosquito bite avoidance will likely be of most benefit if delivered within two weeks of intense summertime rainfall. It is important that public health practitioners recognise weather and other environmental events favourable to mosquito proliferation.

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