Government of **Western Australia**
Department of **Health**

Medical Entomology Annual Report: 2018-19

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Acknowledgements

The extensive and diverse work program undertaken by Medical Entomology (ME), within the Western Australia Department of Health (the Department), could not have been achieved without significant assistance from, and collaboration with, many partners and stakeholders.

ME wishes to thank a number of teams within the Department for their ongoing support in regard to this important public health program, including:

- the Environmental Health Directorate;
- the Communicable Disease Control Directorate;
- the Communications Directorate;
- Population Health Units/Area Health Services within the Western Australia Country Health Service (WACHS); and
- PathWest Laboratory Medicine WA (PathWest)

During 2018-19, PathWest continued to play a significant role in the Department's surveillance program through the provision of laboratory services that allow for the detection of arboviruses of public health significance.

We thank the many local government (LGs) throughout the State, together with WACHS Population Health Units, for their ongoing role in following-up notified cases of human disease.

Finally, we commend all LG environmental health teams actively involved in the management of mosquitoes throughout WA. Their efforts play a critical role in reducing the public health risk and impact on amenity associated with mosquitoes within their own jurisdictions.

Collectively, these organisations are involved in provision of data, case follow up investigations, care and bleeding of chickens within the sentinel chicken program, trapping of mosquitoes, control treatments, community education and risk communication throughout WA.

The collaborative approach and effort by the teams and agencies described above is a feature of this truly statewide, integrated program, and its effective delivery across the largest jurisdiction in Australia by area.

Biological and Applied Environmental Health Hazards
Environmental Health Directorate | Public and Aboriginal Health Division
WA Department of Health
PO Box 8172 | Perth Business Centre | Perth WA 6849

Contents

Glossary

ASR	age standardised rate
BAEHH	Biological and Applied Environmental Health Hazards
BFV	Barmah Forest virus
CHIKV	chikungunya virus
CLAG	Contiguous Local Authorities Group
CR	crude rate
DENV	dengue viruses
Department (the)	Department of Health
ENSO	El Niño–Southern Oscillation
ESD	enhanced surveillance data
FTB	Fight the Bite
JEV	Japanese encephalitis virus
KUN	Kunjin (disease)
LG	Local government
MAL	malaria protozoan parasite
ME	Medical Entomology
MVEV	Murray Valley encephalitis virus
Public Health Act	*Public Health Act 2016* (WA)
RRV	Ross River virus
RT-PCR	reverse transcriptase polymerase chain reactions
SOI	Southern Oscillation Index
TC	tropical cyclone
WA	Western Australia
WANIDD	Western Australian Notifiable Infectious Disease Database
WNV_{KUN}	West Nile virus Kunjin strain
ZIKV	Zika virus

Executive Summary

This Annual Report summarises the mosquito-borne disease case data from Western Australia (WA), as well as the varied and comprehensive activities undertaken by Medical Entomology (ME), with the WA Department of Health (the Department) for 2018-19 (1 July 2018 - 30 June 2019). Northern trapping data from 2017-18 has also been included, as mosquito identification took place during the reported financial year.

Briefly, 2018-19 was characterised by below average numbers of mosquitoes and notified cases of mosquito-borne disease throughout the State (see 2018-19 Snapshot). This low level of activity was largely attributed to WA experiencing neutral El Niño–Southern Oscillation (ENSO) conditions for most of the year, which in turn resulted in below average rainfall patterns and a reduction in the frequency and magnitude of tidal surges. The only tropical cyclone (TC) to cross the WA coastline during this time was TC Veronica. Despite subjecting the Pilbara coastline to a prolonged period of destructive winds and heavy rainfall, the impact on mosquito populations and disease notifications was minimal.

Supporting local government

ME continued to support local government (LG) through the provision of training and technical advice and oversight of Fight the Bite, as well as the coordination of the Contiguous Local Authorities Group (CLAG) scheme and aerial treatment program. The Department approved CLAG funding requests, totalling $300,128.70, and spent a further $535,405.17 on the provision of aerial larviciding treatments across high risk regions of the State's South West.

Mosquito and arbovirus surveillance

The arbovirus surveillance program continued to play an important role in informing LG mosquito management activities and determining the need for, and timing of, media statements released by the Department in an effort to minimise the public health risk associated with mosquitoes throughout WA.

A total of 87,444 mosquitoes were collected across 21 routine surveillance sites between Mandurah and Busselton in WA's South West. Ross River virus (RRV) was detected eight times across three different sites in the Peel and Leschenault regions. There were no detections of Barmah Forest virus (BFV).

A total of 3,888 blood samples were collected from sentinel chickens across 23 flocks throughout northern WA, before they were tested for flavivirus antibodies. Seven seroconversions were detected, indicating that flavivirus activity was present in the east Kimberley during 2018-19. Mosquitoes were also collected from the Kimberley region between 22 March - 1 April 2019, during ME's annual northern surveillance trip. These mosquitoes will be identified to species level and processed for detection of arboviruses during 2019-20.

Exotic mosquito surveillance

The Commonwealth Department of Agriculture Science Support Program detected two importations of exotic mosquitoes in 2018-19. ME confirmed the identifications as *Culex nigropunctatus* and *Aedes aegypti,* collected at Fremantle Wharf and an approved arrangement facility located near Perth International Airport, respectively.

MEDICAL ENTOMOLOGY
2018-19 Snapshot

Surveillance efforts throughout WA are used to inform public health warnings and interventions

Southwest mosquito and arboviral surveillance

481 Mosquito traps set over 21 sites in WA's South West

87,444 Adult mosquitoes collected

Adult mosquitoes trapped by region

- Geographe - 35,681
- Peel - 28,727
- Leschenault - 23,036

8 Ross River virus detections

0 Barmah Forest virus detections

24 aerial larvicide applications **totaling 2,525 ha**

Disease surveillance

Mosquito-borne disease cases acquired in WA

404	Ross River virus disease
18	Barmah Forest virus disease
0	Murray Valley encephalitis
0	Kunjin virus disease

Mosquito-borne disease cases acquired overseas

266	Dengue
60	Malaria
4	Chikungunya
1	Zika

23 Sentinel chicken flocks managed throughout WA

3,888 blood samples tested

7 Mosquito-borne virus infections detected in chickens

Stakeholder engagement

2 Media statements issued

17 CLAG funding applications assessed

2 Mosquito ID courses conducted

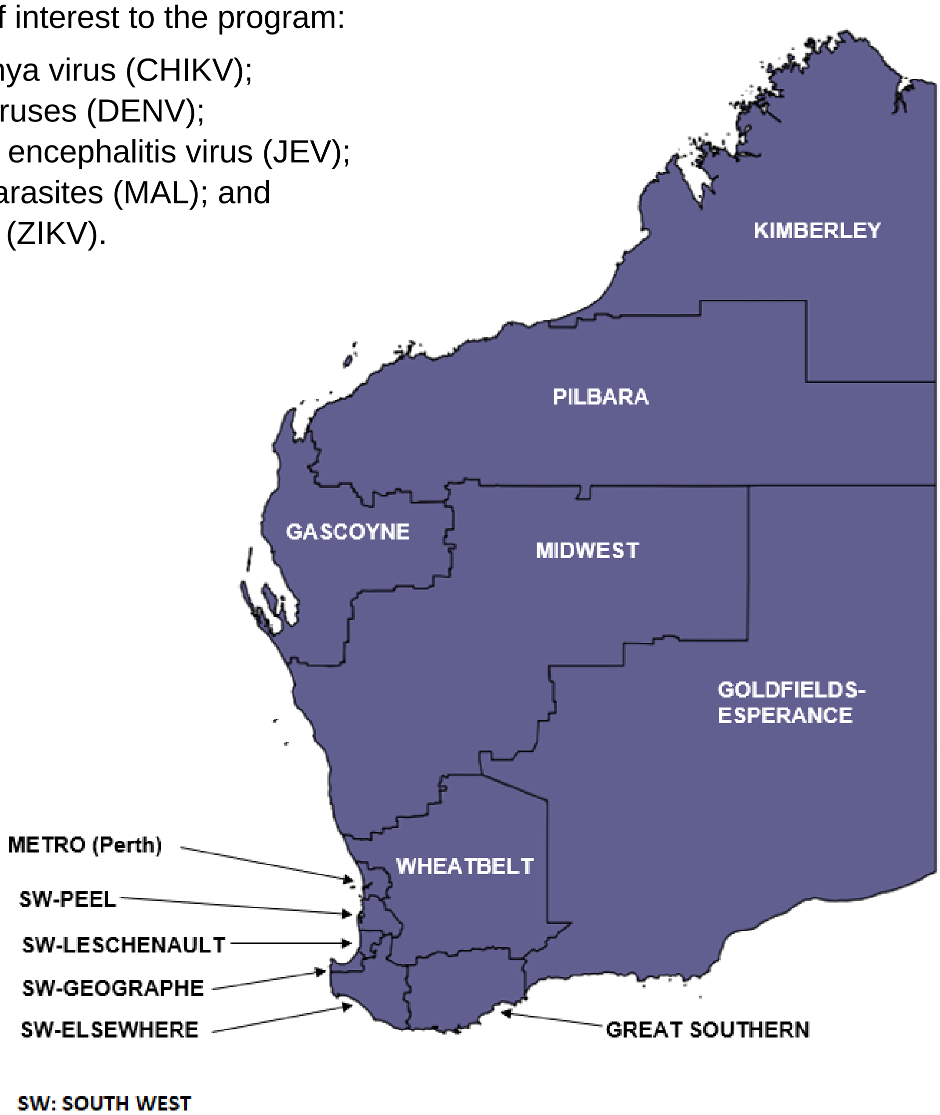
1.0 Introduction

There are 300 different species of mosquitoes in Australia, of which approximately 100 are known to occur in WA. Viruses have been isolated from over 30 species across Australia and many other species have not been tested to determine their ability to transmit these viruses. Medical Entomology (ME) monitors the following four mosquito-borne viruses, which are all known to cause locally acquired, notifiable diseases in the following regions* of WA:

1) Ross River virus (RRV) – all of WA;
2) Barmah Forest virus (BFV) – all of WA;
3) Murray Valley encephalitis virus (MVEV) – northern WA (Kimberley, Pilbara, Gascoyne and Midwest regions); and
4) West Nile virus Kunjin strain (WNV_{KUN}) – northern WA (Kimberley, Pilbara, Gascoyne and Midwest regions).

ME also monitors the incidence of exotic mosquito-borne diseases acquired overseas, by visitors or residents returning from countries outside of Australia. The following exotic mosquito-borne pathogens are of interest to the program:

1) chikungunya virus (CHIKV);
2) dengue viruses (DENV);
3) Japanese encephalitis virus (JEV);
4) malaria parasites (MAL); and
5) Zika virus (ZIKV).



*Note: ME reports data according to the regional boundaries shown here. These boundaries differ slightly compared to WA Public Health Regions.

1.1 The role of Medical Entomology

ME is responsible for:

- monitoring human cases of mosquito-borne diseases through the Western Australian Notifiable Infectious Disease Database (WANIDD) to determine patterns of disease occurrence, issue media statements and provide warnings to at-risk communities;

- provision of expert advice to the Minister for Health, senior Department executives, other State government agencies, local government authorities and members of the public on matters concerning mosquitoes and mosquito-borne disease risk;

- undertaking mosquito and arbovirus surveillance to monitor RRV and BFV activity in the South West, and surveillance of MVEV and WNV_{KUN} activity through sentinel chicken flocks in the northern two-thirds of WA;

- coordination of the aerial larviciding program in high mosquito-borne disease risk regions of WA's South West;

- coordination of the Contiguous Local Authorities Group (CLAG) funding scheme;

- resource development and coordination of the Department's public awareness campaign, Fight the Bite, to raise awareness of mosquitoes and improve prevention practices;

- issuing media statements when virus activity escalates, environmental conditions are suitable for vector breeding or surveillance activities identify potential public health risks;

- provision of training courses, forums, seminars and lectures to personnel involved in mosquito management and to disseminate information to stakeholders and the public;

- provision of specialist advice related to development applications through the identification of public health risk associated with proximity to existing mosquito breeding sites, and potential to create new breeding habitats as a result of the development itself;

- conducting and assisting other agencies in research projects focusing on mosquito ecology, arboviruses, innovative mosquito management practices, mosquito management equipment trials and calibration and newly available chemicals and/or formulations for mosquito control;

- assisting LG in field investigations and surveys of mosquito-breeding habitat related to disease outbreaks and public complaints;

- provision of technical assistance and advice on mosquito control treatments and ongoing monitoring related to exotic mosquito incursions throughout WA;

- development of policies for best practice mosquito control and use of chemicals, mosquito management plans, minimising risks for residential developments and avoidance of man-made mosquito breeding;

For further information on a range other activities, projects and research initiatives undertaken by ME, please review the Environmental Health Directorate's Yearbook.

2.0 Endemic arbovirus diseases

2.1 Ross River virus

Ross River virus (RRV) is the most common arbovirus known to cause human disease in WA. Patients with RRV infection experience a polyarthritic condition with or without other symptoms such as fever, sore muscles, rash, lethargy and headaches. These symptoms can last from weeks to months, and in very rare cases years. Serological testing is the only reliable way to definitely diagnose an active RRV infection.

2.1.1 Overview of Ross River virus cases

In 2018-19, there were 404 RRV cases notified in WA (Figure 1). This number was significantly less than the 5-year moving average for all months. Enhanced surveillance data (ESD) are available for 68 of these cases. Predominant weather patterns were not conducive to mosquito breeding leading to lower mosquito abundance across much of the State and thus, a reduced incidence of disease.

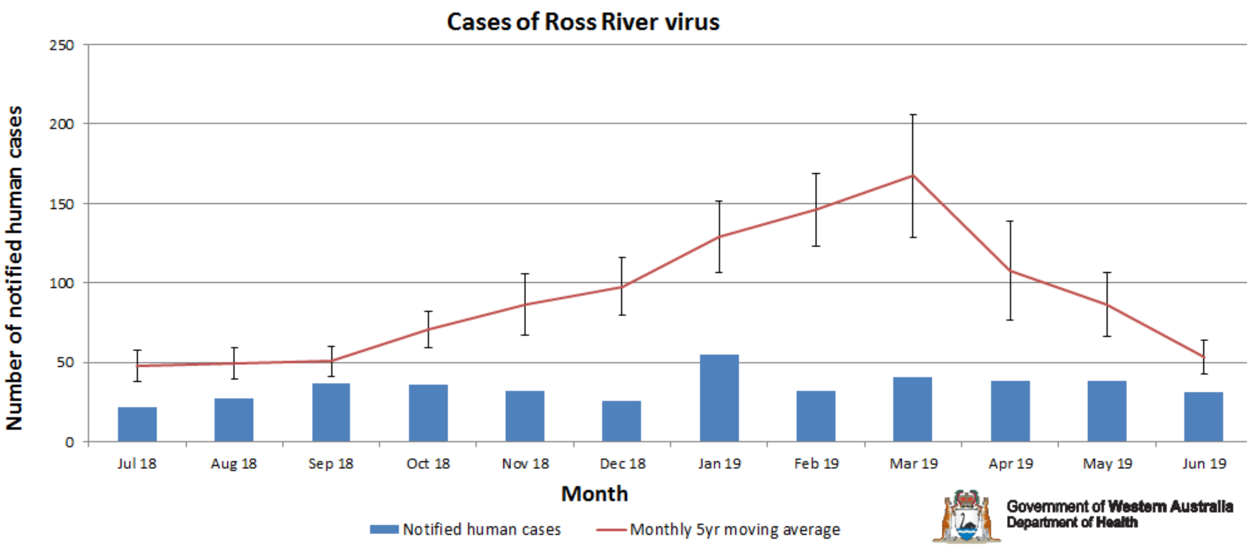


Figure 1: Total number of Ross River virus cases notified in Western Australia, per month between 1 July 2018 to 30 June 2019*

**Based on enhanced notified human cases from the Western Australian Notifiable Infectious Disease Database (WANIDD) and includes enhanced surveillance data from follow-up questionnaires.*

2.1.2 Enhanced surveillance data response rates

There were 180 (45%) doctor notified cases of RRV that could be followed up for ESD. As above, completed ESD questionnaires were received from 68 of these, resulting in a response rate of 38%.

2.1.3 Age and sex distribution of Ross River virus cases

In 2018-19, most notified RRV cases were middle aged adults (Figure 2). The median age was 49 years, with 46 years for females (peaking at 35-39 and 50-59 year age groups) and 52 years for males (peaking at 35-39 and slightly later between 55-64 years).

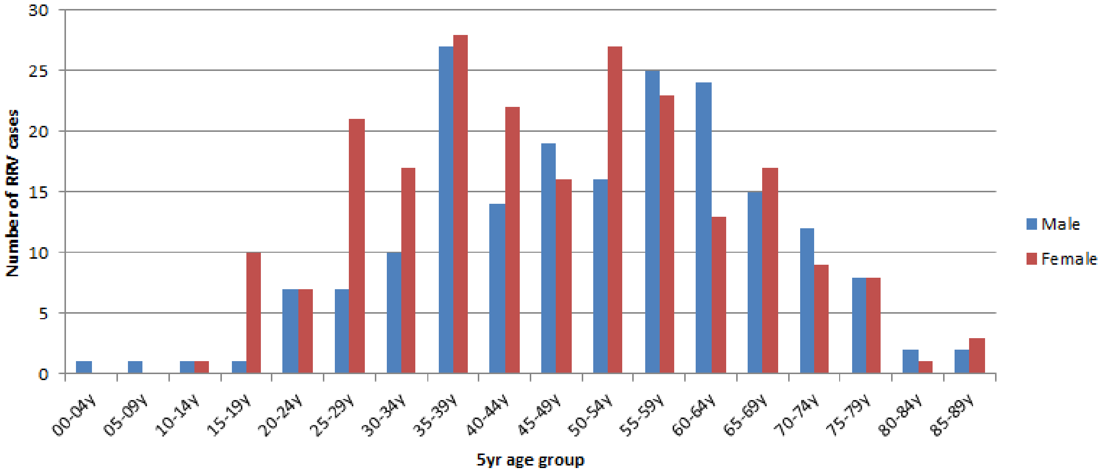


Figure 2: Total number of Ross River virus cases notified in Western Australia, by age group and sex, between 1 July 2018 to 30 June 2019

2.1.4 Regional summaries of Ross River virus cases

The highest number of RRV cases reported was from the Perth metropolitan and South West regions, with 160 and 168 cases respectively (Table 1). Data from WA's South West is further divided into four regions (Peel, Leschenault, Geographe and South West-elsewhere) to provide a more detailed breakdown of disease distribution. The majority of cases reported in the South West were notified from Peel (107).

For all disease data tables in this report, the Crude Rate (CR) represents the number of disease notifications per 100,000 population in each region and the Age Standardised Rate (ASR) adjusts for differences in the age distribution between the regions to enable direct comparison of the rates across regions. The highest CR and ASR of 49.8 and 61.1 per 100,000 respectively, was recorded from the Kimberley region.

The number of RRV cases in the Perth was significantly less than the 5-year moving average for the metropolitan region across all months (Figure 3). Although the number of cases appears high compared to other regions, the CR and ASR were actually the second lowest across the State (Table 1). This is a result of the large population living in Perth.

Across the South West, the number of RRV cases remained significantly lower than the 5-year moving average for all months except August and September 2018, when the number was within the normal range (Figure 4).

Table 1: Serologically confirmed, doctor-notified, and laboratory reported cases of Ross River virus disease per month for each WA region from 1 July 2018 to 30 June 2019. Crude rate is per 100,000. Age standardised rate compared to Australian standard population*.

REGION	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total	Crude Rate	Age Std Rate
KIMBERLEY	3	4	0	0	3	1	1	1	1	1	2	1	18	49.8	61.1
PILBARA	0	1	3	0	0	1	0	0	0	3	3	3	14	22.8	17.2
GASCOYNE	1	0	0	0	0	0	0	0	0	0	0	0	1	10.4	11.2
MIDWEST	0	1	0	0	0	0	0	0	0	1	1	1	4	6.5	6.0
WHEATBELT	2	0	1	1	1	0	1	0	2	0	2	4	14	20.2	18.9
METRO	7	8	12	16	13	7	23	16	13	17	19	9	160	9.0	8.6
PEEL	5	7	13	10	5	8	18	9	10	11	7	4	107	40.2	38.6
LESCHENAULT	1	2	2	3	3	2	3	1	6	0	1	4	28	38.0	36.9
GEOGRAPHE	2	2	3	2	3	2	3	2	4	1	1	2	27	48.1	47.5
ELSEWHERE SW	0	0	0	1	1	0	2	0	1	1	0	0	6	12.7	11.3
SOUTH WEST	8	11	18	16	12	12	26	12	21	13	9	10	168	37.9	
GREAT SOUTHERN	1	1	0	2	0	2	3	1	2	0	1	1	14	23.1	20.9
GOLDFIELDS-ESPERANCE	0	1	2	1	1	2	0	0	2	1	0	1	11	19.6	21.1
WA UNDETERMINED	0	0	0	0	0	0	0	0	0	0	0	0	0		
INTERSTATE	0	0	1	0	2	1	2	2	0	3	0	1	12		
WA TOTAL (does not include interstate)	**22**	**27**	**36**	**36**	**30**	**25**	**54**	**30**	**41**	**36**	**37**	**30**	**404**		

**Table may vary from previous or future version due to inclusion of additional surveillance data.*

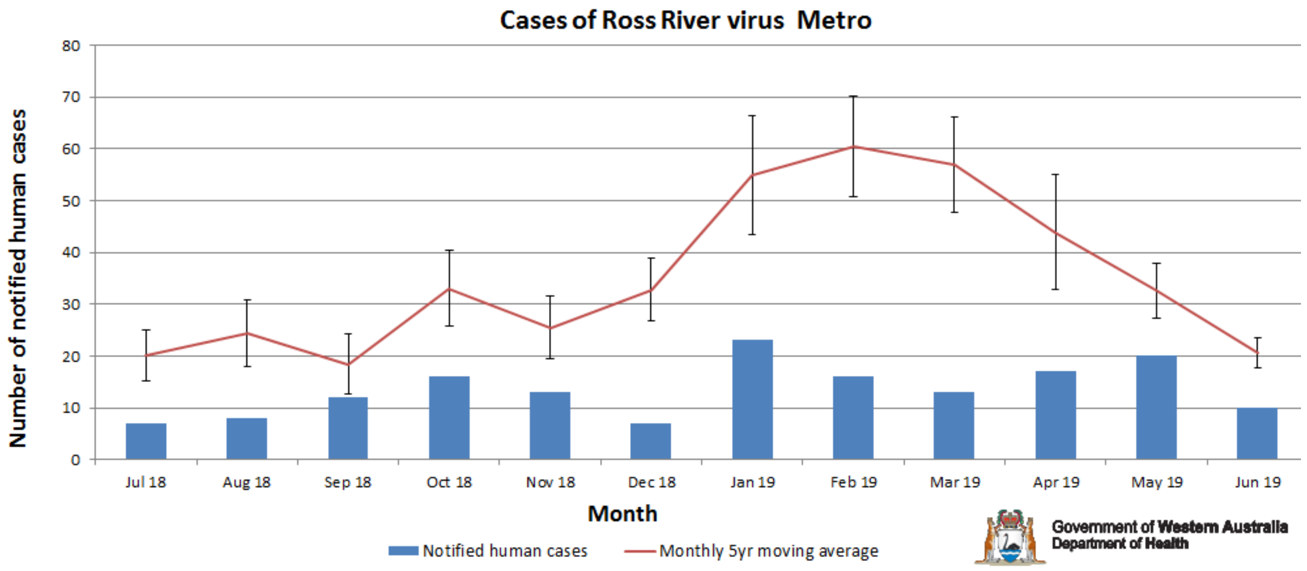


Figure 3: Total number of Ross River virus disease cases notified in the Perth Metropolitan region, per month between 1 July 2018 to 30 June 2019

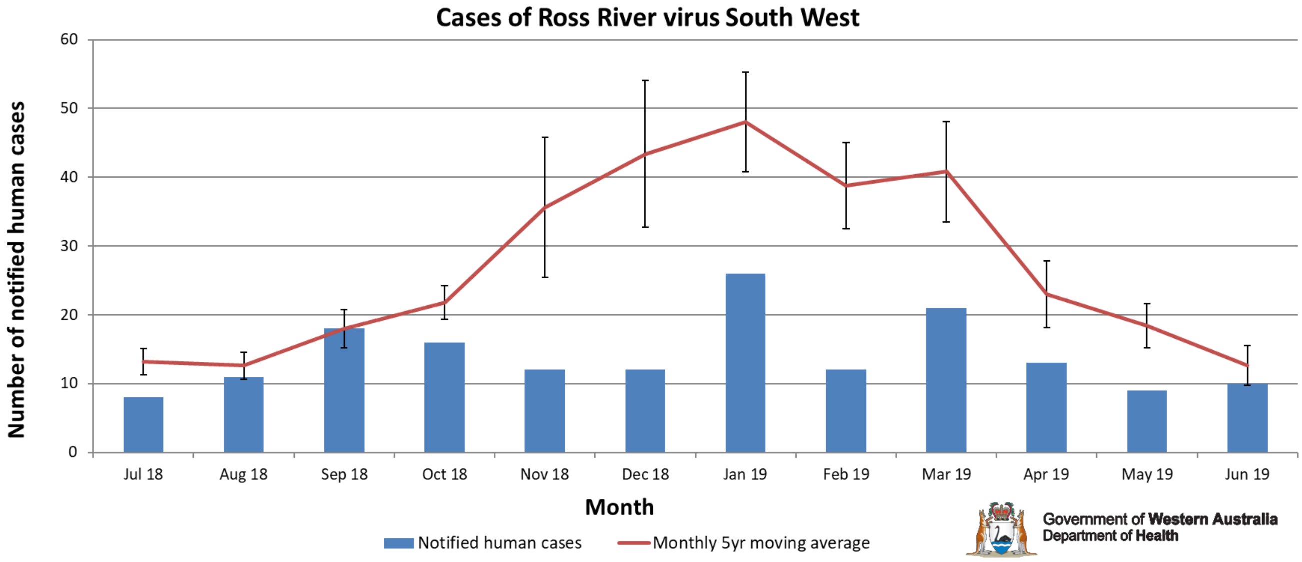


Figure 4: Total number of Ross River virus disease cases notified in the South West region, per month between 1 July 2018 to 30 June 2019.

During 2018-19, most LGs reported similar rates of RRV disease compared to the State average (Figure 5). Only 12 of 137 LGs had significantly higher rates compared to the State average, including Wyndham-East Kimberley, Broome, Karratha and several LGs in the South West (Figure 6).

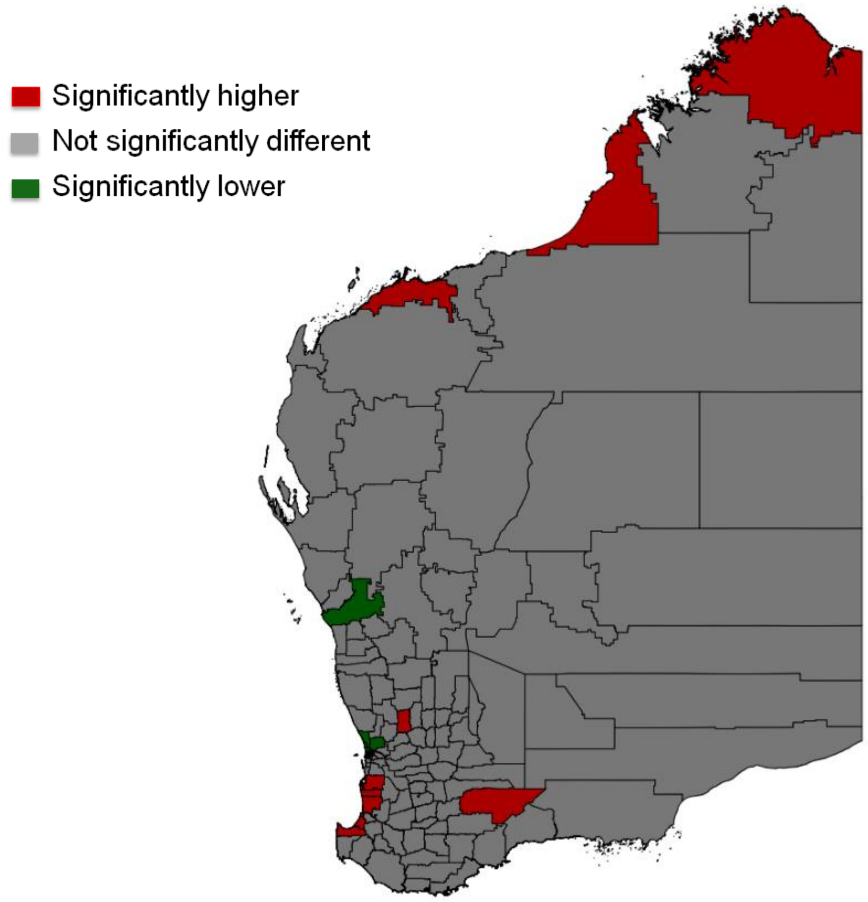


Figure 5: Map of WA showing rates of Ross River virus disease cases per 100,000 of population by local government area compared to the State average rate for 2018-19

2.1.5 Summary of Ross River virus cases: Perth metropolitan area

As is the case most years, several LGs within the Perth metropolitan region reported RRV rates that were similar or significantly lower than the State average (Figure 6).

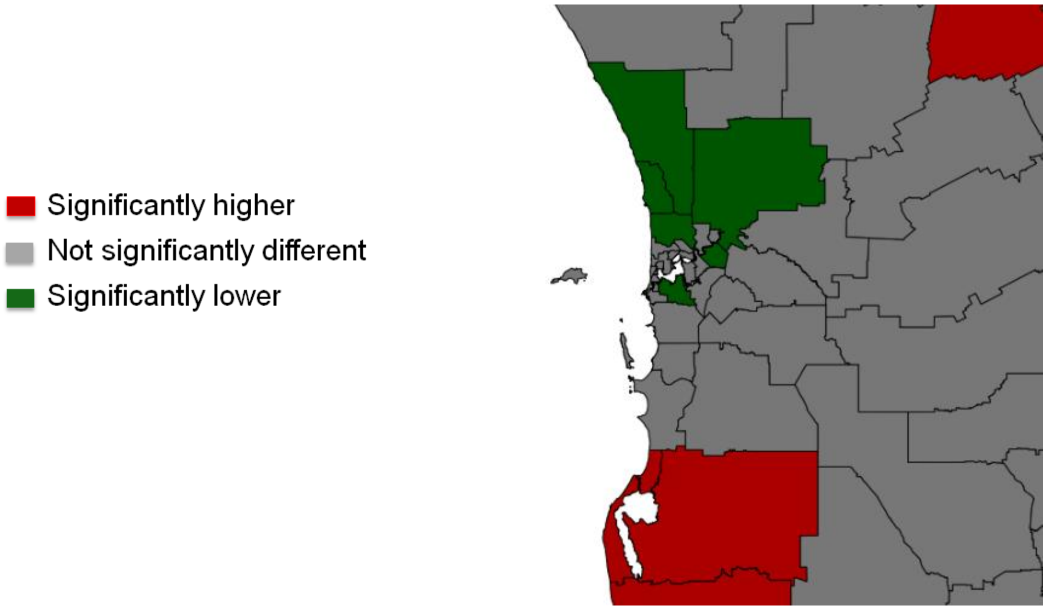


Figure 6: Map of Perth Metropolitan area showing rates of Ross River virus disease cases per 100,000 of population by local government area compared to the State average rate for 2018-19

2.2 Barmah Forest virus

Barmah Forest virus (BFV) is the second most common arbovirus causing human disease in WA. The virus is closely related to RRV and the symptoms of infection are similar. However, BFV is generally regarded as the milder of the two and fewer BFV cases are reported. Serological testing is the only reliable way to correctly diagnose the causative virus and differentiate an active infection from RRV.

2.2.1 Overview of Barmah Forest virus cases

In 2018-19, there were 18 BFV cases notified in WA (Figure 7). This number was less than the monthly 5-year moving average for all months except August and September 2018. However, due to the low number of monthly cases, these differences were not considered statistically significant.

2.2.2 Enhanced surveillance data response rates

There were 12 (67%) doctor notified BFV cases that could be followed up for ESD. As above, completed ESD questionnaires were received from three individuals, resulting in a response rate of 25%.

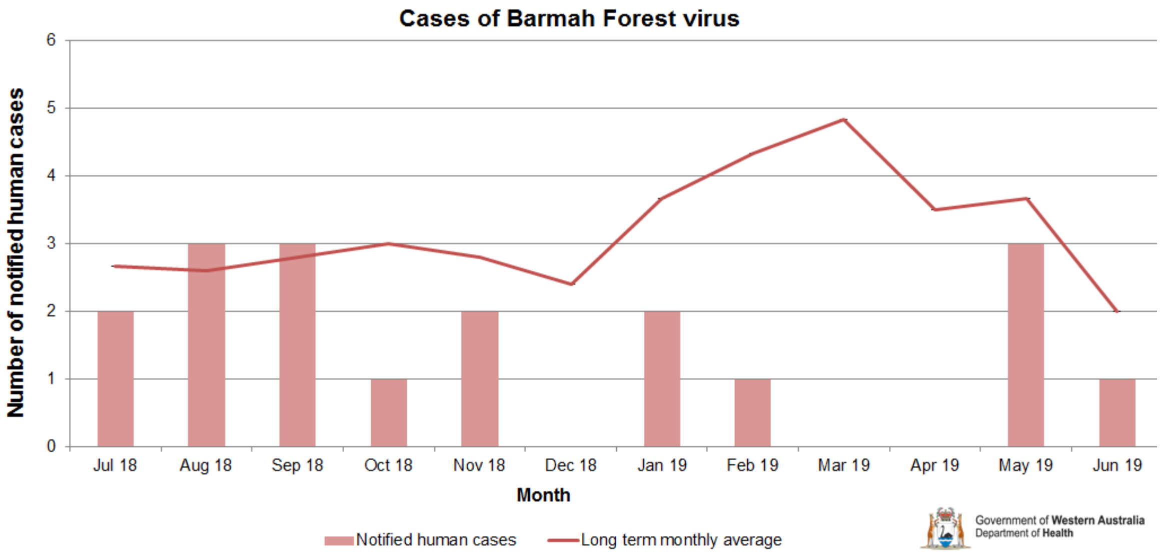


Figure 7: Total number of Barmah Forest virus cases notified in Western Australia, per month between 1 July 2018 to 30 June 2019*

**Based on enhanced notified human cases from the Western Australian Notifiable Infectious Disease Database (WANIDD) and includes enhanced surveillance data from follow-up questionnaires.*

2.2.3 Age and sex distribution of Barmah Forest virus cases

In 2018-19, most notified BFV cases were middle aged adults, in the 40-44 and 55-59 year age groups (Figure 8). There were 10 females (with a median age of 48 years) and eight males (with a median age of 44 years).

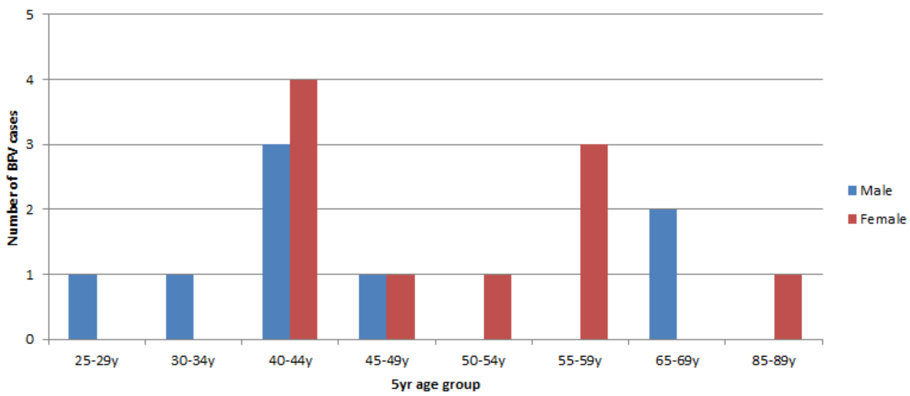


Figure 8: Total number of Barmah Forest virus cases notified in Western Australia, by age group and sex between 1 July 2018 to 30 June 2019*

**Based on enhanced notified human cases from the Western Australian Notifiable Infectious Disease Database (WANIDD) and includes enhanced surveillance data from follow-up questionnaires.*

2.2.4 Regional summaries of Barmah Forest virus cases

The combined South West region reported the highest number of BFV cases (8) for 2018-19. Four of these occurred in the South West-elsewhere sub-region (Table 2).

The highest CR and ASR were reported from the Gascoyne region, with 20.9 and 17.7 per 100,000 respectively, with one case reported in both August and September 2018. In the Gascoyne region, the moving monthly average is usually less than 1 case per month.

The second highest CR and ASR were reported from the South West-elsewhere region, with 8.5 and 8.6 per 100,000 respectively. In the South West-elsewhere region, the moving monthly average is usually up to one case per month.

Table 2: Serologically confirmed, doctor-notified, and laboratory reported cases of Barmah Forest virus disease per month for each region from 1 July 2018 to 30 June 2019. Crude rate is per 100,000 of population. Age standardised rate compared to 2001 Australian standard population*.

REGION		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total	Crude Rate	Age Std Rate
KIMBERLEY		0	1	0	0	0	0	0	1	0	0	0	0	2	5.5	6.0
PILBARA		0	0	0	0	0	0	0	0	0	0	1	0	1	1.6	1.4
GASCOYNE		0	1	1	0	0	0	0	0	0	0	0	0	2	20.9	17.7
MIDWEST		0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
WHEATBELT		1	0	1	0	0	0	0	0	0	0	0	0	2	2.9	2.9
METRO		0	0	0	0	1	0	0	0	0	0	0	1	2	0.1	0.1
	PEEL	0	1	0	0	0	0	1	0	0	0	0	0	2	0.8	0.9
	LESCHENAULT	0	0	0	1	0	0	0	0	0	0	0	0	1	1.4	0.9
	GEOGRAPHE	0	0	0	0	1	0	0	0	0	0	0	0	1	1.8	1.9
	ELSEWHERE SW	1	0	0	0	0	0	1	0	0	0	2	0	4	8.5	8.6
SOUTH WEST		1	1	0	1	1	0	2	0	0	0	2	0	8	1.8	
GREAT SOUTHERN		0	0	1	0	0	0	0	0	0	0	0	0	1	1.7	1.2
GOLDFIELDS-ESPERANCE		0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
WA UNDETERMINED		0	0	0	0	0	0	0	0	0	0	0	0	0		
INTERSTATE		0	0	0	0	0	0	0	0	0	0	0	0	0		
WA TOTAL (does not include interstate)		**2**	**3**	**3**	**1**	**2**	**0**	**2**	**1**	**0**	**0**	**3**	**1**	**18**		

**Table may vary from previous or future version due to inclusion of additional surveillance data*

2.3 Murray Valley encephalitis

The rare but potentially fatal Murray Valley encephalitis (MVE) virus is endemic in the Kimberley region and epidemics can at times extend further south into the Pilbara. The virus is occasionally active in regions further south, including the Gascoyne, Goldfields and Midwest.

Only one in a thousand people bitten by a mosquito carrying the virus will develop disease symptoms. In young children, symptoms of MVE can include fever, floppiness, irritability, excessive sleepiness and fits. In older children and adults, symptoms can include fever, drowsiness, confusion, headache, stiff neck, nausea, vomiting, muscle tremors and dizziness. Patients with severe MVE infections become ill very quickly with confusion, worsening headaches, increasing drowsiness and possible seizures. Patients can slip into a coma, suffer permanent brain damage or die.

In 2018-19, there were no MVE cases notified in WA (Figure 9). The last confirmed case of MVE was acquired in June 2018, in either the Kimberley, Pilbara or Northern Territory. Prior to this, the last confirmed cases of MVE in WA occurred in 2011, with nine cases reported between January - May.

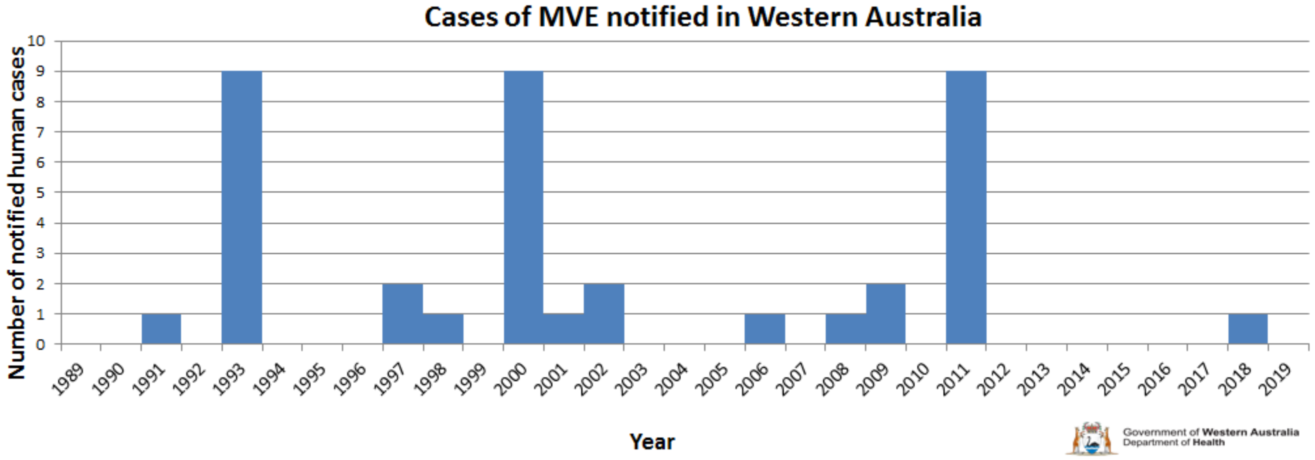


Figure 9: Total number of Murray Valley encephalitis cases notified in Western Australia by year between 1 January 1989 to 30 June 2019

2.4 West Nile virus Kunjin strain

West Nile virus Kunjin strain (WNV_{KUN}) is closely related to MVE virus. Symptoms of Kunjin (KUN) disease are similar to, but generally less severe, than MVE although it is often associated with joint pain.

In 2018-19, there were no KUN cases notified in WA (Figure 10). The most recent cases were acquired between April - June 2017, with four cases acquired in the Kimberley region and one case that was notified in WA but potentially acquired in the Northern Territory.

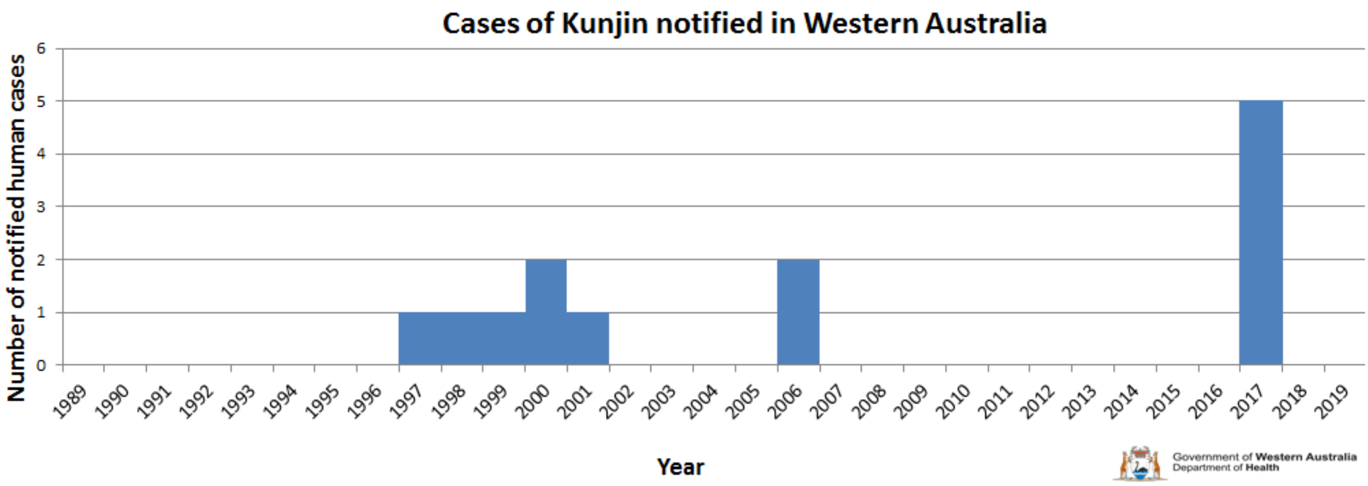


Figure 10: The total number of Kunjin cases notified per year in Western Australia from 1989 to 2019

3.0 Exotic mosquito-borne diseases

A number of mosquito-borne diseases are diagnosed in WA, in residents or visitors returning from international travel. Due to the legislative requirements to notify infectious diseases to the Department, these cases are entered into the WANIDD, but are considered ‘exotic’ as they are not locally acquired within the State.

The most common exotic mosquito-borne diseases diagnosed in WA are due to infections with dengue and chikungunya viruses, and malaria (caused by infection with one of five different species of protozoan parasites). All notified cases of exotic diseases are followed up with an enhanced questionnaire to ensure the patients acquired the disease overseas.

3.1 Chikungunya virus

The risk of infection with chikungunya virus (CHIKV) has traditionally been highest in Africa and Asia. More recently, the disease has emerged in countries in the Pacific and Indian Ocean regions as well as south-east Asia and the Caribbean. It is not endemic to Australia and the known vectors of this disease are not present in WA. It is suspected that some mosquito species native to WA, such as *Aedes vigilax, Aedes notoscriptus* and *Coquillettidia* species near *linealis,* may be capable of transmitting CHIKV and allow it to become established here if CHIKV was introduced into WA.

Symptoms of chikungunya disease include fever, chills, muscle aches, headache, fatigue, nausea, vomiting and a flat rash on the limbs and torso. Many patients experience joint pain in peripheral joints such as the hands or feet.

In 2018-19 there were four chikungunya cases notified in WA, all acquired overseas (Figure 11). This is one less than reported for the previous year. Enhanced surveillance questionnaires found two of these cases were acquired from India and one each from Nigeria and the Maldives.

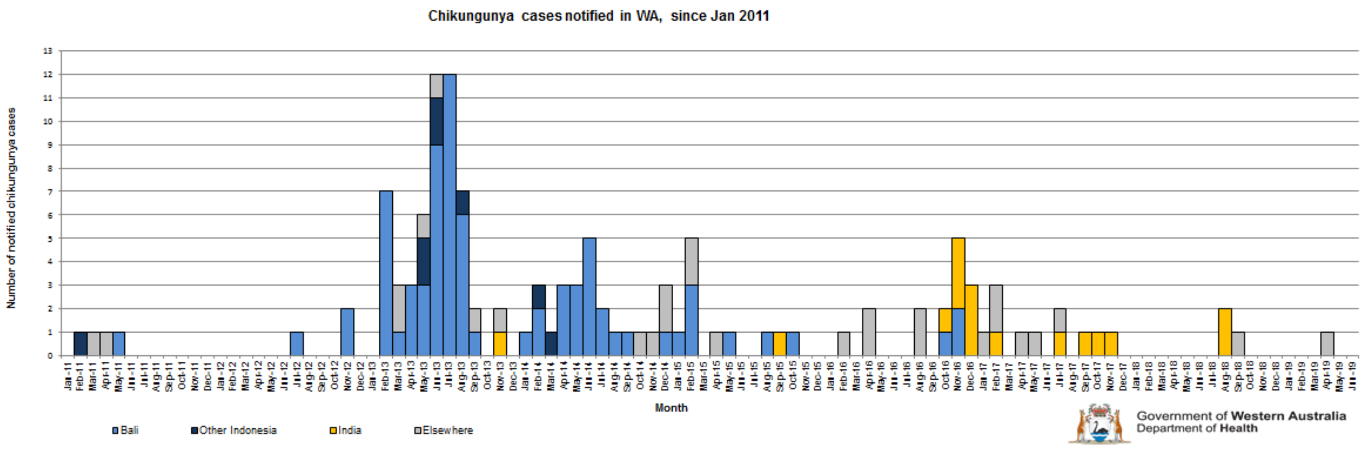


Figure 11: Total number of chikungunya cases notified in Western Australia by month between 1 January 2011 to 30 June 2019

3.2 Dengue viruses

Currently, there are four recognised dengue virus (DENV) serotypes. An initial infection with the virus will result in dengue fever, characterised by fever, headache, muscle and joint pain and skin rashes. A subsequent infection with a different serotype can lead to dengue haemorrhagic fever and dengue shock syndrome, which can result in bleeding from body orifices, blood spots on the skin, a weak pulse and may be fatal. There is currently no commercially available vaccine. DENV is spread by the bite of infected *Aedes aegypti* or *Aedes albopictus* mosquitoes, neither of which is established in WA.

In 2018-19 there were 266 dengue cases notified in WA, all acquired overseas (Figure 12). The number of dengue cases has increased compared to 2017-18. Most cases were acquired in Bali, with others originating from Indonesia (other than Bali) and Thailand.

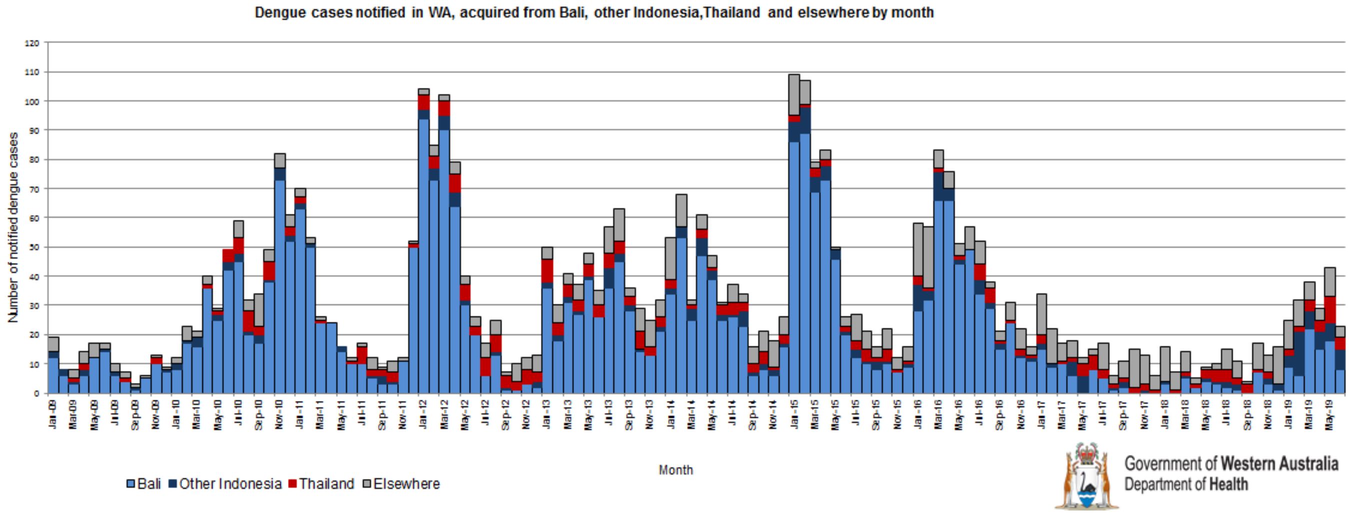


Figure 12: Total number of dengue cases notified in Western Australia by month between 1 January 2009 to 30 June 2019

3.3 Japanese encephalitis virus

Annually there are an estimated total of 68,000 Japanese encephalitis (JE) cases world-wide, with up to 30% being fatal. Symptoms range from a mild febrile illness to encephalitis. It is not endemic to WA although the vector *Culex annulirostris* is present over much of the State.

In 2018-19 there were no JE cases notified in WA. The most recent case notified in WA in April 2018, was acquired in Thailand and was unfortunately fatal. Prior to this time, there were three cases notified in 1998, 1999 and 2013, acquired in Vietnam, Bali and Indonesia respectively.

3.4 Malaria

Malaria (MAL) is caused by infection with one of five species of the *Plasmodium* parasite. *Plasmodium falciparum*, *P. vivax*, *P. ovale*, *P. malariae* and *P. knowlesi* are transmitted through the bite of infected *Anopheles* mosquitoes. Travellers to tropical regions of Asia, Africa and Central or South America are most at risk of infection. MAL caused by *P. falciparum* and *P. knowlesi* can be fatal.

MAL is characterised by fever, shivering, chills, headache and sweats but can also present as respiratory or gastrointestinal illness. Effective treatment relies on early diagnosis and specific anti-malarial medications. Anti-malarial medication must be taken prior to and during travel to prevent infection. The most effective anti-malarial treatment will depend on the region of travel and the length of time away.

In 2018-19 there were 60 MAL cases notified in WA, all acquired overseas (Figure 13). Most of these cases were notified in travellers and refugees from Africa. The majority (62%) were infected with *P. falciparum*. The monthly number of MAL cases was similar to recent years (Feb 2013 to

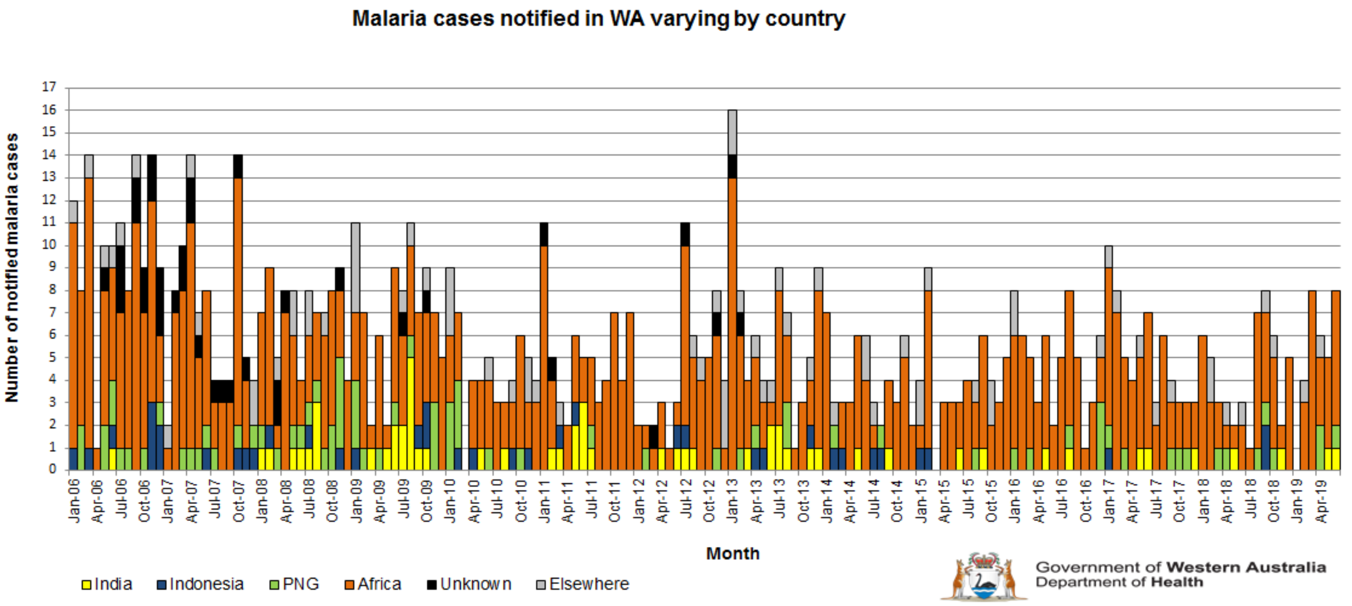


Figure 13: Total monthly number of malaria cases notified in Western Australia between 1 January 2006 to 30 June 2019

3.5 Zika virus

Zika virus (ZIKV) causes an illness known as Zika virus disease, characterised by mild fever, rash, conjunctivitis and muscle and/or joint pain. Research suggests that ZIKV infection in women during the first trimester of pregnancy may also be linked to abnormal foetal brain development, leading to a reduction in the size of the baby's head, known as microcephaly, which can result in permanent brain damage.

Since 1947, ZIKV activity was limited to parts of Africa, with occasional small outbreaks in Asia. However, since 2015, virus activity has spread to the Pacific Ocean, South America, Central America, the Caribbean and North America. In August 2018, there was one Zika case notified in WA, acquired in Thailand (Figure 14).

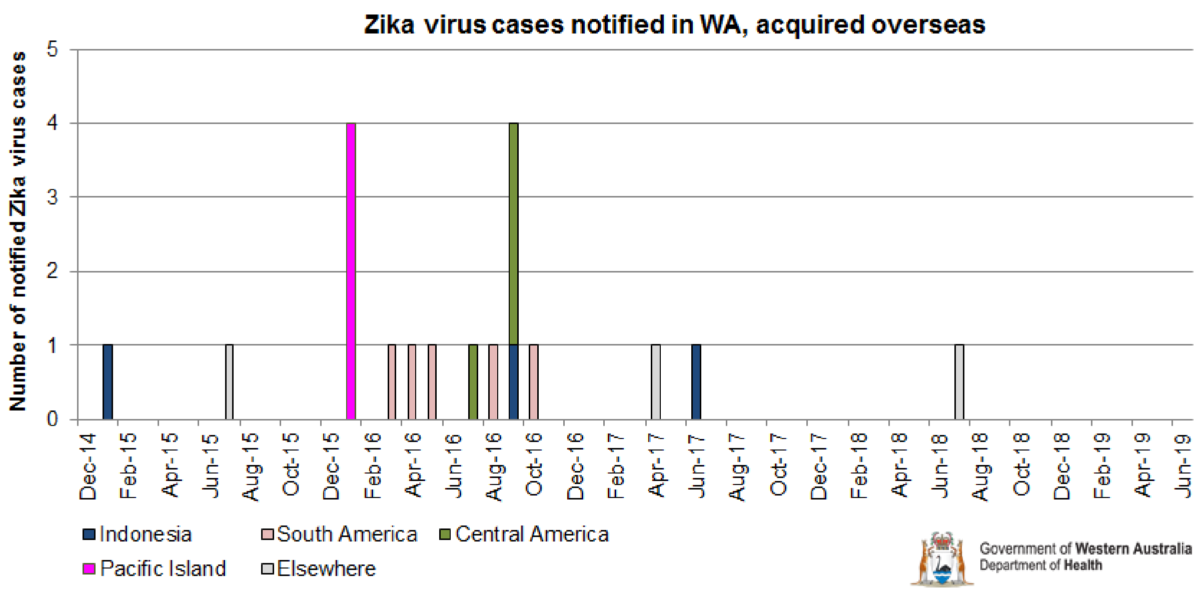


Figure 14: Total number of Zika cases notified in Western Australia from December 2014 to 30 June 2018

4.0 Climatic conditions

4.1 El Niño–Southern Oscillation (ENSO)

El Niño refers to extensive warming of the central and eastern tropical Pacific that leads to a major shift in weather patterns across the Pacific. La Niña refers to extensive cooling of the central and eastern tropical Pacific Ocean and is sometimes considered the opposite of El Niño. La Niña events are associated with increased probability of wetter conditions over much of Australia and has been correlated with higher numbers of tropical cyclones during cyclone season. Importantly for WA, La Niña conditions translate to increased occurrence and magnitude of high tides (including an increased frequency of 'king' tides). This is particularly important in the South West of WA, where the majority of mosquito egg-hatching is tidally driven.

During 2018-19, WA experienced mostly neutral conditions with only the sporadic month entering into El Niño or La Niña conditions (Figure 15). The largely neutral Southern Oscillation Index (SOI) observed in 2018-19 was associated with below average rainfall patterns and a reduction in the frequency and magnitude of tidal surges leading to an overall reduction in mosquito production in many of the high-risk areas of WA (including the South West and Kimberley regions).

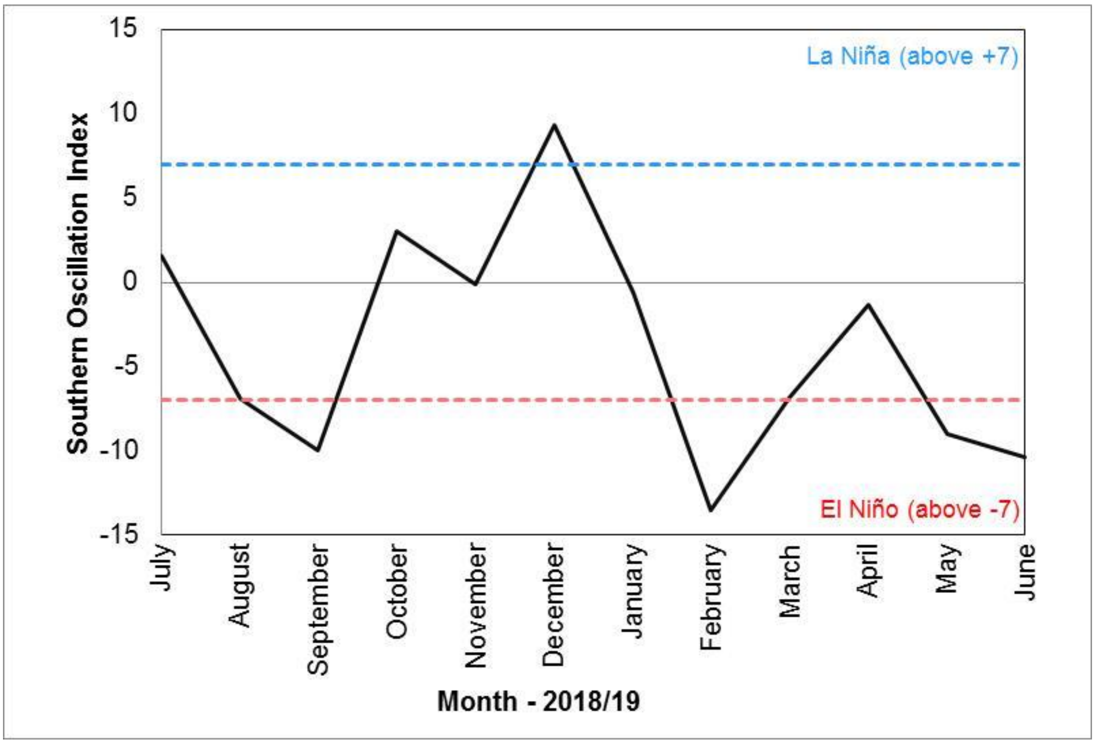


Figure 15: Southern Oscillation Index (SOI) values for the 2018-19 financial year (data source: Commonwealth Bureau of Meteorology)

*Sustained positive SOI values above +7 typically indicate La Niña while sustained negative values below −7 typically indicate El Niño conditions. Values between about +7 and −7 generally indicate neutral conditions. Dotted lines are at both +7 and -7.

4.2 Rainfall

During 2018-19, the overall rainfall pattern ranged from average, to the lowest on record for much of WA (Figure 16). Karratha was a notable exception, recording above average rainfall for the year (Figure 16), which was a result of tropical cyclone (TC) Veronica in the January-March quarter (Figure 17C).

The quarterly rainfall breakdown (Figure 17A-D) also indicates average to below average rainfall for much of the State, with the exception being spring. October-December brought above average rainfall to the central and south east regions of WA (Figure 17B).

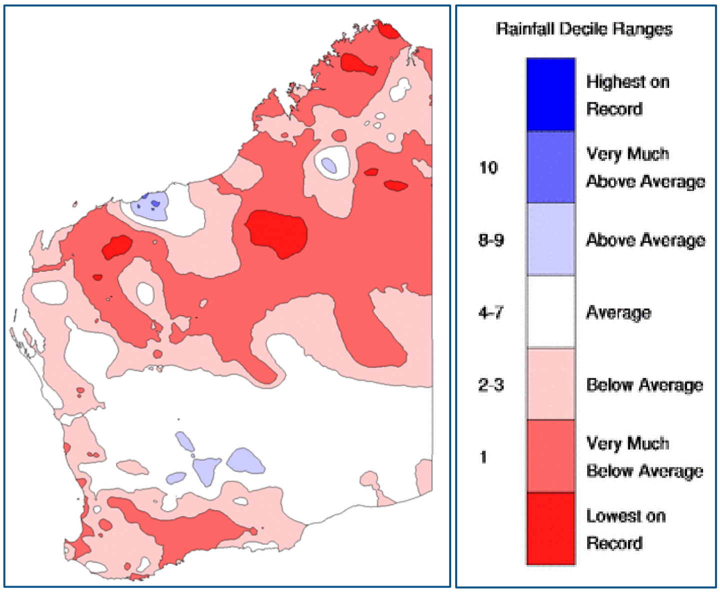


Figure 16: Western Australian rainfall deciles for July 2018-June 2019 (source: Commonwealth Bureau of Meteorology)

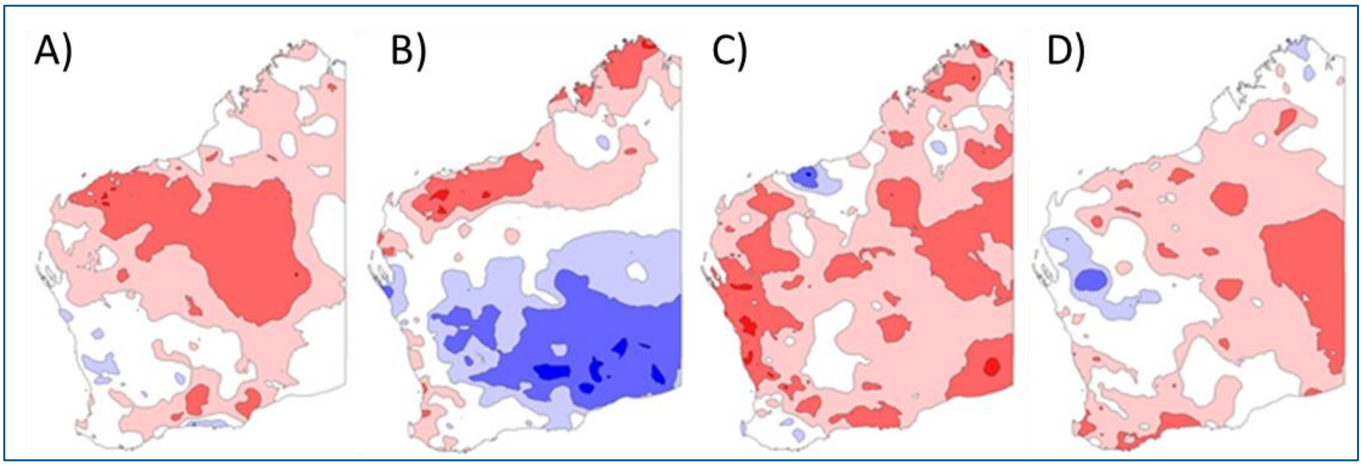


Figure 17 A-D: Three-monthly summaries of Western Australian rainfall deciles. A: July-September 2018; B: October-December 2018; C: January-March 2019; D: April-June 2019 (source: Commonwealth Bureau of Meteorology)

4.3 Temperature

4.3.1 Maximum temperature

Maximum temperature deciles were the highest on record for much of WA, with most of the State experiencing maximum temperatures above average, to the highest on record (Figure 18). This trend can be observed particularly during the winter (Figure 19A) and summer (Figure 19C) periods. Maximum temperatures remained high for the northern regions of WA during all quarters. The only areas that showed average maximum temperature deciles in spring (Figure 19B) and autumn (Figure 19D) was the South West and southern regions of WA respectively.

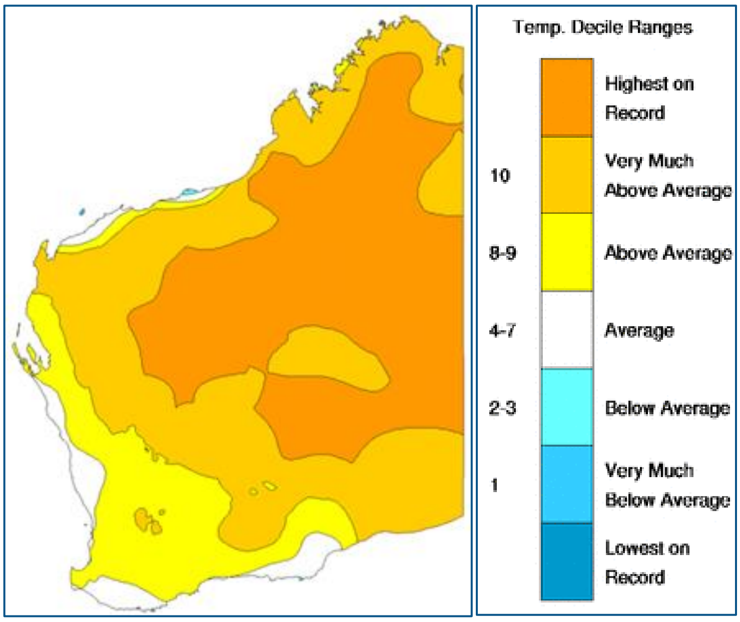


Figure 18: Western Australian maximum temperature deciles for July 2018 - June 2019 (source: Commonwealth Bureau of Meteorology)

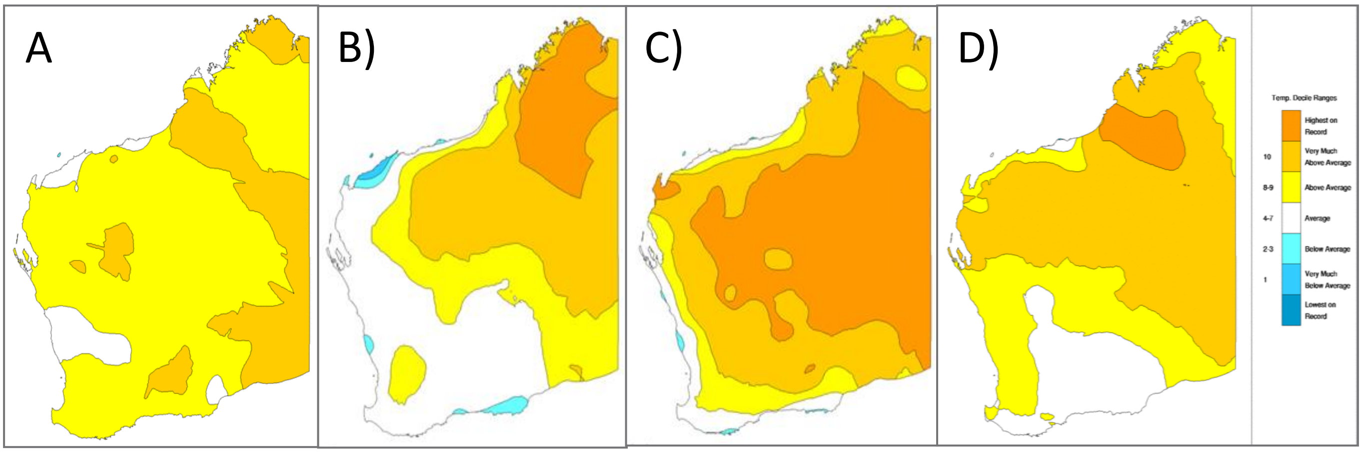


Figure 19 A-D: Three-monthly summaries of Western Australian maximum temperature deciles. A: July-September 2018; B: October-December 2018; C: January-March 2019; D: April-June 2019 (source: Commonwealth Bureau of Meteorology)

4.3.2 Minimum temperature

Minimum temperatures were typically average, to very much above average across central and eastern WA during 2018-19 (Figure 20), while southern and coastal areas remained average. Quarterly minimum temperatures across the State are shown in Figure 21.

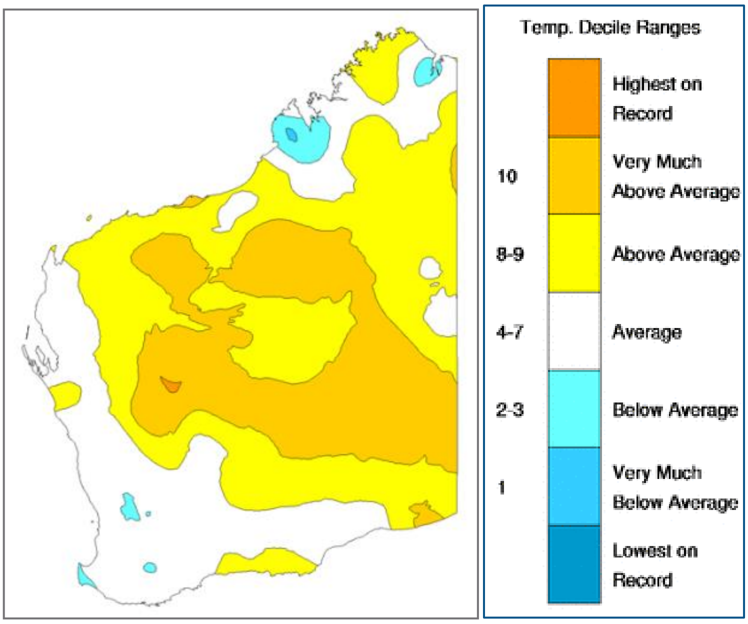


Figure 20: Western Australian minimum temperature deciles for July 2018-June 2019 (source: Commonwealth Bureau of Meteorology)

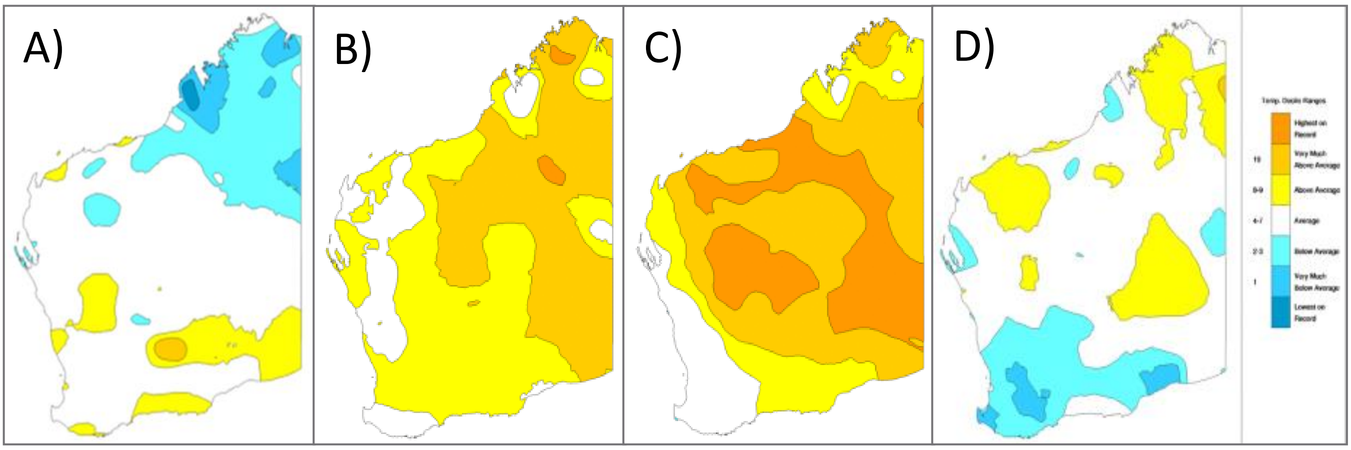


Figure 21 A-D: Three-monthly summaries of Western Australian minimum temperature deciles. A: July-September 2018; B: October-December 2018; C: January-March 2019; D: April-June 2019 (source: Commonwealth Bureau of Meteorology)

4.4 Australian tropical cyclone season summary

The only tropical cyclone (TC) to approach the WA coastline during 2018-19 was TC Veronica in late March (Figure 22).

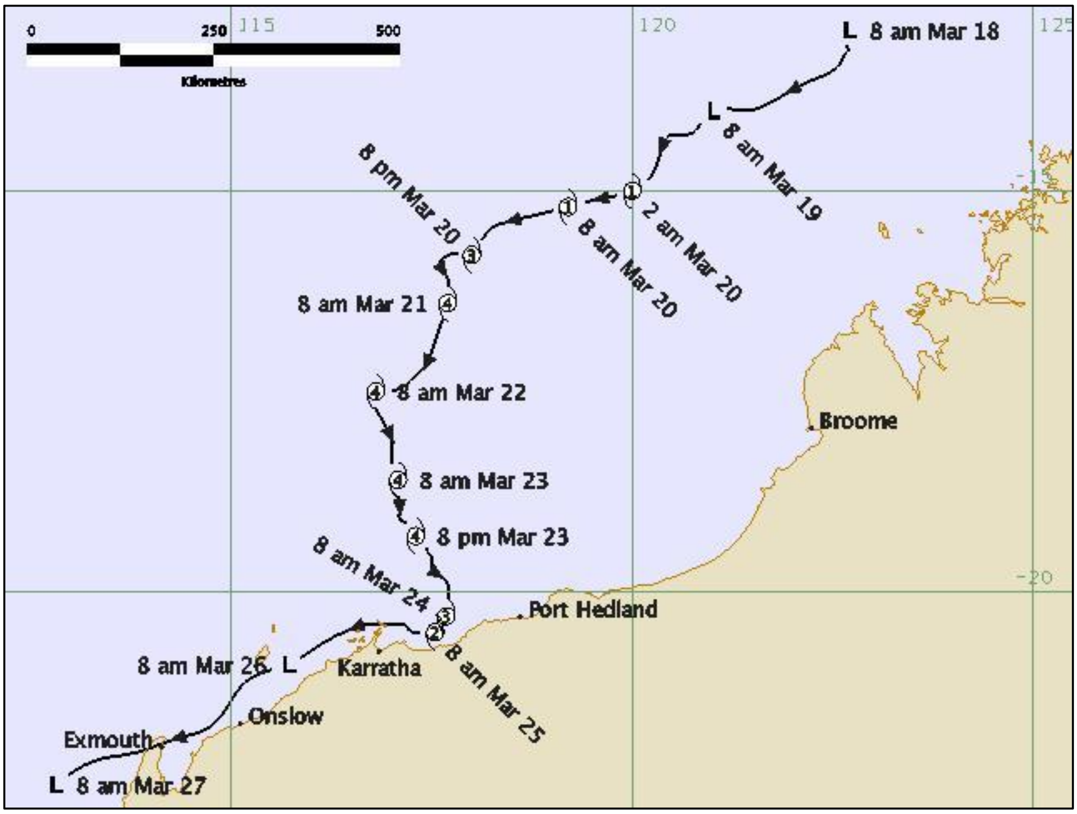


Figure 22: Documented path of Tropical Cyclone Veronica National Climate Centre, [Commonwealth of Australia, Bureau of Meteorology]

TC Veronica formed on 20 March 2019, when it was located 400 kilometres northwest of Broome. Whilst building to a category 4 cyclone off-shore, it weakened as it approached the Pilbara coast between 22-23 March.

By 8am AWST 24 March, TC Veronica was located about 100 kilometres west of Port Hedland, only about 50 kilometres directly north of the Pilbara coastline. The motion of the cyclone slowed to almost stationary through the next 24 hours, subjecting the Pilbara coastline between Port Hedland and Karratha to a prolonged period of destructive winds and highest on record rainfall.

5.0 Mosquito-borne disease surveillance programs

5.1 South West arbovirus surveillance program

Outbreaks of RRV and BFV occur in the South West region every three to five years. The Department undertakes regular arbovirus surveillance in this region, from Mandurah to Busselton, to monitor virus activity and provide an early warning of increased disease risk. Monitoring of mosquitoes and mosquito-borne virus activity in the South West region commenced in 1987.

The neutral weather conditions resulted in average mosquito abundance average across the South West (Figure 23). The dominant species collected around the Peel region were *Aedes camptorhynchus*, *Ae. notoscriptus and Ae. vigilax* (Table 3). *Aedes camptorhynchus* and the spring species *Ae. clelandi* and *Ae. hesperonotius* were the dominant species at sites further south (Tables 4-7). High numbers of *Ae. vigilax* are usually observed from December onward, however this did not occur during the 2018-19 summer (Figure 24).

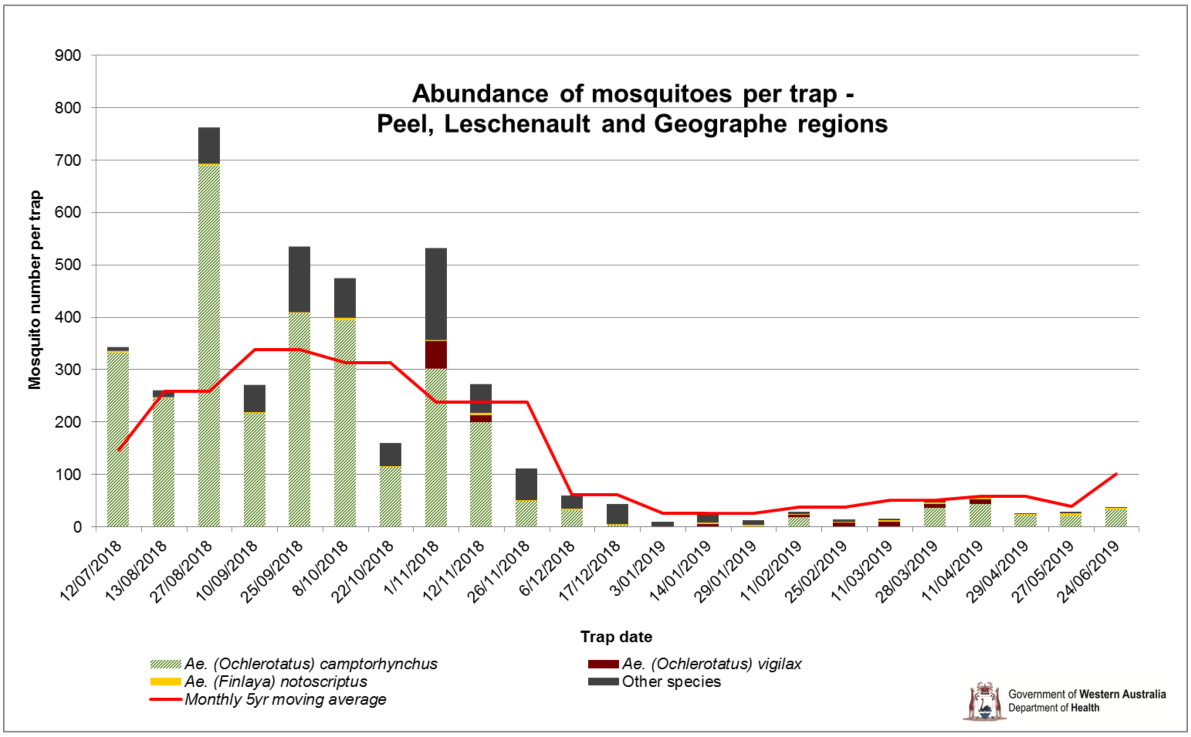


Figure 23: Mosquito abundance in the South West regions of Peel, Leschenault and Geographe from July 2018 to June 2019

For this season, a total of 87,444 mosquitoes were collected from fortnightly trapping at approximately 21 sites between Mandurah and Busselton in WA's South West (Table 3-7). In total, 504 traps were set , of which 481 were successful (95% success rate).

Ross River virus was detected at three different trap sites in the Peel and Leschenault regions over this time. Detections were recorded from the Peel region sites at Falcon on 1 November 2018, Dawesville on 12 and 26 November, and in the Leschenault region at freshwater larval site on 12 November 2018. There were 8 real-time RT polymerase chain reactions (RT-PCR) detections of RRV from pools of *Ae. camptorhynchus* female mosquitoes. RRV was not detected in any other species this year. BFV was not detected at any of the routine surveillance sites in the South West in 2018-19 (Tables 3-8).

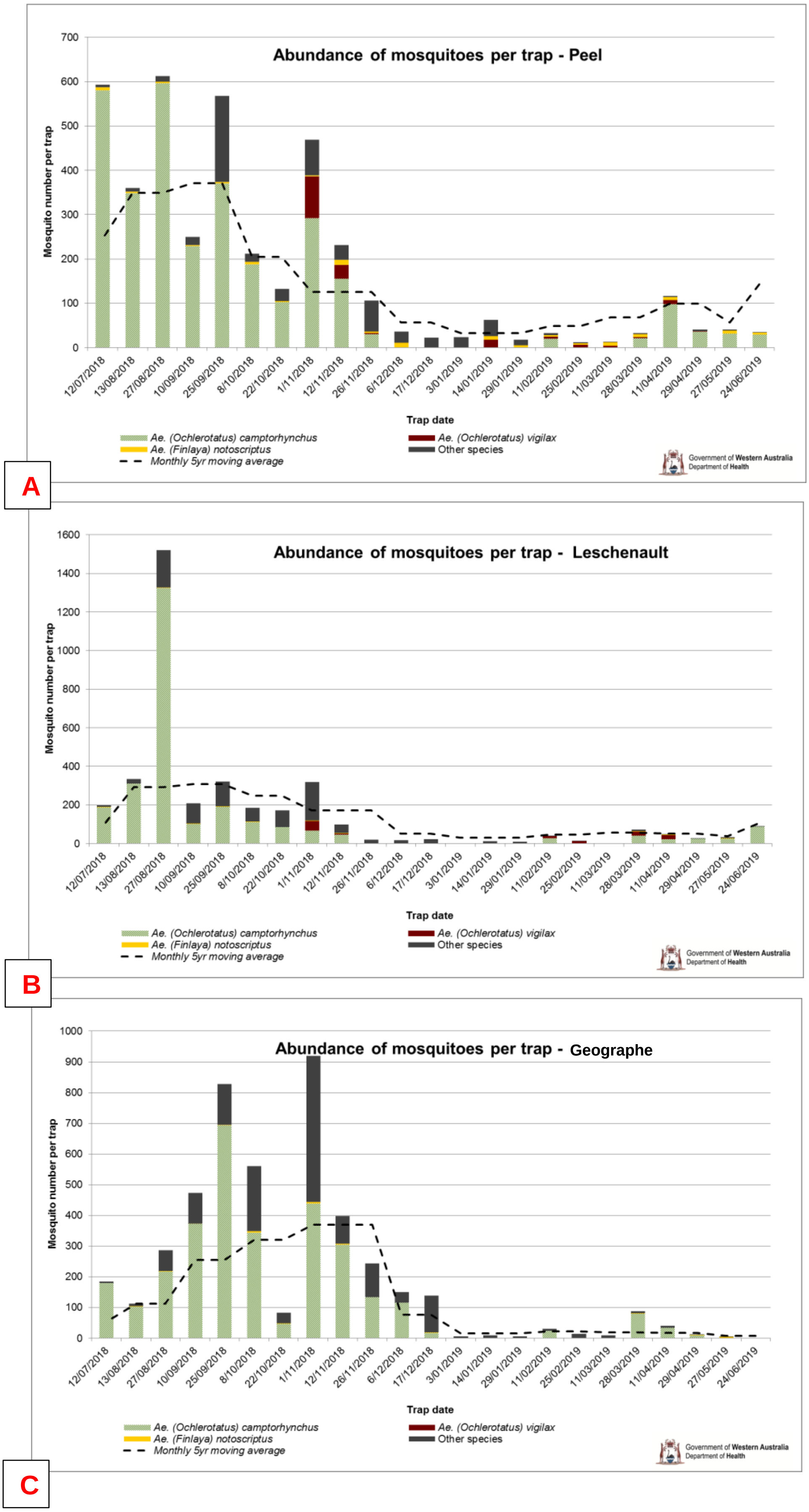


Figure 24: *Ae camptorhynchus, Ae vigilax, Ae notoscriptus* and all other species collected per trap for **A**: Peel **B**: Leschenault and **C**: Geographe regions of WA from July 2018 to June 2019

Table 3: Details of mosquitoes collected and processed for virus detection from the Peel inlet within the Peel region of Western Australia, 1 July 2018 to 30 June 2019

Species	Total	%	Processed	Pool Count	Pinned	Virus	MIR
Female	**28,519**	**99.28**	**18174**	**1401**	**16**		
Ae. (Finlaya) alboannulatus	201	0.70	171	60	0		
Ae. (Finlaya) notoscriptus	745	2.59	674	112	3		
Ae. (Ochlerotatus) camptorhynchus	22,262	77.50	13,377	708	0	7RRV	0.5
Ae. (Ochlerotatus) clelandi	939	3.27	267	29	0		
Ae. (Ochlerotatus) hesperonotius	532	1.85	239	18	0		
Ae. (Ochlerotatus) nigrithorax	7	0.02	3	3	0		
Ae. (Ochlerotatus) ratcliffei	6	0.02	5	4	0		
Ae. (Ochlerotatus) turneri	24	0.08	5	4	2		
Ae. (Ochlerotatus) vigilax	1,206	4.20	1,039	94	0		
An. (Cellia) annulipes s.l.	99	0.34	76	32	0		
Cq. (Coquillettidia)* species near *linealis	12	0.04	12	8	0		
Cs. (Culicella) atra	33	0.11	33	13	0		
Cx. (Culex) annulirostris	87	0.30	86	23	0		
Cx. (Culex) australicus	203	0.71	194	44	0		
Cx. (Culex) globocoxitus	1,856	6.46	1,730	145	0		
Cx. (Culex) quinquefasciatus	133	0.46	104	44	10		
Tripteroides (Polylepidomyia) atripes	1	<0.01	0	0	1		
Unidentifiable *Aedes* sp. (damaged/features missing)	69	0.24	67	18	0		
Unidentifiable *Culex* sp. (damaged/features missing)	101	0.35	89	41	0		
Male	**131**	**0.46**	**122**	**42**	**1**		
Ae. (Ochlerotatus) camptorhynchus	1	<0.01	1	1	0		
***Ae*. species (unidentified) - new or difficult to ID species**	15	0.05	15	8	0		
***Cx.* species (unidentified) - new or difficult to ID species**	118	0.41	109	33	1		
Blood fed	**77**	**0.27**	**0**	**0**	**0**		
Ae. (Ochlerotatus) camptorhynchus	76	0.26	0	0	0		
Cs. (Culicella) atra	1	<0.01	0	0	0		
Total	**28,727**	**100**	**18,296**	**1,443**	**17**	**7RRV**	**0.5**

Table 4: Details of mosquitoes collected and processed for virus detection from the Harvey Estuary site within the Peel region of Western Australia, 1 July 2018 to 30 June 2019. **Note: Virus/MIR columns do not appear as virus was not detected in this region.*

Species	Total	%	Processed	Pool Count	Pinned
Female	**3288**	**99.22**	**2468**	**192**	**0**
Ae. (Finlaya) alboannulatus	26	0.78	24	7	0
Ae. (Finlaya) notoscriptus	16	0.48	16	9	0
Ae. (Ochlerotatus) camptorhynchus	2,155	65.03	1,553	85	0
Ae. (Ochlerotatus) clelandi	18	0.54	12	5	0
Ae. (Ochlerotatus) hesperonotius	1	0.03	1	1	0
Ae. (Ochlerotatus) nigrithorax	8	0.24	8	1	0
Ae. (Ochlerotatus) ratcliffei	60	1.81	43	8	0
Ae. (Ochlerotatus) vigilax	346	10.44	268	20	0
An. (Anopheles) atratipes	2	0.06	2	2	0
An. (Cellia) annulipes s.l.	617	18.62	506	32	0
Cq. (Coquillettidia)* species near *linealis	2	0.06	2	2	0
Cx. (Culex) annulirostris	3	0.09	3	2	0
Cx. (Culex) australicus	8	0.24	7	4	0
Cx. (Culex) globocoxitus	16	0.48	13	7	0
Cx. (Culex) molestus	1	0.03	1	1	0
Cx. (Culex) quinquefasciatus	3	0.09	3	2	0
Unidentifiable *Aedes* sp. (too damaged/features missing)	2	0.06	2	2	0
Unidentifiable *Culex* sp. (too damaged/features missing)	4	0.12	4	2	0
Male	**6**	**0.18**	**5**	**5**	**0**
An. (Cellia) annulipes s.l.	2	0.06	2	2	0
***An.* species (unidentified) - new or difficult to ID species**	1	0.03	1	1	0
***Cx.* species (unidentified) - new or difficult to ID species**	3	0.09	2	2	0
Blood fed	**20**	**0.60**	**0**	**0**	**0**
Ae. (Finlaya) alboannulatus	2	0.06	0	0	0
Ae. (Ochlerotatus) camptorhynchus	15	0.45	0	0	0
Ae. (Ochlerotatus) vigilax	2	0.06	0	0	0
An. (Cellia) annulipes s.l.	1	0.03	0	0	0
Total	**3,314**	**100**	**2473**	**197**	**0**

Table 5: Details of mosquitoes collected and processed for virus detection from the Leschenault region of Western Australia, 1 July 2018 to 30 June 2019

Species	Total	%	Processed	Pool Count	Pinned	Virus	MIR
Female	**19,470**	**98.72**	**11,257**	**983**	**66**		
Ae. (Finlaya) alboannulatus	256	1.30	228	57	0		
Ae. (Finlaya) notoscriptus	165	0.84	147	48	0		
Ae. (Ochlerotatus) camptorhynchus	13,668	69.30	6,839	371	15	1RRV	0.1
Ae. (Ochlerotatus) clelandi	100	0.51	89	16	0		
Ae. (Ochlerotatus) hesperonotius	1,437	7.29	1057	62	0		
Ae. (Ochlerotatus) nigrithorax	275	1.39	162	12	0		
Ae. (Ochlerotatus) purpureifemur	1	0.01	0	0	1		
Ae. (Ochlerotatus) ratcliffei	167	0.85	157	20	0		
Ae. (Ochlerotatus) turneri	4	0.02	4	4	0		
Ae. (Ochlerotatus) vigilax	646	3.28	618	53	25		
An. (Anopheles) atratipes	12	0.06	9	7	3		
An. (Cellia) annulipes s.l.	79	0.40	70	40	0		
Cq. (Coquillettidia)* species near *linealis	85	0.43	78	24	7		
Cs. (Culicella) atra	112	0.57	97	21	15		
Cx. (Culex) annulirostris	60	0.30	59	21	0		
Cx. (Culex) australicus	330	1.67	286	48	0		
Cx. (Culex) globocoxitus	1,666	8.45	1162	103	0		
Cx. (Culex) quinquefasciatus	107	0.54	93	41	0		
Tripteroides (Polylepidomyia) atripes	1	0.01	1	1	0		
Unidentifiable *Aedes* sp. (too damaged/features missing)	58	0.29	43	15	0		
Unidentifiable *Culex* sp. (damaged/features missing)	241	1.22	58	19	0		
Male	**58**	**0.29**	**55**	**25**	**0**		
***Ae.* species (unidentified) - new or difficult to ID species**	10	0.05	10	6	0		
***Cx.* species (unidentified) - new or difficult to ID species**	48	0.24	45	19	0		
Blood fed	**194**	**0.98**	**0**	**0**	**0**		
Ae. (Finlaya) alboannulatus	1	0.01	0	0	0		
Ae. (Ochlerotatus) camptorhynchus	186	0.94	0	0	0		
Ae. (Ochlerotatus) hesperonotius	4	0.02	0	0	0		
Cx. (Culex) globocoxitus	3	0.02	0	0	0		
Total	**19,722**	**100**	**11,312**	**1,008**	**66**	**1RRV**	**0.1**

Table 6: Details of mosquitoes collected and processed for virus detection from Capel within the Geographe region of Western Australia, 1 July 2018 to 30 June 2019. **Note: Virus/MIR columns do not appear as virus was not detected in this region.*

Species	Total	%	Processed	Pool Count	Pinned
Female	**12,235**	**98.88**	**7,905**	**576**	**1**
Ae. (Finlaya) alboannulatus	141	1.14	110	33	0
Ae. (Finlaya) mallochi	1	0.01	0	0	1
Ae. (Finlaya) notoscriptus	107	0.86	90	27	0
Ae. (Ochlerotatus) camptorhynchus	11,350	91.73	7122	371	0
Ae. (Ochlerotatus) clelandi	22	0.18	16	7	0
Ae. (Ochlerotatus) hesperonotius	10	0.08	5	2	0
Ae. (Ochlerotatus) nigrithorax	5	0.04	3	3	0
Ae. (Ochlerotatus) ratcliffei	130	1.05	125	14	0
Ae. (Ochlerotatus) vigilax	1	0.01	1	1	0
An. (Cellia) annulipes s.l.	131	1.06	115	26	0
Cq. (Coquillettidia)* species near *linealis	5	0.04	5	5	0
Cs. (Culicella) atra	24	0.19	24	7	0
Cx. (Culex) annulirostris	13	0.11	13	8	0
Cx. (Culex) australicus	42	0.34	42	12	0
Cx. (Culex) globocoxitus	214	1.73	197	41	0
Cx. (Culex) quinquefasciatus	6	0.05	6	6	0
Unidentifiable *Aedes* sp. (too damaged/features missing)	19	0.15	19	4	0
Unidentifiable *Culex* sp. (too damaged/features missing)	14	0.11	12	9	0
Male	**41**	**0.33**	**37**	**14**	**0**
***Ae.* species (unidentified) - new or difficult to ID species**	1	0.01	1	1	0
An. (Cellia) annulipes s.l.	15	0.12	15	3	0
***Cx.* species (unidentified) - new or difficult to ID species**	25	0.20	21	10	0
Hermaphrodite	**1**	**0.01**	**0**	**0**	**1**
Ae. (Ochlerotatus) camptorhynchus	1	0.01	0	0	1
Blood fed	**96**	**0.78**	**0**	**0**	**0**
Ae. (Finlaya) alboannulatus	3	0.02	0	0	0
Ae. (Ochlerotatus) camptorhynchus	93	0.75	0	0	0
Total	**12,373**	**100**	**7,942**	**590**	**2**

Table 7: Details of mosquitoes collected and processed for virus detection from Busselton wetlands sites, within the Geographe region of Western Australia, 1 July 2018 to 30 June 2019. **Note: Virus/MIR columns do not appear as virus was not detected.*

Species	Total	%	Processed	Pool Count	Pinned
Female	**22,738**	**97.56**	**13502**	**982**	**80**
Ae. (Finlaya) alboannulatus	137	0.59	119	31	0
Ae. (Finlaya) notoscriptus	128	0.55	113	36	0
Ae. (Ochlerotatus) camptorhynchus	17,034	73.08	9,736	520	0
Ae. (Ochlerotatus) clelandi	772	3.31	448	43	0
***Ae. (Ochlerotatus) clelandi* with banded legs**	1	<0.01	0	0	1
Ae. (Ochlerotatus) hesperonotius	989	4.24	507	43	0
Ae. (Ochlerotatus) hodgkini	1	<0.01	1	1	0
Ae. (Ochlerotatus) nigrithorax	1	<0.01	1	1	0
Ae. (Ochlerotatus) ratcliffei	100	0.43	75	13	0
Ae. (Ochlerotatus) stricklandi	1	<0.01	0	0	1
Ae. (Ochlerotatus) turneri	3	0.01	3	3	0
Ae. (Ochlerotatus) vigilax	64	0.27	52	9	0
An. (Anopheles) atratipes	2	0.01	2	2	0
An. (Cellia) annulipes s.l.	863	3.70	551	62	35
Cs. (Culicella) atra	34	0.15	32	17	0
Cx. (Culex) annulirostris	4	0.02	4	1	0
Cx. (Culex) australicus	287	1.23	248	36	0
Cx. (Culex) globocoxitus	2,079	8.92	1,440	113	43
Cx. (Culex) quinquefasciatus	81	0.35	75	24	0
Unidentifiable *Aedes* sp. (damaged/features missing)	56	0.24	43	15	0
Unidentifiable *Culex* sp. (damaged/features missing)	101	0.43	55	12	0
Male	**392**	**1.67**	**169**	**50**	**9**
Ae. (Ochlerotatus) camptorhynchus	18	0.08	7	3	1
***Ae.* species (unidentified) - new or difficult to ID**	40	0.17	31	11	0
An. (Cellia) annulipes s.l.	3	0.01	3	3	0
***An*. species (unidentified) - new or difficult to ID**	5	0.02	1	1	0
Cs. (Culicella) atra	1	<0.01	0	0	0
***Cx.* species (unidentified) - new or difficult to ID**	325	1.39	127	32	8
Blood fed	**178**	**0.76**	**1**	**1**	**0**
Ae. (Finlaya) alboannulatus	3	0.01	0	0	0
Ae. (Finlaya) notoscriptus	2	0.01	0	0	0
Ae. (Ochlerotatus) camptorhynchus	157	0.67	0	0	0
Ae. (Ochlerotatus) clelandi	2	0.01	0	0	0
Ae. (Ochlerotatus) hesperonotius	5	0.02	0	0	0
Ae. (Ochlerotatus) ratcliffei	4	0.02	1	1	0
An. (Cellia) annulipes s.l.	2	0.01	0	0	0
Cx. (Culex) globocoxitus	2	0.01	0	0	0
Cx. (Culex) quinquefasciatus	1	<0.01	0	0	0
Total	**23,308**	**100**	**13,675**	**1,033**	**89**

Table 8: Details of virus detections in mosquitoes collected across the South West of Western Australia, 1 July 2018 to 30 June 2019

Locality	Date of collection	Trap location	Species	Virus	No. positive pools
Peel					
	01.11.18	Falcon	*Aedes camptorhynchus*	RRV	1
	12.11.18	Warrungup Spring, Dawesville	*Aedes camptorhynchus*	RRV	5
	26.11.18	Warrungup Spring, Dawesville	*Aedes camptorhynchus*	RRV	1
Leschenault					
	12.11.18	Freshwater larval site	*Aedes camptorhynchus*	RRV	1

5.2 MVE and WNV_{KUN} virus surveillance

In WA, the Department monitors flavivirus activity primarily via its sentinel chicken program. This surveillance program is also supported by an annual mosquito survey.

The aim of this program is to provide an early warning system for the detection of MVEV and WNV_{KUN} activity in WA's north. This in turn helps to inform LG mosquito management efforts, as well as the development and release of media statements advising the general public to take personal protection measures against mosquito bites.

5.2.1 Northern arbovirus surveillance program

2018-19 northern mosquito trapping

During 2018-19, mosquito collections were conducted in the Kimberley region of WA from 22 March - 4 April 2019. The opportunity was also used to meet with LG environmental health officers to discuss mosquito management issues. The trip was timed to coincide with the end of the wet season in the region. The trap sites were selected based on historical data of mosquito abundance, virus detection, proximity to sentinel chicken flocks and proximity to mosquito breeding habitats.

Traps were set at Broome, Willie Creek, Roebuck Plains, Derby, Fitzroy Crossing, Kununurra, Wyndham, Parry's Creek, Lake Argyle and Halls Creek. The mosquitoes were collected using dry ice (carbon dioxide) baited EVS (encephalitis virus surveillance) traps. The traps were set at or before sunset and retrieved close to or after sunrise the following morning. The mosquitoes were then frozen on dry ice and transported to the ME laboratory in Perth. It is estimated that almost 20,000 mosquitoes were collected in approximately 170 traps. Mosquito numbers were lower than 2017-18 due to reduced rainfall in the Kimberley region during the 2019 wet season.

The mosquitoes will be identified to species level in the ME laboratory. They will then be screened for detection of specific arboviruses of public health significance including RRV, BFV, MVEV and WNV_{KUN}. Additionally, detection of a range of other alpha and flaviviruses, that may or may not cause illnesses in humans, can be screened.

The 2018-19 mosquito collections are still being processed and results will be reported in the 2019-20 Annual Report.

2017-18 northern mosquito trapping data

Results from 2017-18 northern surveillance are included in this report as the mosquito identification was undertaken during the reported period. A total of 111 adult mosquito traps were set in the east Kimberley at Halls Creek, Billiluna, Wyndham (including Parry's Creek) and Kununurra (Table 9). A further 93 adult mosquito traps were set across the west Kimberley, at Fitzroy Crossing, Derby, Broome (including Willie Creek) and Roebuck Plains. Trapping was also undertaken at various locations in the Pilbara, including the towns of Port Hedland, Tom Price, Paraburdoo and Newman, as well as Mount Magnet in the Midwest region (Table 10).

Table 9: Mosquito collections in the Kimberley region of Western Australia (March – April 2018)

Kimberley sub-region	Locality	No. mosquitoes collected
East Kimberley		**107**
	Halls Creek	107
North east Kimberley		**56,915**
	Kununurra	12,415
	Wyndham	44,500
South east Kimberley		**471**
	Billiluna	471
Upper Fitzroy River Floodplain		**1,086**
	Fitzroy Crossing/Geikie Gorge	1,086
Lower Fitzroy River Floodplain		**14,874**
	Derby	12,757
	Willare	2,117
West Kimberley		**330,046**
	Broome	140,138
	Coconut Wells	21,904
	Roebuck Plains	148,805
	Willie Creek	19,199
Total		**403,499**

Table 10: Mosquito collections in the Pilbara and Midwest regions of Western Australia (March - April 2018)

Region	Locality	No. mosquitoes collected
Pilbara		**1,845**
	Port Hedland	272
	Tom Price	1,030
	Paraburdoo	129
	Newman	414
Midwest		**185**
	Mount Magnet	185
Total		**2,030**

Culex sitiens was the dominant species caught in traps across the Kimberley region, particularly in those sites in the west Kimberley, where it accounted for 56% of the total mosquitoes collected (Table 11). The next most abundant species were *Culex annulirostris* (36%); *Aedes vigilax* (2.2%) and *Anopheles hilli* (1.3%).

Table 11: Details of mosquito species collected in the Kimberley region of Western Australia (March - April 2018)

Species	East Kimberley	Northeast Kimberley	Southeast Kimberley	Fitzroy River floodplain	Lower Fitzroy River floodplain	Upper Fitzroy River floodplain	West Kimberley	Total
Ad. (Aedeomyia) catasticta	37	99		2	1	1		**140**
Ae. (Aedimorphus) alboscutellatus		5						**5**
Ae. (Chaetocruiomyia) elchoensis		3						**3**
Ae. (Finlaya) britteni		9		1				**10**
***Ae. (Finlaya) kochi* group**		22						**22**
Ae. (Finlaya) notoscriptus	1	98			29		79	**207**
Ae. (Finlaya) pecuniosus		1			1			**2**
***Ae. (Macleaya)* species**	14	115	167	4	54	10	353	**717**
Ae. (Macleaya) tremulus		3						**3**
Ae. (Mucidus) alternans		7			54		31	**92**
Ae. (Neomellanoconion) lineatopennis		355						**355**
Ae. (Ochlerotatus) normanensis	9	323	44		18		3	**397**
Ae. (Ochlerotatus) phaecasiatus		2						**2**
Ae. (Ochlerotatus) pseudonormanensis			8					**8**
Ae. (Ochlerotatus) vigilax		411			3,007		5,485	**8,903**
***Ae.* species (unidentified) - new or difficult to ID**	3	7	10	2	85	9	11	**127**
An. (Anopheles) bancroftii		1,045		1				**1,046**
An. (Cellia) amictus		395	121		6	1	111	**634**
An. (Cellia) annulipes s.l.	6	783	56	62	211	29	31	**1,178**
An. (Cellia) hilli		78			613	1	4720	**5,412**
An. (Cellia) meraukensis		320						**320**
An. (Cellia) novaguinensis		78						**78**
***An.* species (unidentified) - new or difficult to ID**				11	1	1		**13**
Cq. (Coquillettidia) xanthogaster		794						**794**
Cx. (Culex) annulirostris	23	49,864	30	770	4051	116	91,638	**146,492**
Cx. (Culex) bitaeniorhynchus		254		1			18	**273**
Cx. (Culex) crinicauda		19					8	**27**
Cx. (Culex) gelidus		2						**2**
Cx. (Culex) globocoxitus	1				1	1		**3**
Cx. (Culex) quinquefasciatus	8	35	3		9	2	90	**147**
Cx. (Culex) sitiens		223			6,400		219,962	**226,585**
Cx. (Culex) squamosus		1						**1**
Cx. (Culex) starckeae		2						**2**
Cx. (Culiciomyia) pullus		202			6			**208**
Cx. (Lophoceraomyia) cylindricus							3	**3**
***Cx. (Lophoceraomyia)* E.N.Marks' species No. 167**		5						**5**
Cx. (Lophoceraomyia) hilli		6						**6**
***Cx. (Lophoceraomyia)* species**		14					1	**15**
***Cx.* species (unidentified) - new or difficult to ID species**		3		6	15		921	**945**

Table 11 continues on next page

Table 11 continued from previous page

Species	**East Kimberley**	**Northeast Kimberley**	**Southeast Kimberley**	**Fitzroy River floodplain**	**Lower Fitzroy River floodplain**	**Upper Fitzroy River floodplain**	**West Kimberley**	**Total**
Hodgesia **E. N. Marks' species No. 157**		3						**3**
Ma. (Mansonioides) uniformis		651						**651**
Tripteroides (Polylepidomyia) punctolateralis	3	7			7		1	**18**
Unidentifiable *Aedes* sp. (damaged/features missing)		8	8	2	11	1	7	**37**
Unidentifiable *Anopheles* sp. (damaged/features		1	24		71	1	641	**738**
Unidentifiable *Culex* sp. (damaged/features missing)	2	496		37	223	14	5,926	**6,698**
Ur. (Uranotaenia) albescens		8						**8**
Ur. (Uranotaenia) nivipes		15						**15**
Ve. (Verrallina) funerea		62					6	**68**
Ve. (Verrallina) reesi		81						**81**
Total	**107**	**56,915**	**471**	**899**	**14874**	**187**	**330,046**	**403,499**

The dominant mosquito species at the Pilbara sites were *Culex annulirostris,* followed by *Culex quinquefasciatus*, *Anopheles annulipes* s.l. and *Aedes (Macleaya) species* (2.8%) (Table 12). The most dominant species from Mt Magnet in the Midwest was *Cx quinquefasciatus.*

Table 12: Details of mosquitoes collected in the Pilbara and Midwest region of WA (March - April 2018)

Species	**Port Hedland**	**Tom Price**	**Paraburdoo**	**Newman**	**Mount Magnet**	**Total**
Ad. (Aedeomyia) catasticta		1				**1**
Ae. (Finlaya) notoscriptus		28			6	**34**
***Ae. (Macleaya)* species**	40	8	3	1	39	**91**
Ae. (Mucidus) alternans		3				**3**
Ae. (Ochlerotatus) vigilax	57					**57**
Ae. *species (unidentified)* - new or difficult to ID species	5	25	3		2	**35**
An. (Cellia) amictus	1		1	14		**16**
An. (Cellia) annulipes s.l.	4	22	4	53	17	**100**
An. (Cellia) hilli		1				**1**
***An.* species (unidentified) - new or difficult to ID species**				1		**1**
Cq. (Coquillettidia) xanthogaster				22		**22**
Cx. (Culex) annulirostris	132	814	40	240	4	**1,230**
Cx. (Culex) australicus					23	**23**
Cx. (Culex) quinquefasciatus	24	94	78	60	64	**320**
Cx. (Culex) sitiens	2					**2**
Cx. (Lophoceraomyia) cylindricus				21		**21**
***Cx.* species (unidentified) - new or difficult to ID species**	1			1	29	**31**
Tripteroides (Polylepidomyia) punctolateralis		26				**26**
Unidentifiable *Aedes* sp. (damaged/features missing)	4					**4**
Unidentifiable *Anopheles* sp. (damaged/features missing)				1		**1**
Unidentifiable *Culex* sp. (damaged/features missing)	2	8			1	**11**
Total	**272**	**1,030**	**129**	**414**	**185**	**2,030**

5.2.2 Sentinel chicken flavivirus surveillance program

MVEV and WNV_{KUN} are maintained in a bird – mosquito – bird cycle in northern two thirds of WA. The Department manages a sentinel chicken flavivirus surveillance program, which provides an early warning for activity of these viruses.

Chickens are bled by trained environmental health officers or volunteers and the blood samples are sent to PathWest to detect antibodies to these viruses. When MVEV or WNV_{KUN} virus is detected, the information is used by the Department to issue a media statement warning residents and travellers to the affected regions of the increased risk to public health and the need to take personal protection measures to prevent mosquito bites. The confirmation of virus activity is reported to LGs, who can then undertake appropriate management activities to reduce mosquito numbers and the potential for virus transmission. It is only through the integrated program involving the Department, PathWest and LGs that the system can be effective in providing an early warning detection of these mosquito-borne viruses and protect the public from potentially fatal mosquito-borne diseases.

Figure 25: Locations of the sentinel chicken flocks in Western Australia in 2018-19

In 2018-19, 23 sentinel chicken flocks were located in major towns and communities in the Kimberley, Pilbara, Gascoyne, Midwest and Wheatbelt regions of WA (Figure 25).

The level of flavivirus activity in sentinel chickens in northern WA in 2018-19 was lower than in recent years, with virus activity only detected in Wyndham and Kununurra in the east Kimberley (Table 13). Seroconversions were detected in seven of the 3,888 samples tested (0.20%).

Table 13: Number of sentinel chickens from flocks throughout Western Australia that developed antibody to flaviviruses during 2018-19

Site within Kimberley Region	Month	No. of chickens/antibody				Total
		MVE	Kunjin	MVE/Kunjin	Flavivirus	
Wyndham	March	2				**2**
	June	1				**1**
Kununurra	January	4				**4**
Total		**7**				**7**

6.0 Exotic mosquito detections at Perth International Airport

During 2018-19, the exotic mosquito surveillance program employed by the Commonwealth Department of Agriculture Science Support Program detected two importations of exotic mosquitoes. ME confirmed the identifications as *Culex nigropunctatus* and *Aedes aegypti* collected in Department of Agriculture mosquito monitoring traps at Fremantle Wharf and an approved arrangement facility located near Perth International Airport, respectively. ME provided technical assistance and advice on mosquito control treatments and ongoing monitoring.

7.0 Aerial larviciding program across the South West of WA

The Department funds the use of a helicopter for aerial application of mosquito larvicide in high mosquito-borne disease risk areas in the South West of WA. The aerial larviciding program is an important preventative public health activity.

Annually, the coastal South West region experiences RRV and BFV activity. In some years this can lead to significant outbreaks of disease among local residents and visitors. By controlling vector mosquito populations with larvicide, the program aims to reduce the number of cases of both diseases.

Mosquito breeding is determined by environmental and meteorological factors such as temperature, rainfall and tidal activity. LG staff monitor mosquito breeding habitat within their jurisdictions and assess when mosquito numbers need to be controlled. LG request aerial larvicide treatments by submitting a pre-treatment form to the Department.

The Department reviews the data and notifies the helicopter contractor of the proposed treatment date. LG staff record treatment details and conduct a post-treatment survey to confirm that the treatment was effective.

In 2018-19, the Department spent $535,405.17 (including contractor retainer cost) on the provision of aerial larviciding treatments through the procurement of helicopter services in the South West region. This involved a total of 24 aerial larvicide treatments covering over 2,500 hectares (Table 14). The larvicides used were granulated forms of S-methoprene and *Bacillus thuringiensis israelensis* (Bti).

Table 14: The number of aerial larvicide treatments and area treated, by region, during 2018-19

Region	Treatments	Area treated (ha)
Peel	13	1,274
Leschenault	3	143
Geographe	8	1,108
Total	**24**	**2,525**

8.0 Contiguous Local Authorities Group (CLAG) funding scheme

The Contiguous Local Authorities Group (CLAG) funding scheme is a mechanism to assist LGs with management, funding and advice on the technical aspects of health-driven mosquito control, in an effort to reduce the risk of mosquito-borne disease throughout WA.

CLAGs are comprised of one or more (contiguous or adjacent) LGs that share a common mosquito problem, usually in the form of natural or man-made habitat that breed mosquitoes which subsequently impact on surrounding communities.

The CLAG funding guidelines were revised in 2018-19, to reflect the importance of integrated mosquito management. The scheme now provides;

- 50% funding towards mosquito management costs related to chemicals, equipment, physical and cultural control (public education) strategies,
- up to 100% mosquito management related training costs, and
- 100% of the helicopter costs associated with the aerial larviciding program in high risk regions of WA's South West.

During 2018-19, there were 17 active CLAGs in WA (Figure 26);

- Ashburton (Shire of Ashburton),
- Broome (Shire of Broome),
- Carnarvon (Shire of Carnarvon),
- Derby-West Kimberley (Shire of Derby-West Kimberley),
- East Pilbara (Shire of East Pilbara),
- East Swan River (Towns of Bassendean and Victoria Park, and Cities of Bayswater, Belmont and Swan),
- Esperance (Shire of Esperance),
- Geographe (City of Busselton and Shire of Capel),
- Halls Creek (Shire of Halls Creek),
- Leschenault (City of Bunbury and Shires of Dardanup and Harvey),
- Karratha (City of Karratha),
- Peel (Cities of Mandurah and Rockingham and Shires of Murray and Waroona),
- Port Hedland (Town of Port Hedland),
- South Coastal (City of Albany),
- South Metropolitan (Cities of Cockburn and Kwinana),
- Swan-Canning Rivers (Primary members - Cities of South Perth, Canning, Melville and Perth; Secondary members – Cities of Nedlands and Subiaco), and
- Wyndham/East Kimberley (Shire of Wyndham East Kimberley).

The Shire of Exmouth began the process of forming the Exmouth CLAG, however, it was not formally endorsed by the MCAC until the beginning of 2019-20.

In 2018-19, the Department approved $300,128.70 in CLAG funding. Due to carryover funds held by CLAGs from 2017-18, the Department was only required to provide $240,047.47 in new funding for the financial year. The amount each CLAG received was dependent on their unique requirements.

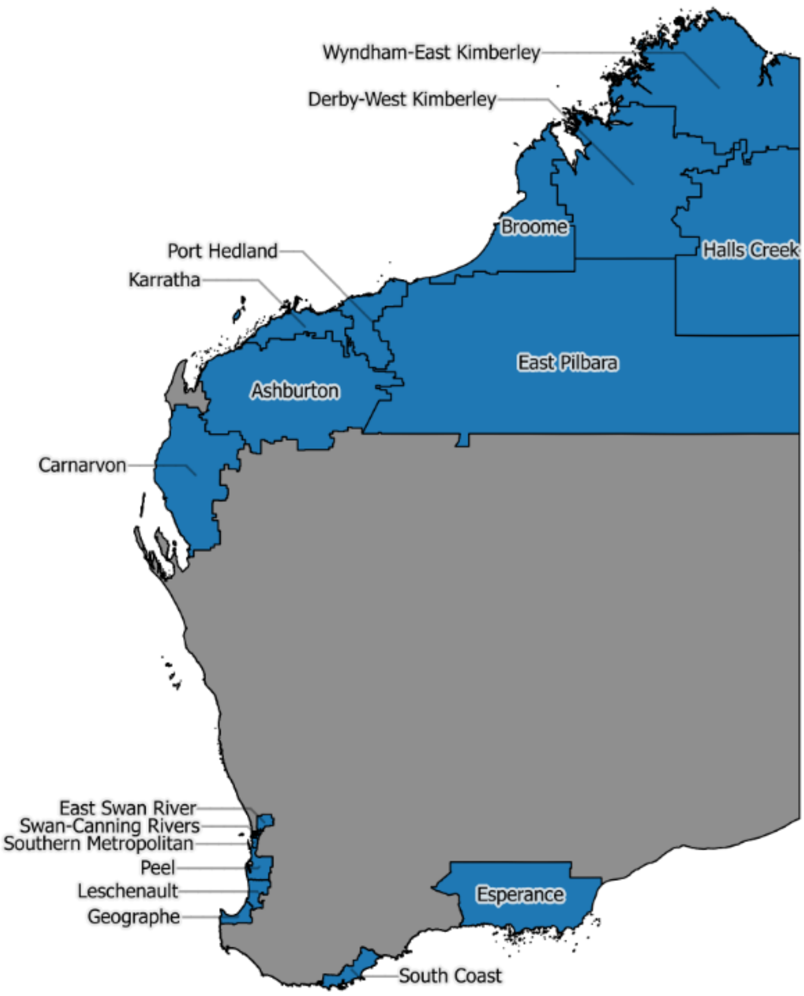


Figure 26: Map of Western Australia showing Contiguous Local Authorities Group (CLAG) boundaries of local governments participating in the CLAG funding scheme during 2018-19

9.0 Fight the Bite

Fight the Bite (FTB) is a public awareness campaign coordinated by the Department, and promoted by LG, to actively raise awareness of mosquitoes and mosquito-borne disease in WA. The campaign was launched during 2015-16 and has evolved in the years since that time. A large number of LGs both in and outside of the CLAG scheme proactively work to promote the campaign throughout the State.

During 2018-19, a new campaign webpage was launched, providing LG with access to all digital *Fight the Bite* resources. Formal campaign evaluation results were analysed and published in the peer reviewed journal, *Frontiers in Public Health* entitled *Evaluation of a Health Communication Campaign to Improve Mosquito Awareness and Prevention Practices in Western Australia.* A brief summary of evaluation results are provided below and on the Department's website.

9.1 Evaluation results

9.1.1 Recall

On average, 8.2% of survey participants across the state were able to recall FTB. This is likely to underestimate the true campaign reach, as a further 13.6% of individuals recalled other communication material that included indirect media exposure related to the campaign, such as newspaper editorials, radio interviews and nightly news coverage, generated from the Department and LG efforts.

Campaign recall (Figure 27) was significantly greatest in the Kimberley (27.6%) and Geographe (22.0%) regions, as well as the Pilbara (17.3%) and Gascoyne (17.6%) regions, where the FTB had been intensively promoted over the evaluation period.

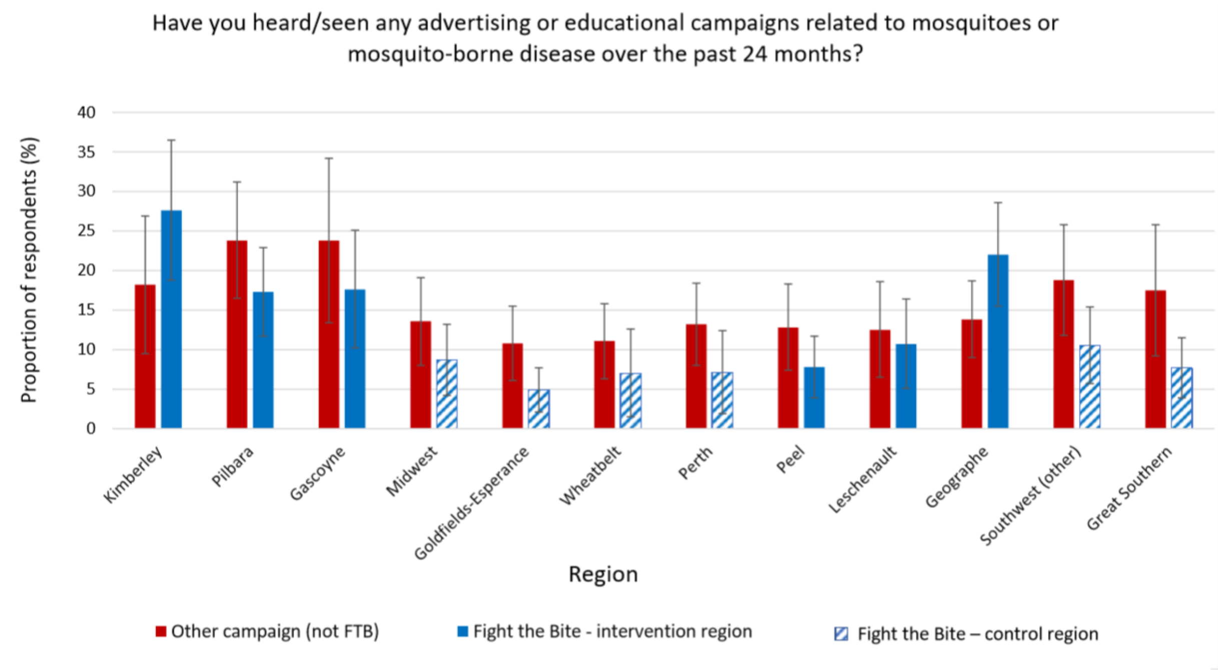


Figure 27: Recall of Fight the Bite and other mosquito-related material across the 12 regions surveyed in Western Australia (with 95% confidence intervals).

9.1.2 Awareness and behaviour change

Of the individuals who recalled FTB, 43.8% reported an increase in awareness of mosquitoes and mosquito-borne diseases. The key health messages (Cover Up, Repel and Clean Up), were recalled by 72.6%, 60.2% and 47.8% of the subset of survey participants who recalled the campaign, respectively.

A total of 27.4% of those with campaign recall reported improved prevention behaviour and practices, with a further 61.5% reportedly doing everything FTB recommends (Figure 28).

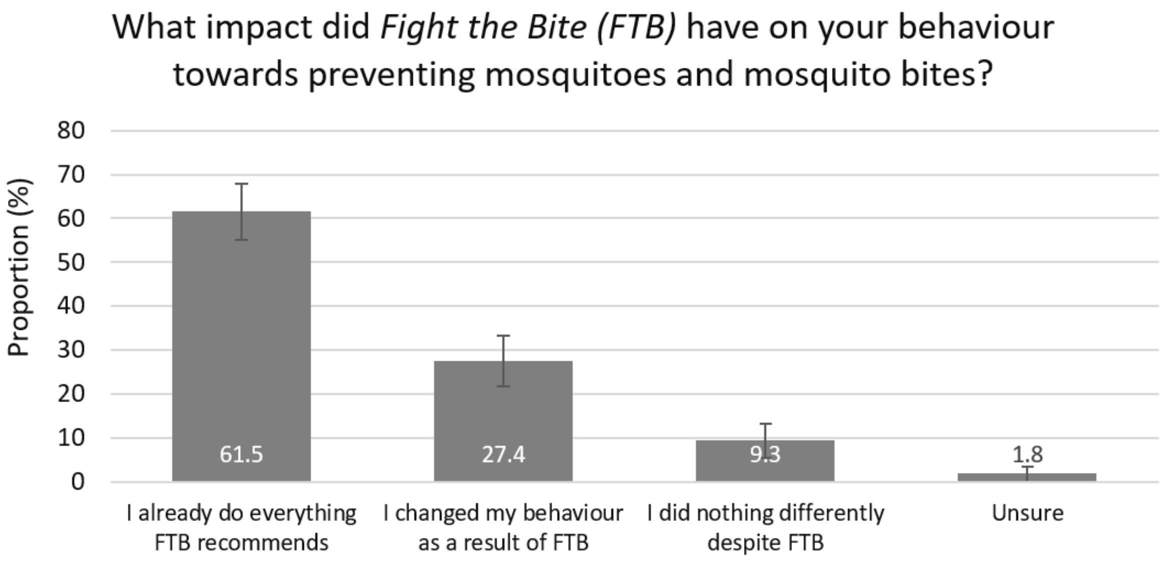


Figure 28: Impact of Fight the Bite on behavior and prevention practices among survey respondents with campaign recall (with 95% confidence intervals).

9.1.3 Effective campaign advertising mediums

FTB was most commonly recalled through television, followed by direct LG efforts. The proportion of individuals who recalled the campaign by a variety of delivery methods is shown in Figure 29.

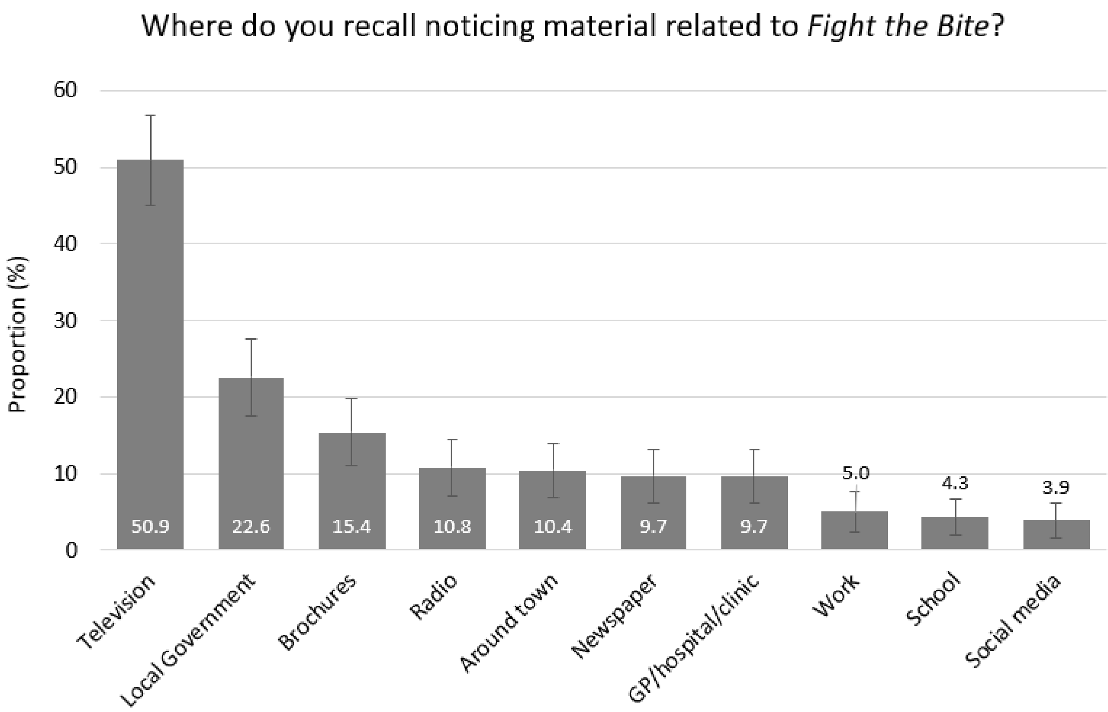


Figure 29: Advertising and promotional mediums noticed by survey respondents with *Fight the Bite* recall (with 95% confidence intervals).

The results of this evaluation demonstrate that FTB improved awareness and prevention practices among those individuals who were exposed to the campaign. This is particularly promising, given the modest budget, resources and time period over which the campaign was run prior to evaluation.

As public education is recognised as playing an important role in integrated mosquito management programs, the future goal will be to increase the campaign reach throughout WA. In order to achieve this, it will be important for key stakeholders in WA to garner the necessary support and resources to integrate FTB into ongoing communication efforts.

Aims of future campaigns includes increasing reach through heightened and sustained promotion of FTB by both the Department and LG, as well as expanded collaboration with a range of stakeholders within the community.

10.0 Other projects

10.1 Mosquito legislation project

The *Public Health Act 2016* (WA) (Public Health Act) received Royal Assent on 25 July 2016. The Department is currently reviewing health regulations under the previous *Health Act 1911* (WA), to transfer under the Public Health Act or to request the creation of new regulations for public health topics that are currently not included in legislation.

ME drafted a discussion paper in 2017, titled *Managing the public health risks of biting insects in WA*, to examine the risks that biting insects present to public health and propose a number of options to address mosquito management under the Public Health Act. This discussion paper was then submitted to Legal and Legislative Services for feedback. Due to staff movements, the project did not progress any further at the time.

During 2018-19, ME began the process of assessing feedback from Legal and Legislative Services as a first step in progressing the discussion paper to the next stage. This project will be ongoing into 2019-20.

10.2 Constructed wetlands

During 2018-19, ME began investigating mosquito productivity in various constructed wetlands and stormwater infrastructure within the Perth metropolitan area with an aim to:

- identify the potential for mosquito breeding and associated nuisance risks related to constructed freshwater wetlands in urban areas in WA; and
- further define public health risks and identify practical management solutions associated with constructed wetlands in urban areas in WA.

Constructed wetlands are commonly designed to mimic natural wetlands. They are often used in urban areas to manage storm and waste water, but may also be used for aesthetics, recreation, or as habitat for wildlife. Unfortunately, what is often considered a good design for removing nutrients and contaminants (before stormwater makes its way back to river systems) may not be ideal for mosquito management. The ME team will use the findings from the investigation to inform guidelines for mosquito management in constructed wetlands in urban areas.

10.3 Tide gauges

Continuation of the Funding Initiative for Mosquito Management in WA (FIMMWA) funded tide gauge project progressed during 2018-19. The installation of tide gauges, powered by solar panels, at select locations along the Swan and Canning Rivers proceeded by engaging Naval Architects to analyse the effect of the different pole designs on the movement of the gauges. A single pole design was selected, with the predicted sway well within the requirements of the Department of Transport, and this was trialled at one site on the Canning River. Preliminary testing of this gauge returned positive results and ME is currently awaiting the installation of the final two gauges on the Swan River. When all tide gauges are fully installed tidal data will become available online through the Department of Transport website.

11.0 Training workshops and forums

11.1 Mosquito identification refresher courses

ME hosted two, one-day mosquito identification courses in November 2018, for LG officers involved in mosquito management.

The first was held in Capel for LGs in the South West of WA, and the second targeting metropolitan LGs held at Grace Vaughan House, Perth. The courses were well attended by 37 participants, representing 20 LGs, the Department and industry consultants.

Participants were given an opportunity to learn or refresh mosquito identification skills, by providing a combination of theory and practical sessions, to support their local programs. The course also addressed how to incorporate this information into LG mosquito management plans so as to provide a measure of mosquito-borne disease risk to the public.

11.2 Combined CLAG Forum

The eighth annual combined CLAG Forum was hosted by ME in June 2019. This one-day event was well attended by 51 participants, representing 20 LGs, the Department, and the South Eastern Regional Centre for Urban Landcare (SERCUL).

The key theme at this year's forum was community engagement, with an emphasis on using social media to promote FTB and raise public awareness of mosquitoes as a public health risk. Other sessions focused on the management of midge and mosquito breeding in constructed wetlands, options for managing mosquitoes under the Public Health Act, and LG examples of innovative initiatives within their programs. The level of attendance and positive feedback received regarding this forum is evidence that mosquito management remains a high priority for many LGs.