Murray Valley encephalitis virus surveillance and control initiatives in Australia

a report on behalf of the National Arbovirus Advisory Committee of the Communicable Diseases Network Australia

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Abstract

Mechanisms for monitoring Murray Valley encephalitis (MVE) virus activity include surveillance of human cases, surveillance for activity in sentinel animals, monitoring of mosquito vectors and monitoring of weather conditions. The monitoring of human cases is only one possible trigger for public health action and the additional surveillance systems are used in concert to signal the risk of human disease, often before the appearance of human cases. Mosquito vector surveillance includes mosquito trapping for speciation and enumeration of mosquitoes to monitor population sizes and relative composition. Virus isolation from mosquitoes can also be undertaken. Monitoring of weather conditions and vector surveillance determines whether there is a potential for MVE activity to occur. Virus isolation from trapped mosquitoes is necessary to define whether MVE is actually present, but is difficult to deliver in a timely fashion in some jurisdictions. Monitoring of sentinel animals indicates whether MVE transmission to vertebrates is actually occurring. Meteorological surveillance can assist in the prediction of potential MVE virus activity by signalling conditions that have been associated with outbreaks of Murray Valley encephalitis in humans in the past. Predictive models of MVE virus activity for south-eastern Australia have been developed, but due to the infrequency of outbreaks, are yet to be demonstrated as useful for the forecasting of major outbreaks. Surveillance mechanisms vary across the jurisdictions. Surveillance of human disease occurs in all States and Territories by reporting of cases to health authorities. Sentinel flocks of chickens are maintained in 4 jurisdictions (Western Australia, the Northern Territory, Victoria and New South Wales) with collaborations between Western Australia and the Northern Territory. Mosquito monitoring complements the surveillance of sentinel animals in these jurisdictions. In addition, other mosquito monitoring programs exist in other States (including South Australia and Queensland). Public health control measures may include advice to the general public and mosquito management programs to reduce the numbers of both mosquito larvae and adult vectors. Strategic plans for public health action in the event of MVE virus activity are currently developed or being developed in New South Wales, the Northern Territory, South Australia, Western Australia and Victoria. A southern tri-State agreement exists between health departments of New South Wales, Victoria and South Australia and the Commonwealth Department of Health and Aged Care. All partners have agreed to co-operate and provide assistance in predicting and combatting outbreaks of mosquito-borne disease in south-eastern Australia. The newly formed National Arbovirus Advisory Committee is a working party providing advice to the Communicable Diseases Network Australia on arbovirus surveillance and control. Recommendations for further enhancement of national surveillance for Murray Valley encephalitis are described. *Commun Dis Intell* 2001;25:33-47.

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Prologue

Arboviruses (arthropod-borne viruses) of public health importance in Australia include flaviviruses and alphaviruses. Within the flavivirus group the important human pathogens include Murray Valley encephalitis (MVE), Kunjin (KUN), Japanese encephalitis (JE) and Dengue (DEN) viruses. Alphaviruses causing human disease include Ross River (RR) and Barmah Forest (BF) viruses. Other arboviruses including Sindbis (SIN), Alfuy (ALF), Edge Hill (EH), Kokobera (KOK), Gan Gan (GAN), Trubanaman (TRU) and Stratford (STR) virus cause only mild or inapparent infections.[1]

Of all the arbovirus infections, Murray Valley encephalitis causes the most severe disease. In the last 2 years MVE virus activity has increased with record levels of cases reported in Western Australia and widespread activity in the Northern Territory. In early 2001, 2 cases of Murray Valley encephalitis acquired in the Alice Springs area of the Northern Territory were reported, and a further case was detected in Mt. Isa, Queensland (see case reports in this issue of *Communicable Diseases Intelligence*). At the same time sentinel chickens in New South Wales showed seroconversions to MVE virus for the first time since the last national outbreak of Murray Valley encephalitis in 1974 (for sentinel chicken results see report in this issue of *Communicable Diseases Intelligence*).

In response to the increased MVE virus activity, the National Arbovirus Advisory Committee (NAAC), a working party of the Communicable Diseases Network Australia (CDNA) proposed that a scoping study of all current and possible surveillance mechanisms for Murray Valley encephalitis be undertaken. The collation of the information would facilitate, in the event of a national outbreak, rapid identification and co-ordination of these surveillance systems. The call for the review also reflected the perceived need to address cross-border issues that may arise during outbreaks and identify gaps in the current surveillance mechanisms. This document provides a summary of surveillance mechanisms and vectorborne disease control initiatives for MVE virus in Australia. Existing systems are described and other surveillance systems that may be utilised in the event of a widespread outbreak are discussed. Specific recommendations for the improvement of national MVE virus surveillance are proposed.

Background

Epidemiology of Murray Valley encephalitis

MVE virus is enzootic in the Kimberley region of Western Australia and the Top End of the Northern Territory. The virus is epizootic in the Pilbara and regions further south in Western Australia and the southern half of the Northern Territory. The situation in Queensland is less well understood due to the dearth of data over the past three decades. However, human cases occur sporadically throughout the State, including southern Queensland.[1] Since 1974, however, nearly all cases of arboviral encephalitis due to MVE virus have been reported from Western Australia and the Northern Territory,[2,3,4] with MVE activity and human disease occurring in most years. Virus activity occurs in the wet season, with human cases being infected between February and July.

Prior to 1974 only 1 case of encephalitis due to MVE virus had been reported from Western Australia, and none from the Northern Territory. Strong circumstantial evidence has indicated that ecological and environmental changes resulting from damming the Ord River and establishing the irrigation area in the north-east Kimberley may have provided conditions conducive to increased MVE virus activity and endemicity.[3] Any future changes to the waterways in the north of Australia may further change the ecology of the flaviviruses.

The history of severe epidemics of encephalitis in south-eastern Australia (particularly in the Murray/Darling River system) and the subsequent identification of MVE virus has been previously described.[4] These outbreaks started in December/January, peaked in February/March and declined in the cooler months. They occurred at irregular intervals, the last being in 1974 and involving approximately 58 cases, 13 of whom died.[5,6,7]

The 1974 outbreak spread to all mainland States of Australia and led to the introduction of the term 'Australian encephalitis (AE)'. The term AE has subsequently been used to refer to encephalitis due to either MVE or KUN infection,[8,9] and has led to considerable confusion. It is recommended that this term no longer be used and the terms MVE encephalitis and KUN encephalitis replace this nomenclature. If the infecting flavivirus cannot be differentiated, MVE/KUN encephalitis should be used. While surveillance mechanisms for KUN virus may be similar to that for MVE virus, the focus of this paper will be MVE virus.

Clinical aspects

It has been estimated that 1 in approximately 1,000-2,000 persons infected with MVE virus will develop severe encephalitis.[10,11] A larger proportion will develop a milder illness[12] but the vast majority remain asymptomatic. However, estimations of the case:infection ratios are not based on prospective data and are potentially inaccurate. It is likely that the rates will be higher during epidemics or in those at higher risk of severe disease.[13]

Murray Valley encephalitis is a potentially serious infection, with symptoms that include headache, neck stiffness, fever, tremor, weakness, confusion, fitting, and sometimes coma and death. Burrow and colleagues describe specific clinical features.[9] These signs may not be immediately associated with Murray Valley encephalitis by physicians when cases occur in non-enzootic areas. Persisting fevers and seizures are common in children. Cerebellar signs, brainstem features (e.g. cranial nerve palsies such as facial palsies and ophthalmoplegias) and spinal cord involvement (pseudopolio) are seen in more severe cases, often with an associated tremor. Computerised tomography scans are usually normal, but abnormalities on magnetic resonance imaging may be dramatic (e.g. thalamic lesions). Examination of the cerebral spinal fluid (CSF) usually shows a lymphocytic pleocytosis and samples should be sent to a reference laboratory for culture, serology and Polymerase Chain Reaction (PCR).

The case fatality rate for Murray Valley encephalitis is 20 per cent and approximately 40 per cent of survivors will be left with permanent neurological damage.[6,12] Young Aboriginal children in Western Australia have a particularly poor outcome.[13] The incubation period has not been well defined due to the difficulty in defining exact exposure episodes. No primary sources of data provide information regarding the

MVE virus-specific incubation period, other than from a single case report from the 1974 outbreak, with an incubation period of 28 days.[5] This exceeds the range reported for other arboviruses (5 to 15 days)[14] and at the moment the best estimate of the incubation period is 5-28 days.

MVE virus life cycle

There is a complex relationship between humans, vertebrate hosts, mosquito vectors and the environment involved in the ecology of most arboviruses. A range of factors may be involved in establishing and maintaining the MVE virus life cycle (Table 1).

MVE virus is transmitted to humans by mosquitoes and there is no direct transmission from person to person. The most common vector is the fresh water mosquito *Culex annulirostris*,[1,7] although other possible vectors have been identified.[1,11] The possibility of survival of MVE virus in arid areas via desiccation resistant *Aedes tremulus* eggs has been described.[15]

Both field and experimental infection studies have been used to investigate a number of vertebrate species as potential hosts for MVE virus. A comprehensive review of studies has been previously published.[7] Investigation of wild and domestic animals around the time of the 1974 outbreak revealed infections in domestic fowls,[16] wild birds and horses.[17] While serological field studies do confirm that particular species can be infected with MVE virus, they do not indicate what viral titres are achieved during infection and how long these infections are maintained. Both of these factors influence whether a particular vertebrate species is likely to be a major host in the MVE virus life cycle. Experimental studies have been undertaken to address these issues. Following experimental infection, wild birds, including herons and egrets, have been shown to develop viraemias of 3 to 5 days duration. Maximal titres were obtained in younger birds.[18] Studies have shown that domesticated animals such as fowl, pigs, cattle and horses may also be experimentally infected[19] but the role of these species in natural transmission cycles is not believed to be important. On the basis of laboratory and field experiments, wild birds, particularly wading water birds are thought to be important in the life cycle of MVE virus. The rufous night heron (*Nycticorax caledonicus*, also known as the nankeen night heron) is recognised as a major vertebrate host of MVE virus.[7]

Meteorological events such as rainfall, temperature and humidity also play a major role in the transmission of MVE virus.[20] Mosquito abundance is affected by the availability of aquatic breeding habitats. Other factors such as temperature, wind speed and wind direction affect their distribution and life cycle. Outbreaks of Murray Valley encephalitis may occur after unusually heavy and persistent rainfall and subsequent flooding. Abnormal rainfall may increase the numbers of mosquitoes and lead to movement of infected birds from enzootic regions to epizootic regions.[5,21] The mechanisms by which outbreaks in south-eastern Australia commence are unclear. One possibility is that MVE virus may be enzootic in south-eastern Australia in cryptic foci that are not detected by vector and vertebrate surveillance mechanisms in the intervening periods between outbreaks, but this seems to be an unlikely explanation given the extensive surveillance efforts. A more plausible explanation is that the virus is reintroduced by birds from the northern latitudes following periods of extreme rainfall and flooding. Indeed, genetic evidence demonstrates a lack of independent divergence of Australian MVE lineages, which strongly

Table 1. Factors that may affect establishment and maintenance of MVE virus life cycle

Virus	Enzootic presence or reintroduction into the environment
	Inter-epidemic survival
Vector	Density, fecundity and longevity
	Feeding patterns and feeding preferences
	Oviposition and over-wintering
	Distribution of vectors
	Natural predators of vectors
	Control mechanisms by humans
Vertebrate host	Range of potential hosts species
	Viral titre and duration of viraemia
	Host species density and breeding
	Prior exposure to the MVE virus
	Movement and migration
	Mosquito avoidance mechanisms
Environment	Climate and weather, particularly temperature, rainfall and humidity
	Physical landscape, such as presence of waterways
	Human interventions on the environment, such as irrigation, drainage of swamps etc
Human	Prior exposure to the MVE virus
	Population distribution
	Lifestyle factors
	Use of preventative measures to avoid being bitten by mosquitoes

supports the re-introduction of MVE virus rather than the presence of cryptic foci.[22]

Surveillance mechanisms

Mechanisms for monitoring MVE virus activity include surveillance of human cases, surveillance of MVE virus activity in vertebrate hosts, monitoring of mosquito vectors for abundance, virus isolation from mosquitoes and climate surveillance.[23] In some jurisdictions monitoring of human cases alone is insufficient for public health action, particularly when there are alternative surveillance mechanisms which may trigger action prior to the detection of human cases, and when the outcomes of infection can be so severe. If viewed in purely economic terms, the financial costs of these additional surveillance systems must be weighed against the cost of preventing human disease. The prevention of 1 human case with permanent neurological damage would make these systems cost effective. In the United States of America (US) it has been estimated that the community cost of a patient with permanent neurological damage is $US3 million. No equivalent costings are available in Australia, although it is likely that the value may be less than that estimated for the US.

The additional surveillance systems are used in concert to signal the risk of human disease. Monitoring sentinel animals for MVE virus activity provides information regarding whether MVE transmission to vertebrates is actually occurring. Sentinel chickens flocks maintained in a number of states and territories provide information on MVE virus activity.[24] Vector surveillance includes mosquito trapping for speciation and enumeration of mosquitoes to monitor population sizes and composition. Monitoring of weather conditions and vector surveillance determines whether there is potential for MVE activity to occur. Virus isolation from trapped mosquitoes is necessary to define whether MVE is actually present, but is difficult to deliver in a timely fashion in some jurisdictions.

The trapping of live vector collections does require the use of CDC/EVS CO_2 baited traps, which may have logistical constraints for remote regions of Australia, such as the Kimberley region of Western Australia. The development of PCR assays for detection of MVE virus in pools of mosquitoes would allow more timely reporting of the detection of virus in mosquitoes and may obviate the need for live mosquito collections. It would be advantageous if these methods could be applied to mosquitoes that have been collected in traps for up to a week. These methods remain in the developmental stage in a number of laboratories across Australia until technical problems are overcome. These problems include the storage of trapped mosquitoes, prevention of fungal growth, viral RNA degradation and the presence of PCR inhibitors in large pools of mosquitoes. Optimal pooling sizes must be determined before PCR is a cost-effective and timely replacement for virus isolation using current cell culture techniques.

Meteorological surveillance is used in the prediction of MVE virus activity by signalling conditions that have been associated with outbreaks of Murray Valley encephalitis in humans in the past. Examination of climate meteorologic information including rainfall, temperature and the Southern Oscillation (SO) may assist the prediction of risk situations. The SO is an inter-annual oscillation in tropical sea level pressure between eastern and western regions of the Pacific Ocean. The Southern Oscillation Index (SOI) is calculated from the monthly or seasonal fluctuations in the air pressure difference between Tahiti and Darwin. Positive SOI values suggest that rainfall will be above average across eastern Australia, while negative values suggests that rainfall will be below average. The SOI predicts rainfall to a lesser extent in central and western Australian states.

There are 2 models for the prediction of Murray Valley encephalitis activity for south-eastern Australia using climatic information. The Forbes model[2] utilises rainfall patterns and provides a quantitative approach to predicting outbreaks of Murray Valley encephalitis. The model relies on rainfall patterns in the preceding and current season of MVE virus activity. The model predicts MVE amplification where there has been above average rainfall in the current and preceding summers, with the underlying hypothesis that abnormal rainfall enhances breeding of both wading birds and mosquitoes. The Nicholls model[25] suggests a qualitative association between Darwin atmospheric pressure (a measure of SO) in autumn, winter and spring of the preceding season and Murray Valley encephalitis activity.

A mathematical model based on host and vector factors, has been developed[26] for the rural amplification of MVE virus in southern Australia during the 1951 and 1974 outbreaks. This model predicted the likely duration of the rural amplification phase, estimated to have commenced in October of the year prior to an outbreak. Thus it appears that seeding of the south-eastern areas of Australia in the previous year is important for the establishment of an outbreak in the following season.

Evidence supporting the use of animal, vector and climate surveillance mechanisms to predict disease in humans

The complex MVE virus life cycle means that a number of surveillance mechanisms can be utilised to predict MVE virus activity. Whether this activity heralds human disease is enhanced by drawing together of data from a number of surveillance systems and evaluating their predictive ability in light of human cases. The appropriate surveillance tools for monitoring MVE virus activity may vary from jurisdiction to jurisdiction. Factors such as whether the virus is enzootic or epizootic, the frequency of human disease, the geography and climate, the availability of laboratory facilities and other infrastructure, competing public health concerns and the availability of public health resources will affect what surveillance mechanisms are appropriate. The ability to evaluate the use of animal, vector and climate surveillance is affected by the frequency of human disease, indeed, it is difficult to evaluate the use of surveillance mechanisms in the Murray Valley region given the last human cases occurred in 1974.

Some of the best evidence for the use of non-human surveillance mechanisms for predicting MVE activity comes from Western Australia. The State has marked climate variability and encompasses enzootic and epizootic regions, as well as regions where no MVE virus activity has ever been detected. Due to the logistical difficulties associated with mosquito monitoring, sentinel chicken and climate surveillance are the key elements for predicting MVE virus activity in Western Australia. Large outbreaks (e.g. in 1993 and 2000) have been associated with abnormal weather patterns in Western Australia. Data collected over the last 10 years of the sentinel chicken program indicate that

seroconversions in sentinel chickens have preceded likely dates of exposure of the first human cases by 2 to 18 weeks in all but one situation during that period.[27]

While it has been shown that large outbreaks of Murray Valley encephalitis are associated with abnormal weather patterns in Western Australia, the use of climate surveillance to predict outbreaks in south-eastern Australia remains controversial, and should be used in conjunction with other surveillance data. The Nicholls model provides more timely prediction of the risk of Murray Valley encephalitis activity compared with the Forbes model as it does not rely on collection of data during the current season. The Forbes model, however, has proved more accurate in recent years. This model suggested there would be MVE virus activity in south-eastern Australia during the 1999/2000 season when there were a number of cases of Murray Valley encephalitis in the Alice Springs area of the Northern Territory and a single case in the north of South Australia. The Forbes model again predicted activity for the 2000/2001 season, which did occur. In comparison, the Nicholls model suggested activity was unlikely in both seasons (personal communication, S Doggett).

One of the difficulties with both the Forbes and the Nicholls models is that they were based on major outbreaks of arboviral encephalitis in south-eastern Australia, which have not occurred since 1974. Both models were developed using very small data sets and neither incorporates observed activity in sentinel animals or addresses subclinical infections. Neither scheme takes into account the impact of other factors such as the breeding and movements of vertebrate hosts and vectors, or the influence of human activities on the natural landscape, such as irrigation and land development. Similarly, public health messages regarding the risk of arbovirus infection and widespread vector management programs may have reduced the incidence of human disease despite the presence of weather conditions that have been associated with outbreaks in the past.

Laboratory testing

Testing for MVE virus in humans

Virus isolation from blood is only possible in the very early acute phase of the illness prior to the appearance of antibodies. MVE virus has only been isolated from a small number of human cases, and none since 1974. While detection of viral RNA in CSF[8] or blood[28] using PCR has a higher yield, most infections are diagnosed serologically. Due to high levels of background flavivirus infection in endemic areas, and the long-term persistence of IgM, it is important to demonstrate rising titres of IgG or to have a positive viral detection test (culture or PCR) to confirm acute infection. If confirmatory laboratory evidence is unavailable or inconclusive, then a detailed exposure and clinical assessment is required to determine the likelihood of recent infection. As there is broad cross-reactivity in antibodies to the flaviviruses, assigning a particular virus as the cause based on serology requires a test that is sufficiently specific. Diagnostic and reporting guidelines for MVE (and other

Table 2. Arbovirus research laboratories in Australia providing testing for vertebrate and vector surveillance systems for MVE virus*

Location	Laboratory	Institute	Testing provided
Western Australia	Western Australian Arbovirus Surveillance and Research Laboratory	University of Western Australia	Serological testing of vertebrate hosts Mosquito collection and identification Virus isolation from mosquitoes
Northern Territory	AL Rose Virology Laboratory	Department of Primary Industry and Fisheries	Serological testing of vertebrate hosts Mosquito collection and identification
	Medical Entomology Branch	Territory Health Services	Mosquito collection and identification
New South Wales	NSW Arbovirus Laboratory	Institute of Clinical Pathology and Medical Research, Westmead	Serological testing of vertebrate host Mosquito collection and identification Virus isolation from mosquitoes
Victoria	Victorian Institute of Animal Sciences	Department of Natural Resources and Environment	Serological testing of vertebrate hosts Mosquito collection and identification Virus isolation from mosquitoes
	Australian Animal Health Laboratory	Commonwealth Scientific and Industrial Research Organisation	Serological testing of vertebrate hosts
Queensland	Queensland Health Scientific Services	Queensland Health	Mosquito collection and identification
	Arbovirus and Emerging Diseases Laboratory	University of Queensland	Serological testing of vertebrate hosts Mosquito collection and identification Virus isolation from mosquitoes
	Tropical Public Health Unit	Queensland Health	Mosquito collection and identification
South Australia	Mosquito Research Laboratory	University of South Australia	Mosquito collection and identification

* excluding opportunistic testing

arboviral diseases) have been developed[29] and have subsequently been refined in the Public Health Laboratory Network case definitions.[30]

Vertebrates and vectors

There is a network of laboratories across Australia that provides a range of testing for MVE virus activity in vertebrates and vectors, including serological testing, mosquito identification and viral isolation from mosquitoes (Table 2). In addition, there are laboratories that provide such services, but are not currently contributing to surveillance systems. These laboratories may provide services on an *ad hoc* basis for research purposes, for example, for the opportunistic testing of domestic animals. Local councils in some jurisdictions may also undertake mosquito identification.

Public health action

Public health action is determined by assessing data from the various surveillance mechanisms. It is impossible to fully eliminate mosquito breeding, therefore, it is important to warn the general public of the risk of Murray Valley encephalitis once conditions are optimal for virus transmission. Advice on personal protection and reducing risk behaviour are the major public health messages. Such warnings can be developed specifically to target the lifestyles and literacy levels of at-risk communities. Mosquito control programs may reduce the numbers of both mosquito larvae and adult vectors in certain circumstances. However, as there is no specific treatment for Murray Valley encephalitis, prevention remains the most important strategy for averting disease.

While it has not been possible to formally evaluate their effectiveness, targeted public health campaigns, drawing on evidence from animal, vector and climate surveillance, are believed to be more effective than general warnings. Data from these additional surveillance mechanisms can be used to stimulate public awareness prior to the detection of human cases.

Surveillance mechanisms in Australia

Surveillance of human cases

State and territory notifications

MVE virus is enzootic in the Northern Territory and cases of Murray Valley encephalitis have been reported in a number of years since the 1974 outbreak.[10] In recent years, members of CDNA agreed that notifiable diseases should be reported by the jurisdiction in which the case is diagnosed, rather than the likely place of infection. Infection may be acquired as people travel through regions with MVE virus activity, but diagnosis may be undertaken elsewhere, when travellers return home or when severe cases are transferred for medical treatment. The regional location of acquisition of cases of Murray Valley encephalitis notified by the Northern Territory is shown in Table 3. A presumptive case of MVE acquired in Alice Springs was identified in 1997, but could not be confirmed due to the death of the patient.[31]

Forty-one cases of Murray Valley encephalitis acquired in Western Australia have been notified since the 1974 outbreak[2,8,12,32] (regional location, of where infections were acquired are given in Table 4). While regular activity has been confined to the Kimberley, epidemic activity extending

Table 3. Confirmed Murray Valley encephalitis cases notified by the Northern Territory, 1974-2001 to date, by regional location of acquisition

Year	Region	Cases (deaths)
1974	Katherine	1
	Barkly	2
	Alice Springs	2
1981	East Arnhem	1
1987	Darwin	1
1988	Arnhem Land	2
	Darwin - Rural	1
1991	Darwin	1(1)
	Barkly	1
1993	Katherine	5(1)
	Acquired in WA	1
2000	Darwin - Rural/Katherine	1
	Alice Springs	3
	Acquired in WA	2(1)
	Acquired in SA	1
2001	Alice Springs	2

Table 4. Confirmed Murray Valley encephalitis cases notified by Western Australia, 1974-2001 to date, by regional location of acquisition

Year	Region	Cases (deaths)
1974	Kimberley	1
1978	Kimberley	2
	Pilbara	2
1979	Kimberley	1
1981	Kimberley	3
	Pilbara	3
	Gascoyne	1
1984	Kimberley	2
1986	Kimberley	1
1989	Kimberley	1(1)
1990	Kimberley	1(1)
1991	Kimberley	2(1)
1993	Kimberley	9(4)
1997	Kimberley	1
	Gascoyne	1
1998	Kimberley	1
2000	Kimberley*	1(1)
	Pilbara	2
	Mid-west/Kimberley*	1
	Mid-west	3
	Gascoyne	1
	Murchison	1

* Diagnosed and notified nationally by the Northern Territory.

further south causes occasional outbreaks outside this region. In 2000 there was a new southerly extension of MVE virus activity with cases occurring as far south as the Mid-west region, coming within 300 km of the metropolitan area.[12]

As well as a recent case in Mt Isa in 2001, 4 cases of Murray Valley encephalitis have been reported in Queensland since the 1974 outbreak, including 2 in 1991[33] (only 1 of which was a confirmed case), one in 1994[34] and 1 in 1997 (personal communication, J Hanna). The latter case was thought to have contracted the disease in the Northern Territory, and subsequently died. Ten cases scattered throughout Queensland were recorded in the 1974 outbreak. As shown in Table 3, one case of MVE acquired in the north of South Australia was reported by the Northern Territory in 2000. South Australia, New South Wales and Victoria have not recorded a case of Murray Valley encephalitis acquired within the Murray Valley region, since 1974. No Murray Valley encephalitis cases have ever been reported from the Australian Capital Territory or Tasmania.

National surveillance of human cases

All States and Territories report arbovirus infection to the National Notifiable Disease Surveillance System (NNDSS) maintained at the Commonwealth Department of Health and Aged Care. From 1991 to 2000 flavivirus infections were classified as either 'Dengue virus' or 'Arboviruses: not elsewhere classified (NEC)'. From 1996 onwards the latter included infections with MVE, KUN, JE, KOK and STR viruses. It has not been possible to determine the number of MVE notifications at a national level, from NNDSS for these years. NNDSS is currently in the process of a major revision and from 2001 onward it will be possible to distinguish the different arboviruses at a national level.

There is some variation between the case definition for MVE infection used by State and Territory health departments. With the exception of the Northern Territory and Western Australia, all jurisdictions use the 1994 National Health and Medical Research Council (NHMRC) case definition[35] that includes serological identification of all infections with MVE virus, whether encephalitis associated or not. In the Northern Territory the case definition requires the presence of a clinically compatible illness with features of encephalitis. In Western Australia a laboratory diagnosis is supplemented with a clinically compatible illness, however, this need not be encephalitis. Therefore, in Western Australia, encephalitic and non-encephalitic clinical cases are reported, but asymptomatic cases are not. In the Northern Territory, only Murray Valley encephalitis cases are reported. All other jurisdictions report all MVE virus infections.

The Laboratory Virology and Serology Reporting Scheme (LabVISE) is an additional surveillance tool maintained by the Commonwealth Department of Health and Aged Care. LabVISE is a voluntary passive reporting scheme to which sentinel virology and serology laboratories around Australia, contribute. MVE virus is one of the infectious agents reported by this system, however, the number of reports may overestimate the true number of cases of Murray Valley encephalitis as the total number will represent both encephalitic and non-encephalitic infections. State and Territory notifications may not truly represent the location of disease acquisition and duplicates may also occur, due to cross border testing and the transfer of patients for interstate clinical management. IgM positive cases may also be automatically notified even if they have not been shown to be recent infections.

Animal, vector and climate surveillance in States and Territories

Sentinel chicken surveillance programs are active in 4 jurisdictions; Western Australia, the Northern Territory, New South Wales and Victoria and mosquito monitoring complements the surveillance of sentinel animals in these jurisdictions. In addition, other mosquito monitoring programs exist in South Australia and Queensland. No surveillance mechanisms for monitoring MVE virus activity in vectors or vertebrate hosts are operational in the Australian Capital Territory or Tasmania.

New South Wales

Surveillance mechanisms in New South Wales include mosquito-monitoring, virus isolation from mosquitoes and sentinel chicken surveillance. The NSW Department of Health (NSW Health) co-ordinates the New South Wales Arbovirus Surveillance and Vector Monitoring Program. Laboratory work for this program is currently contracted to the Institute of Clinical Pathology and Medical Research (ICPMR), Westmead. Comprehensive reporting from the program is available on the Internet at:
http://www.arbovirus.health.nsw.gov.au.

The New South Wales arbovirus surveillance program has sentinel chickens located across inland areas of the State (Figure 1). Flocks of 15 chickens are located at 12 sites. The flocks are bled at weekly intervals and tested for antibodies to flaviviruses, including MVE and KUN viruses. All chickens are replaced annually in October and additional birds may be included mid season if a large number seroconvert. The program also involves mosquito collection at locations throughout the State (Figure 1). The trapping program operates from mid-spring to mid-autumn (November to April) to cover the period for natural activity and transmission of arboviruses. Mosquitoes are collected weekly for vector identification and quantitation and are processed for isolation of MVE, KUN, EH, ALF, STR, KOK, SIN, RR and BF viruses.

Data on the Southern Oscillation Index, rainfall and temperature are obtained from the Bureau of Meteorology Website (http://www.bom.gov.au). These data are used by the members of the monitoring program to predict mosquito-breeding capabilities. Climatic data are used to predict potential Murray Valley encephalitis outbreaks using both the Forbes and Nicholls models.

Northern Territory

Surveillance for MVE virus activity in the Northern Territory consists of sentinel surveillance of virus antibodies in sentinel chickens and virus isolation from mosquitoes. Surveillance of sentinel chicken flocks for flavivirus activity is a combined program between the Northern Territory Department of Primary Industry and Fisheries (DPI&F), Territory Health Services (THS), the University of Western Australia (UWA) and volunteers. The program is designed to detect flavivirus activity (including the enzootic arboviruses MVE and KUN viruses and exotic arboviruses such as JE), in the Northern Territory. Sentinel chicken flocks are maintained at 9 sites (Figure 2). Flocks are usually bled once a month and the samples are sent to the Arbovirus Surveillance and Research Laboratory, UWA, for specific testing for MVE and KUN viruses. When the majority of chickens in a flock

Figure 1. Monitoring locations in New South Wales

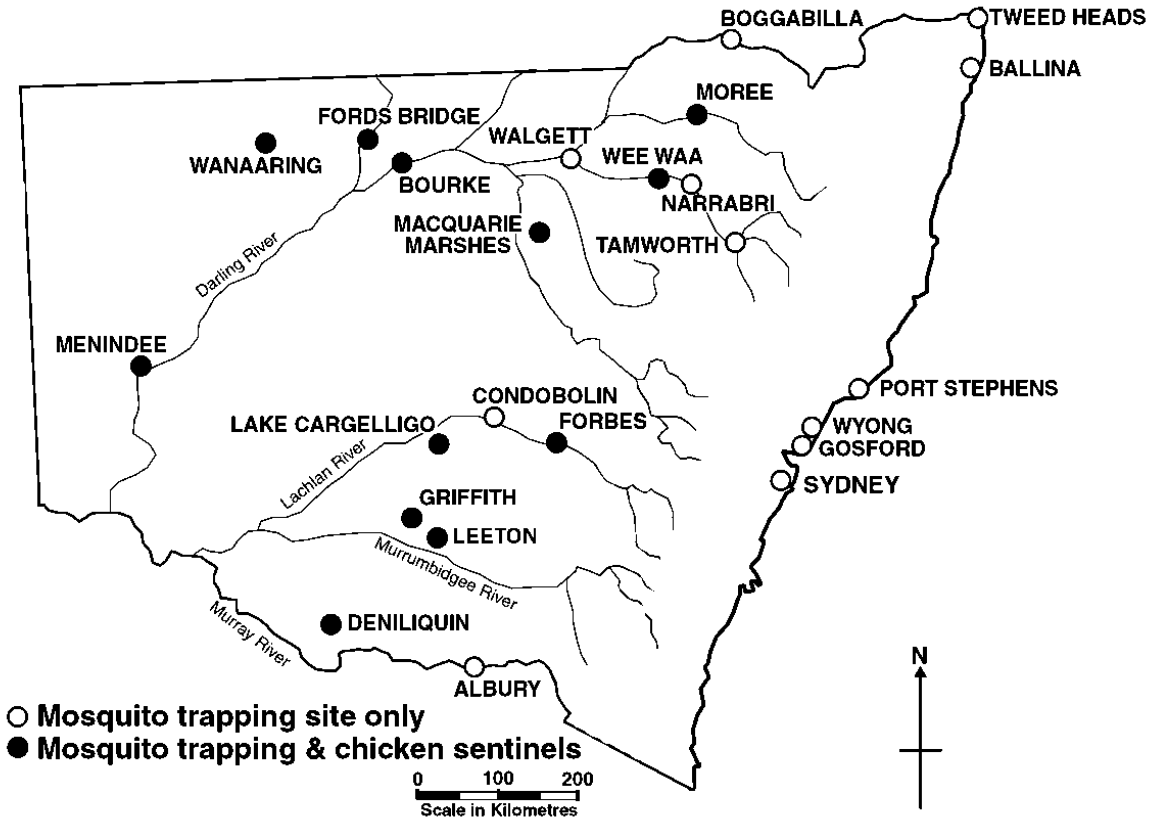
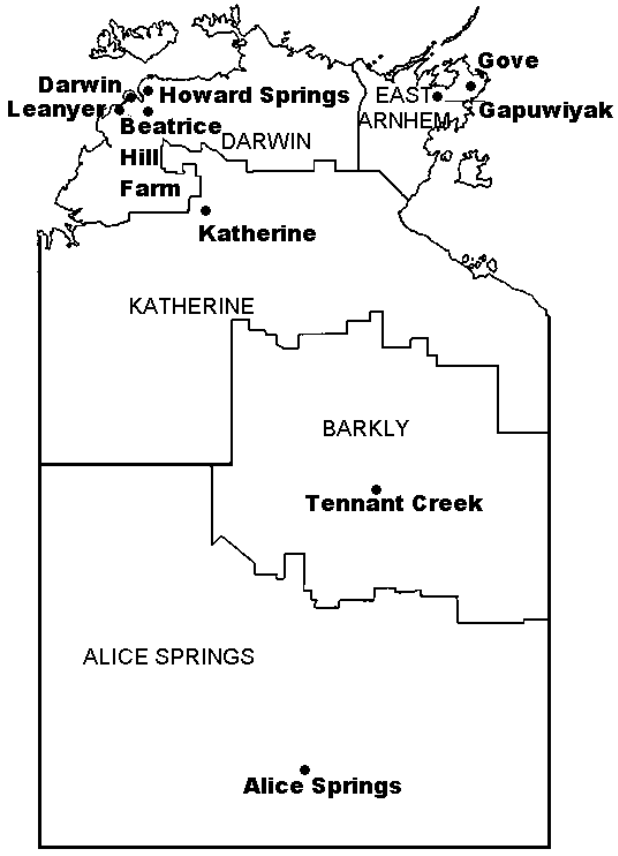


Figure 2. Sentinel chicken flocks in the Northern Territory



seroconvert in a season, the flock is replaced. As the majority seroconvert each year, replacement can occur mid-season. Most flocks are replaced annually and all are replaced within 2 years.

The Northern Territory Mosquito Borne Disease Control Program assists regional authorities with mosquito monitoring and provides advice and funding for direct mosquito control for some of the major towns in the Northern Territory (Darwin, Jabiru, Nhulunbuy on the Gove Peninsula, Katherine, Tennant Creek, Alice Springs, and at Alyangula on Groote Eylandt). Monitoring and control operations are usually carried out by town councils or other local authorities through local environmental health officers, with the identification of all mosquitoes carried out by the Medical Entomology Branch (MEB) of Territory Health Services.

The routine mosquito-monitoring program in Darwin consists of 18 trapping sites throughout the Darwin urban area. Although now discontinued, until recently mosquitoes were routinely collected for virus isolation at Middle Point, near Beatrice Hill. The Middle Point virus isolation collections were part of a combined project with DPI&F and THS. Mosquito trapping near sentinel chicken flocks aims to correlate antibodies and virus isolates in the animals with vector activity. Collection of mosquitoes for virus isolation is currently on an *ad hoc* basis, during actual outbreaks or periods of potential disease activity.

Four additional routine trapping sites are located in Jabiru, 5 in Gove, 3 in Tennant Creek, 4 in Katherine and 3 sites at Alyangula on Groote Eylandt. The mosquito-monitoring program in Alice Springs is a co-operative program between the Alice Springs Town Council and the MEB in Darwin. There are 6 regular mosquito-monitoring sites located in

Alice Springs. Environmental health officers from the Alice Springs Town Council collect mosquitoes from these sites on a weekly basis.

Information from the Bureau of Meteorology is used in conjunction with animal and vector surveillance. Monthly weather reviews are obtained from the Bureau of Meteorology and rainfall patterns and daily rainfall records are used to predict mosquito activity.

Queensland

Queensland has no State-wide surveillance system for monitoring MVE virus activity in vertebrate hosts or vectors and does not maintain sentinel chicken flocks. Mosquito-monitoring is performed by local councils. While there are no regular isolation programs, virus isolations from mosquitoes or animals have been carried out by the University of Queensland, the Tropical Public Health Unit Network (TPHUN) within Queensland Health, the Queensland Health Scientific Services and the Queensland Institute of Medical Research. These research programs are funded in part by Queensland Health and the NHMRC.

Three State health department entomologists are located in Queensland, one in Brisbane and two in Cairns at the Tropical Public Health Unit. Staff from the TPHUN in Cairns and Townsville perform reactive monitoring on demand. Extensive mosquito trapping for monitoring mosquito abundance and arboviral isolation was carried out in a number of sites in the Mt. Isa region in February to March 2001 in response to the human case of Murray Valley encephalitis detected in February, 2001. Research based activities are also carried out by the TPHUN. Mosquito trapping is carried out in the Torres Strait, the Gulf of Carpenteria and Western Cape York by the TPHUN, in collaboration with the University of Queensland. While the trapping is primarily to monitor potential for JE activity and isolate the virus, the program also investigates the presence of novel vectors in the region.

South Australia

Arbovirus surveillance in South Australia is co-ordinated by the Department of Human Services, South Australia, and consists of mosquito trapping in the Murray Riverland area and virus isolation when required. South Australia local councils perform mosquito surveillance and control in areas other than the Torrens Island environs. Several councils contract mosquito surveillance to the Mosquito Research Laboratory at the University of South Australia. Seasonal monitoring of the mosquito population is undertaken along the Murray River. Live collections of mosquitoes for virus isolation are sampled in response to high vector numbers and are sent to Victoria for virus isolation. This has occurred on several occasions in 2001.

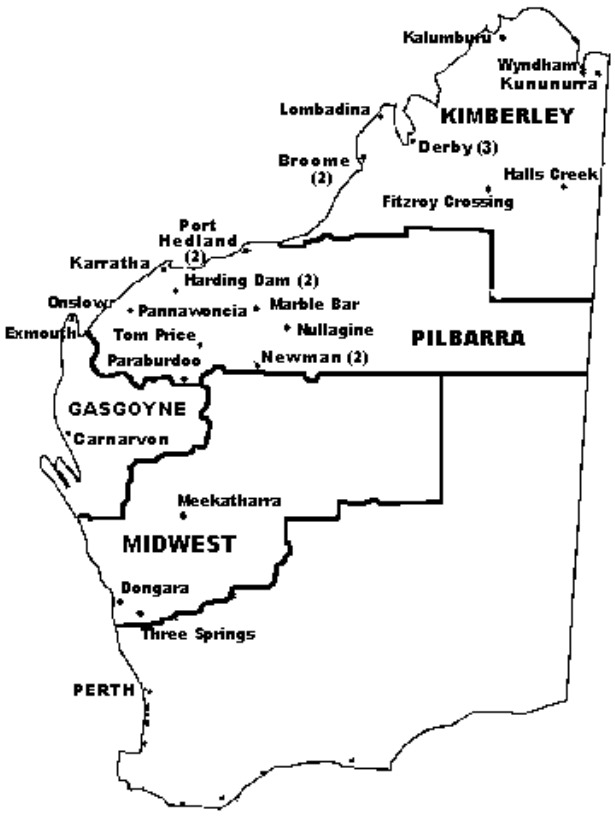
Western Australia

The Western Australia Arbovirus Surveillance and Research Laboratory, UWA, is funded by the Health Department of Western Australia (HDWA) to co-ordinate a sentinel chicken program and mosquito surveillance in Western Australia, as well as providing confirmatory serological testing for other sentinel chicken programs in Australia. Sentinel chicken sites may vary from year to year, depending on virus activity. In 2001, sentinel chicken flocks were maintained at 11 sites in the Kimberley, 13 sites in the Pilbara, at 2 sites in the Gascoyne and at 3 sites in the Mid-west (Figure 3). Twelve birds are maintained at each site. The flocks are bled fortnightly from November to May and monthly at other times during the year. Samples are tested for MVE virus specific antibody activity using an epitope-blocking enzyme immunoassay. Seropositive chickens are replaced once half the chickens in the flock have seroconverted. In addition, all flocks are replaced annually during the dry season.

In the more remote regions of Western Australia it is not logistically or financially feasible to undertake routine mosquito surveillance, and experience has shown that surveillance using sentinel chickens provides adequate warning of increases in the activity of MVE virus. An annual program of mosquito trapping is undertaken towards the end of the wet season when MVE virus activity is usually highest. Field collections are undertaken at all major towns in the Kimberley as well as at some Aboriginal communities. The mosquitoes are collected over a 3 to 4 week period and then subsequently tested in the Arbovirus Surveillance and Research Laboratory, a process that takes several months to complete. While not prospective, this program provides important data on size and species composition of mosquito populations, vector species and virus infection rates. It also assists in matching specific meteorological conditions to breeding and infection rates of vector mosquito species.

Opportunistic field collections are carried out in response to seroconversions in sentinel chickens and extreme weather events in a number of other areas of the State. The University of Western Australia and the HDWA also undertake field surveillance for incursion of exotic vector mosquitoes and viruses, including surveillance at specific new or proposed developments such as dams, irrigation projects or mine sites. Local councils may also undertake

Figure 3. Sentinel chicken flocks in Western Australia



mosquito trapping for species identification, enumeration and evaluation of their mosquito management programs.

Climate surveillance also provides vital information for the prediction of arbovirus activity using meteorological data obtained weekly from the Bureau of Meteorology Website. Graphs of weather patterns in all towns from the Kimberley to Esperance are produced and used to predict arbovirus activity. The SOI is used to predict rainfall, although this measure is not as accurate at predicting rainfall in Western Australia as it is in the south-eastern regions of Australia. Therefore, modelling of Murray Valley encephalitis activity using the Forbes and Nicholls models is not as reliable in Western Australia.

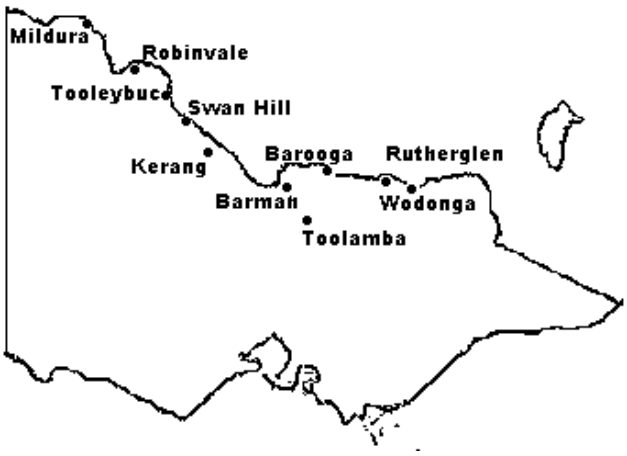
Victoria

The Department of Human Services (DHS) contract the Victorian Institute of Animal Science (VIAS) to conduct sentinel chicken surveillance from November to April. Chicken flocks of 20 birds are located at 10 locations (Figure 4). Flocks are bled weekly from mid-October to April, although surveillance may be extended in periods of MVE virus activity. Flocks are replaced annually. Blood samples are tested for flaviviruses by enzyme linked immunosorbent assay (ELISA). Cross-reactivity with members of the flavivirus family is investigated with further tests to identify the infecting virus.

Six municipal councils in Victoria, including Greater Shepparton, Mildura Rural, Moira, Swan Hill Rural, Wellington and Wodonga Shire Councils, undertake mosquito surveillance. Four traps are placed in each area and mosquitoes are collected weekly and sent live to the VIAS for identification, enumeration and virus isolation.

Adult mosquito abundance and distribution are assessed in combination with climatic information such as temperature, wind direction and wind speed. The Victorian Arbovirus Task Force examines the risk of outbreaks of Murray Valley encephalitis using meteorological surveillance data such as SOI and rainfall deciles using both the Forbes and Nicholls models.

Figure 4. Sentinel chicken flocks in Victoria



Other surveillance mechanisms

Further surveillance mechanisms may include monitoring of other flaviviruses in animals, opportunistic testing of domestic and non-domestic animals, seroprevalence studies in humans and vector monitoring.

Surveillance mechanisms for other flaviviruses in animals

Currently there are programs in operation which monitor other arbovirus activity, including human flaviviruses such as JE, or arboviruses of importance to the livestock industry, such as bluetongue. These systems have the potential to provide additional information about the activity of MVE virus or other flaviviruses. Collections of sera from these programs could be tested for MVE virus activity, although the value of testing of other sentinel animals for MVE virus activity is yet to be fully determined. Both the Australian Animal Health Laboratory (AAHL) and the State veterinary laboratories are involved in surveillance programs.

The National Arbovirus Monitoring Program

The National Arbovirus Monitoring Program deals primarily with bluetongue viruses but also with bovine ephemeral fever and akabane viruses. The program involves approximately 70 sentinel cattle herds of 10 to 15 animals each, distributed around Australia. Sentinel cattle are monitored serologically and by virus isolation. Insect trapping for *Culicoides,* the major vector of bluetongue, is conducted in conjunction with the sentinel herds. The Berrimah Veterinary Laboratories in Darwin undertake virus isolation from weekly collections from sentinel cattle at Beatrice Hill Farm in the Northern Territory.

The Northern Australian Quarantine Strategy

The Commonwealth Government through the Northern Australian Quarantine Strategy (NAQS) of the Australian Quarantine Inspection Service (AQIS) runs a monitoring program for JE. At the start of each wet season, groups of young sero-negative pigs are placed at strategic sites in the Torres Strait Islands, Cape York Peninsula and in the Northern Territory. Animals from Queensland sites are tested by AAHL and Queensland Health Scientific Services. AAHL screens these sentinel pig sera with a competitive ELISA for JE, which detects cross reactions with endemic Australian flaviviruses. Reactive sera are then tested by a plaque reduction neutralisation test for neutralising antibodies to JE, MVE and KUN viruses. The sentinel pigs surveillance system operating in the Northern Territory is co-ordinated by the DPI&F. Pigs are maintained at each site at Berrimah and Beatrice Hill on the Adelaide River flood plain. The animals are bled monthly and tested for broad flavivirus activity by the AL Rose Virology Laboratory at the DPI&F. Positive test results are further investigated with serum neutralisation tests specific for MVE, KUN and JE viruses.

Surveys of feral animals including pigs, cattle, donkeys, goats, and deer are undertaken as part of NAQS. Domestic animals are surveyed in the Torres Strait and in the Northern Peninsular area. A NAQS team periodically samples wild migratory birds in the Torres Strait. The Arbovirus Surveillance and Research Laboratory at UWA tests sera provided by NAQS from cattle herds in the Kimberley for antibody to MVE, KUN and JE viruses. Sera from a wide range of other vertebrates have been tested for flavivirus antibodies since the first detection of JE virus in the Torres Strait in 1995.

Opportunistic testing of animals

Serological surveys provide evidence of past or recent infection with arboviruses in domestic and non-domestic animals, but their use as an early warning system is limited. Survey data are unreliable indicators of recent virus activity, unless undertaken in young animals, and do not take into account issues such as animal migration. They do, however, provide data for hypothesis generation regarding the range of vertebrate hosts of the virus and define regions of virus activity.

Non-domestic animals

Regular testing of sera from birds and animals from both enzootic and epizootic regions of MVE virus activity is undertaken in Western Australia. Serological reactivity to flaviviruses has been investigated in western grey kangaroos opportunistically bled during culling exercises in South Australia (personal communication, M Kokkinn). In January 2001, NSW Health and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) undertook opportunistic sampling of a breeding colony of rufous (nankeen) night herons along the Murray River. In Victoria, wildlife sera collected following culls of kangaroos and possums, are opportunistically tested for MVE virus.

Domestic animals

Opportunistic testing of domestic chickens in regions where sentinel chickens are not located has been used in Western Australia for many years to provide additional information about activity of MVE virus in epizootic regions, particularly to define the spread of MVE virus activity. It was used very successfully, for example, in 2000 to demonstrate the southern and eastern limits of activity of MVE virus during a major outbreak in humans. Results were subsequently used to determine the most appropriate location for new flocks of sentinel chickens in the Mid-west, Murchison and Goldfields regions.

Testing of domestic chickens was recently undertaken in New South Wales in response to sero-conversions in sentinel flocks, targeting areas with large human populations surrounding the sites of sentinel chicken activity. Areas further north were also included to assess whether the virus was moving in a North-South direction. The NSW Department of Agriculture recently tested a range of domestic animals to determine the spatial distribution of MVE virus activity and to compare the usefulness of dogs, cattle, horses, and domestic chickens as sentinels for MVE virus, in and away from major human population centres. In South Australia, DHS co-ordinated the testing of domestic chicken flocks at Paringa in February 2001 in response to recent seroconversions in sentinel chickens in New South Wales and Alice Springs. There are currently plans for testing domestic cattle in the Yunta area of South Australia to further investigate MVE virus activity. Opportunistic testing of cattle has been undertaken in Victoria in response to the recent MVE virus seroconversions in sentinel chickens.

The evidence that arboviruses affecting human health cause disease in animals is controversial. Animals (particularly horses) presenting with symptoms of encephalitis (ataxia) or arthritis (stiffness or swollen joints) may be tested for RR, KUN and MVE viruses. Methods for diagnosing recent arbovirus infection in animals have only lately become available and are not fully validated. Rising KUN IgG titres and RR IgM reactivity have been occasionally demonstrated in animals showing signs of disease, where more common causes of disease have been excluded (personal communication, P Ellis). Further research is required to confirm whether these are coincidental infections or the causative agents. No surveillance mechanisms are active to monitor these diagnoses. The National Animal Health Information System is an analogous system to NNDSS, but does not currently record animal infections with arboviruses that affect human health.

Seroprevalence studies in humans

Seroprevalence studies in humans are useful for determining who is susceptible within a given community and provide information on the epidemiology of MVE virus. When undertaken following an outbreak, it is possible to determine the ratio of symptomatic to subclinical cases. As with studies in animals, seroprevalence studies in humans are not useful for early warning of MVE virus activity. Some of the early seroprevalence studies investigating MVE virus infections in humans[36,37,38,39] are difficult to interpret due to cross-reactions of haemagglutination-inhibition antibodies with other flaviviruses. Studies monitoring the sero-prevalence of antibodies to MVE virus using more specific ELISA have been reported.[9,40,41] These investigations provide an indication of the level and patterns of MVE virus exposure within a community.

Vector monitoring by AQIS

A vector-monitoring program is run by AQIS for the surveillance of exotic mosquito species. Surveillance is conducted at each international airport in Australia (currently 16 locations) and each seaport (currently 47 locations) within a 400 metre radius of the port. The vector monitoring program is supported by the AQIS First Port Airport Disinsection Program and the First Port Seaport Mosquito Control Program with the aim of maintaining an exotic vector free status around airports and seaports. While the focus of this work is not MVE virus surveillance, endemic vector species are trapped frequently. In the event of an outbreak this surveillance mechanism could provide details on vector abundance at the various sites.

Geographical Information Systems

Geographical Information Systems (GIS) have the potential for surveillance of mosquito vector habitats. Dale and colleagues have published a non-technical review of the use of GIS for this purpose.[42] Further investigations may be required to assess the utility of this method of surveillance of vector habitats in relation to MVE virus activity. GIS can overlay data from multiple sources and could be used to map the distribution of human cases, virus activity, climatic and environmental information.

Control mechanisms

Mosquito management

Local government is the main agent of mosquito management in most jurisdictions, including New South Wales, the Northern Territory, Queensland, South Australia, Western Australia and Victoria. Effective mosquito management incorporates a range of practices, with emphasis on an integrated approach, focussing on source reduction, appropriate town planning and other preventative measures as well as vector management using chemicals.[43]

Management programs vary according to regional requirements, as not all procedures are appropriate in all situations. The practicality, logistics and cost of such measures in enzootic areas needs careful consideration. Mosquito control is not feasible in many remote areas of northern Western Australia, Queensland and the Northern Territory where there are large and widespread natural wetlands. Instead, local governments tend to carry out community based procedures. While not applicable in all situations, both larviciding and adulticiding can be used to decrease vector numbers in or near residential areas. Aerial larvicide applications are used in some areas (e.g. in the Northern Territory) when surveillance programs determine that health-driven mosquito management is required. Adulticiding using fogging may be used if an outbreak is indicated, but this measure only temporarily decreases the number of mosquitoes. As the use of adulticiding remains controversial, its use can be restricted to barrier fogging of residential areas in times of very high vector abundance or disease risk and to protect communities where application of larvicides is logistically impossible. There is an emphasis on the use of environmentally acceptable chemicals for mosquito management.

Changes in agricultural practice (e.g. clearing vegetation in waterways and avoiding excessive irrigation), may also affect vector numbers. Land management to control breeding sites through engineering and drainage has been instituted. In addition to monitoring natural mosquito-breeding sites, local councils liaise with town planners to monitor and prevent mosquito breeding in waste-water treatment and disposal facilities, public works and land development projects such as residential, aquaculture, industrial and mining developments.

State and Territory health authorities assist regional authorities with mosquito monitoring. They also:

- provide funding, technical expertise, notification data, educational materials and training programs for local government personnel and other public and private parties who develop and operate mosquito management systems;
- provide funding for the establishment of new mosquito management programs;
- provide emergency mosquito management in the advent of an arbovirus disease outbreak or when there is a risk of disease transmission to humans;
- collaborate with industry towards the development of new mosquito management products and methods; and
- provide research funding for studies on prevention and management of arboviral disease.

Media campaigns

Most jurisdictions have developed educational material on mosquito avoidance and arbovirus disease. Media alerts are distributed in New South Wales, the Northern Territory, Queensland, South Australia and Victoria in response to MVE virus activity. The public is made aware of the health risks associated with mosquito bites and that mosquito bites and domestic breeding sites can be avoided or reduced. Self-protection mechanisms include the use of screens, knockdown aerosol sprays, residual insecticides and mosquito repellents. Information for the public is also available on ways to prevent the contamination of ground pools with organic matter generated from overflowing septic tanks or other waste-water. Human movement into areas of high breeding, for work or recreational purposes increases risk. The public is also advised of measures to avoid being bitten, for example, avoiding fishing at dusk and dawn, and avoiding camping in risk areas during months when the virus is likely to be present. Public access to high-risk areas may be temporarily closed.

Some jurisdictions have developed additional campaigns. As a result of recent activity, NSW Health is developing an emergency management plan for MVE that includes media releases and fact sheets for General Practitioners and the general public. In the Northern Territory a 'mozzie sickness alert' poster is distributed to communities, the Northern Territory tourist bureau, and is displayed in roadhouses. A Murray Valley encephalitis pamphlet is sent to the Northern Territory Tourism association for distribution to the general public. Annual media campaigns including mosquito and disease awareness advertisements are conducted by the THS through the MEB. In South Australia media releases from DHS regarding the risk of vector borne disease are sent out to the public at specific times of the year, such as prior to the Easter and Christmas holidays. In Western Australia a 'beat the bite' campaign is currently being developed to promote education regarding mosquito bites, particularly to school aged children. In addition, a culturally appropriate pictorial health alert has been developed by the UWA and the Kimberley Public Health Unit. This is issued to Aboriginal communities in the Kimberley, Gascoyne and Pilbara regions in association with the wider HDWA public warnings. These have been made available to other states in 2001. Mosquito awareness campaigns have been undertaken in primary schools in Western Australia and Victoria. In response to MVE activity in western Queensland in 2001, the TPHUN used newspaper bulletins and a poster to warn the public of risk and how to protect themselves from mosquitoes.

State-based strategic plans for MVE virus activity

Since 1990 a southern tri-State agreement has existed between the Health Departments of New South Wales, Victoria and South Australia and the Commonwealth Department of Health and Aged Care. All partners have agreed to co-operate and provide assistance in predicting and combatting outbreaks of mosquito-borne disease in south-eastern Australia. In addition, several jurisdictions have developed specific state-based strategic plans.

New South Wales

The New South Wales Arbovirus Disease Control Advisory Group provides advice on arbovirus disease issues and makes recommendations pertaining to surveillance and management activities to NSW Health. Membership of this group includes representatives from NSW Health, the New South Wales Department of Agriculture, local government, the Australian Institute of Environmental Health, the New South Wales Arbovirus Surveillance Program, infectious disease and virology experts and medical entomologists. The committee is chaired by the Director of Health Protection of NSW Health. A strategic plan for arbovirus disease control is being developed[44] and is available at: http://www.health.nsw.gov.au/health-public-affairs/greenpaper/index.html.

Through the New South Wales Arbovirus Surveillance Website (www.arbovirus.health.nsw.gov.au), the Department of Medical Entomology, ICPMR, has provided a comprehensive and readily available resource to the

general public on mosquitoes, mosquito management and mosquito-borne diseases.

Northern Territory

Contingency plans for mosquito control have been developed in the Northern Territory. Due to the vast areas of land affected by water during the wet season, it is impractical to control vectors over large areas or around many of the smaller towns and communities. Strategic plans to control mosquitoes during mosquito-borne disease outbreaks are restricted to high priority sites such as sewerage treatment facilities in smaller communities and swamps adjacent to large urban areas in Darwin and other major towns. Public awareness campaigns are important features in these strategies.

In the event of a mosquito-borne epidemic in Darwin, the Mosquito Control Advisory Committee meets and discusses control and public awareness measures. This committee consists of representatives of the Communicable Diseases Branch, the MEB, the Darwin City Council, a general practitioner and members representing the public and other interested groups. The contingency plan includes information on the organisation, cost and initiation of contingency measures. Additionally, a counter-disaster sub-plan provides further details regarding the control of mosquito vectors in the event of natural disasters, which may be associated with vector borne disease. There is also a Zoonosis Committee chaired by the Centre for Disease Control, Darwin, with representatives from MEB, DPI&F, NAQS, the Royal Darwin Hospital (laboratory and clinical services) and the Parks and Wildlife Commission.

South Australia

The Department of Human Services has convened a special working party to develop a strategic plan for mosquito control. This document has been drafted and is currently being distributed to key stakeholders (particularly local government bodies) for comment.

Western Australia

The State Arbovirus Control Committee (which includes representatives from HDWA, UWA, PathCentre, the Australian Defence Force, Agriculture WA and other national and international experts as required) has developed a contingency plan for Murray Valley encephalitis in Western Australia. The committee developed protocols to reduce exposure of humans to arboviral disease, to be implemented when surveillance systems provide an indication of activity of MVE virus. The protocols include the surveillance systems themselves, a notification procedure, the timing, severity and area to be covered by public warnings and control measures to be implemented. Control measures involve public education at several levels, source reduction and chemical control.

Victoria

A contingency plan for control of arbovirus disease has been developed by the Victorian Arbovirus Task Force.[45] The task force consists of representatives from DHS, the Department of Natural Resources and Environment, the Victorian Infectious Diseases Reference Laboratory and local government. The contingency plan details notification procedures for human cases, mosquito management procedures, surveillance in animals and a response strategy. The latter is based on prediction of epidemic years, based on both the Forbes and the Nicholls models. The plan is a step-by-step guide for personnel involved in an outbreak of arbo-encephalitis as well as detailing procedures used to predict MVE virus activity in the region.

National Strategies

The National Arbovirus Advisory Committee

The National Arbovirus Advisory Committee includes representatives from the Commonwealth Department of Health and Aged Care, State and Territory health departments, CSIRO, AQIS and academia. Laboratories involved with the diagnosis of both human and animal disease, epidemiologists, clinicians and entomologists are also represented on the committee. The NAAC is funded by the Commonwealth Department of Health and Aged Care, which also provides the secretariat. The NAAC is to report and make recommendations to the Communicable Diseases Network Australia on arbovirus surveillance and control.

Conclusions

This scoping exercise has identified a number of surveillance activities operating within Australia that provide information on MVE virus activity and drive public health action. The collation of information regarding these surveillance systems represents the first step in the process of building on our current strengths by recognising opportunities for collaboration and identifying gaps in the current approach. Further steps include addressing these gaps, strengthening old and building new collaborations and developing national approaches. While Murray Valley encephalitis is a relatively rare disease, its increasing incidence and the severity of the condition means we must be pro-active in our approach to ensure we have timely and effective mechanisms for detecting virus activity and delivering warning of this risk to the general public.

Strengthening national surveillance of MVE virus activity is a first step in ensuring that Australia is prepared to rapidly detect, contain or mitigate new or emergent arboviral diseases. The 1999 outbreak of encephalitis associated with West Nile virus in New York City[46] provides a number of valuable lessons regarding the management of arbovirus disease outbreaks, including the need to enhance awareness and training of clinicians, build public health resources and expertise, strengthen laboratory capacity, and improve communication between human and animal health authorities. The very nature of the life cycle of MVE virus and other arbovirus diseases requires that our prevention strategies are built on strong inter-sectorial communication between all stakeholders who have access to timely information on the complex ecology of arboviruses. The use of Web-based information and surveillance systems, including Geographical Information Systems, the further development of predictive models, and the development of comprehensive response plans will assist our ability to assess and manage the risk of important diseases.

Recommendations

Following the review of national surveillance and control mechanisms for Murray Valley encephalitis, the following recommendations can be made.

1. Evaluation and possible expansion of current sentinel animal surveillance mechanisms

This review of national surveillance and control mechanisms for Murray Valley encephalitis has allowed the identification of gaps in our current systems with the outlook to close these gaps in the future. It was not the aim of the current exercise to formally evaluate the existing surveillance mechanisms. All schemes may benefit from a formal appraisal, which may be carried out using the framework for evaluations published by the Centers for Disease Control, Atlanta.[47] Current sentinel animal systems for surveillance of MVE virus activity do not cover all areas where cases of Murray Valley encephalitis have been detected. National surveillance of MVE virus activity could be enhanced by development of sentinel chicken programs in these areas if, after review, these are deemed necessary.

2. Development of national reporting of animal and vector surveillance data

The development of a system for collation of national animal and vector surveillance data would ensure timely reporting and allow cross border comparisons. Development of a Website may represent a feasible option for such a system. This system should be co-ordinated and developed in consultation with key stakeholders, including a range of Commonwealth bodies, State and Territory health departments, virologists, clinicians, epidemiologists, entomologists, veterinarians and other animal health specialists.

3. Development of national human case reporting

Limited data on cases of Murray Valley encephalitis are currently collected on a national basis. While the development of the NNDSS will provide additional data, an enhanced data set could be developed for Murray Valley encephalitis with the flexibility to include other arboviruses. Nationally consistent case definitions, data fields and reporting procedures are important components of standardised case reporting. The surveillance system for human cases could be linked to the animal and vector surveillance system. Issues of confidentiality and security need to be addressed.

4. Establishment of a national strategic approach for Murray Valley encephalitis disease management and control

While some jurisdictions have developed strategic plans for outbreaks of Murray Valley encephalitis at the State and Territory level, it would be beneficial for a national body to develop a framework document providing guidance on the essential elements of response plans and identify multi-jurisdictional issues. Such strategic approaches could encompass all aspects of disease surveillance management and control and would consolidate and establish further inter-sectorial communication between key stakeholders. Strategies should address the issue of new or emerging arboviral disease.

5. Development of laboratory capacity and building public health resources

There is a perceived need to have a better quality assurance programme, and particularly a need to standardise reagents for MVE virus diagnosis. This should also extend to a comparison of the efficacy, sensitivity and specificity of various tests in use by different laboratories. Development of PCR based assays for the detection of MVE virus in pools of mosquitoes would provide more timely and cost effective surveillance, particularly if the methods can be developed to detect viruses in mosquitoes without the need for live collections.

Good communication between all stakeholders is essential. Systems to enhance clinicians' awareness of the clinical features of Murray Valley encephalitis should be explored, and could be incorporated into messages regarding the identification of other emerging arbovirus diseases. Methods for summarising and facilitating rapid and accurate communication of information to those who need to know should be explored. Such mechanisms may include disease modelling, GIS, electronic data transmission and Web-based reporting.

Acknowledgments

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