MOSQUITO-BORNE DISEASE AND MOSQUITO MANAGEMENT IN AUSTRALIA FOR THE OLYMPIC GAMES IN THE YEAR 2000

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Abstract - Mosquito-borne disease is an increasing concern in Australia. Endemic malaria has been eradicated but up to 1,000 infections are imported annually and local cases occur occasionally in the northeast, where local Dengue infections are reported annually and Japanese encephalitis virus has been introduced and caused deaths. Murray Valley encephalitis virus and/or Kunjin virus are active almost annually in the northwest and there are occasional human cases. Barmah Forest virus is increasing in distribution and activity with hundreds of cases recorded each year. Overall, Ross River virus is the most important pathogen, being active annually throughout the country and almost 40,000 cases reported for 1991-1998 with an increasing number of urban infections in all states. Provision of irrigation for agriculture, conservation of natural wetlands and construction of treatment wetlands, and development of residential areas near wetlands, have provided for increased contact between mosquitoes and humans in urban areas, and increased risk of disease. Management of mosquitoes is not well established or organised overall for urban communities, although there are examples of authorities being effective with individual or cooperative efforts using environmental and pesticide methodologies. There has been a concern for mosquitoes and mosquito-borne disease posing a threat for the Olympic and Paralympic Games to be held in Sydney in 2000. There is a perceived threat of exotic pathogens being imported with international visitors arriving for the Games and being transmitted by local mosquitoes. The site for the Games is being developed at Homebush Bay, Sydney, and the new sporting venues and residential areas are relatively close to extensive saline wetlands that are known to produce significant populations of pest mosquitoes and are being conserved for various environmental reasons. Local freshwater wetlands are also being enhanced, and constructed wetlands for water storage and treatment are being established at the site. The local mosquitoes have been intensively studied in recent years. There are important pest and vector species, such as *Aedes vigilax* and *Culex sitiens* in saline habitats, and *Culex annulirostris* and *Coquillettidia linealis* in freshwater habitats, and the period of greatest pest mosquito activity is from December through April. Restoration of tidal flushing in the mangroves, and runnelling the saltmarshes, will reduce numbers of saline mosquitoes. Appropriate design, water and vegetation management, and predatory fish, will mean the freshwater wetlands will produce fewer mosquitoes. Pesticide use will be minimised, with biorational agents such as *Bacillus thuringiensis israelensis* and methoprene preferred. The Olympic/Paralympic Games will be held in September/October 2000, prior to the pest mosquito 'season' in Sydney, and thus few mosquitoes should be evident. Additionally, although there is little evidence that humans acquire mosquito-borne disease in metropolitan Sydney, the arbovirus season in coastal regions of the state is January through May. There should be little or no concern for mosquitoes or mosquito-borne disease during the Games. Continuing recreational and residential use of the area beyond 2000 will require a commitment to continuing mosquito management at the site.
Key words - Arboviruses, vectors, wetlands, saltmarsh, constructed wetlands

INTRODUCTION

Australia has an interesting history and currency with mosquitoes and mosquito-borne disease, and this was recently reviewed in detail (Russell, 1998). There are 15 genera and more than 350 species of mosquito recorded, and a number of undescribed 'species'. The variety of species, and range of important pests and pathogens, reflect the diverse Australian environment. Important pests are found in temporary and permanent inland freshwater and coastal saline habitats, and rural and urban domestic environments, and malarial, filarial and arboviral pathogens are transmitted by various species in different climatic zones.

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In Australia, endemic malaria is eradicated, but transmission is still possible. Up to 1,000 cases of malaria are imported to the country annually, and occasional local transmission occurs (Bryan *et al.*, 1996; Brookes *et al*., 1997). The principal vector in the tropical north is *Anopheles farauti* Laveran s.l. although other species have been involved, and in the temperate south it appears *An. annulipes* Walker s.l. has been responsible for local cases.

Human filariasis was endemic in Queensland but was eliminated and is not a concern in Australia. However, dog heartworm has been an increasing problem with major veterinary (Carlisle and Atwell, 1984) and minor medical concerns (Russell, 1985), and various mosquitoes can be vectors in different regions (Russell, 1985; Russell and Geary, 1996).

More than 75 arboviruses from various families have been reported from Australia (Russell, 1995). The most important are Murray Valley encephalitis (MVE) and Kunjin (KUN) which can cause severe and (with MVE) fatal encephalitis (Marshall, 1988), and Ross River and Barmah Forest (BF) which cause severe polyarthritis (Kay and Aaskov, 1989). Alfuy, Dengue (DEN), Edge Hill, Gan Gan, Kokobera, Sindbis, Stratford and Trubanaman viruses also infect humans (Boughton, 1994; Mackenzie *et al.*, 1994), and the exotic Japanese encephalitis (JE) virus has appeared recently and caused fatalities (Ritchie *et al.* 1997).

The various vectors of the viruses were discussed by Russell (1995). A range of mosquitoes is involved, although the saltmarsh *Aedes camptorhynchus* (Thomson) and *Ae. vigilax* (Skuse) in coastal areas, and the freshwater *Ae. normanensis* (Taylor) and *Culex annulirostris* (Skuse) in the inland, are of particular concern and are associated with a number of viruses. Vertebrate hosts are known to a greater or lesser extent depending on the virus (Russell, 1995); DEN is associated with humans, MVE and KUN with wetland birds (e.g. herons), RR with native mammals (e.g. kangaroos), but there is little data on BF and both mammals and birds may be involved (Mackenzie *et al*., 1994; Russell, 1998).

Arboviruses. Arboviral activity has increased in recent years (Herceg *et al*., 1996). DEN is confined to northern Queensland, and there has been annual activity derived from introduced infections in recent years. The viruses causing encephalitis (MVE, KUN) are endemic in the northwest of the country where they are responsible for less than a handful of cases annually (although communities are small and widely dispersed, and high rates of subclinical infections are typical), and are intermittently active in the south where the major epidemics have occurred. The viruses causing polyarthritis (RR, BF) are active annually throughout the country (Mackenzie *et al*., 1998; Russell, 1998) and infect many humans. Studies in New South Wales (NSW) in the 1980s revealed evidence of arbovirus infection in 30%-40% of residents in some regions (Boughton *et al.*, 1984; Hawkes *et al*., 1985; Boughton *et al.*, 1990), and a study 10 years later indicated the rate of infection was increasing (Hawkes *et al.*, 1993).

The predominant arbovirus is RR. It is active annually and widespread throughout Australia, is transmitted by various mosquito species in different situations, and the epidemiology thus varies with region and circumstance (Russell, 1995, 1998). RR is endemic in all states but 'explodes' in local epidemics.. Case numbers have shown an overall increase in many areas in the past two decades; for 1991-98, almost 40,000 cases were reported nationally. The population of Australia is currently only approximately 18 million, and the national annual incidence rate of RR infection, from reported cases, varied between 14.4 and 50.3 per 100,000 population over 1991-1997.

RR is a significant public health concern. Because of under presentation and under reporting, the 5,000 p.a. national average understates the real incidence. Additionally, regional infection rates can be understated when large urban populations with little or no activity are included. Clinical surveys (Condon and Rouse, 1995; Selden and Cameron, 1996; Westley-Wise *et al*., 1996) have indicated that >50% of those infected with RR virus experience muscle and joint pain, >50% of these develop a debilitating polyarthritis which can preclude normal activities for months to years, and there can be a persisting lethargy. It has been estimated that the disease is costing tens of millions of dollars annually (Boughton, 1994).

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Arbovirus outbreaks are associated with increases in mosquito populations, and areas with greater arbovirus activity usually have more mosquito habitat and larger mosquito populations in closer contact with human communities. Human infections occur with residential, occupational or recreational exposure to mosquitoes, and the provision of irrigation for agriculture near towns, establishment of residential areas near natural wetlands, conservation of natural wetlands near urban areas, and installation of constructed wetlands in urban areas for storm- and waste-water treatment, are thereby a concern.

Although these arboviruses (with the exception of DEN) are associated typically with rural areas, there has been an increasing infiltration to the cities with cases now recorded for urban centres in all mainland states (Russell, 1998). With the increasing rural activity there has been an increase in human introduction of the virus to urban areas, where infections are often attributed to an increase in local contact with recognised periurban vectors such as *Ae. vigilax* and *Cx. annulirostris.* However, there is recent evidence that the domestic container-breeding *Aedes notoscriptus* (Skuse) may be an urban vector; it has been found naturally infected with RR virus in cities in NSW, the Northern Territory, and Queensland (Russell, 1998), and is able to transmit RR virus (Doggett and Russell, 1997; Watson and Kay, 1998) and BF virus (Doggett and Russell, 1997) in the laboratory.

MOSQUITO MANAGEMENT IN AUSTRALIA

Management of mosquito populations in urban communities in Australia is not well established or effectively organised overall, and health authorities have a tendency to emphasise public education and provide ‘early warnings’ as their principal measure to protect communities against outbreaks of mosquitoes/disease.

Most state authorities have developed routine and emergency plans involving distribution of pamphlets on mosquitoes and the diseases, and provision of information to the press and electronic media on preventive and protective measures. Additionally, in some States, there are organised mosquito control programmes that are more or less effective depending on locality and circumstance, but these are generally undertaken to allay nuisance biting and not specifically to reduce risk of disease.

The Northern Territory Department of Health has an integrated programme, with regional surveillance and routine monitoring, source reduction, and larval and adult control, liaison and coordination with developers, and public education (Whelan, 1989). This has lead to a decline in mosquito problems in Darwin and in other centres, and is the best example of a concerted approach by a State authority in Australia.

In Queensland, the Brisbane City Council program is the best example of a progressive and effective effort by a large single local authority to manage saltmarsh mosquitoes (Muller and McGinn, 1997). Elsewhere in the state, some adjoining municipalities have adopted a collaborative model, with a ‘Contiguous Local Authority Group’ (CLAG) providing for a regional approach to mosquito control (Bell, 1989). The southeastern Queensland CLAG represents the most effective joint local government action against mosquitoes in Australia.

In Western Australia, local authorities in some regions (e.g. the southwest) have combined to form CLAGs to provide surveillance and control of vector mosquitoes, and the State Department of Health provides finance to supplement funds provided by the member municipalities (Wright, 1992). In Victoria, the State Health Department provides matching funds to local authorities for mosquito surveillance/control. In South Australia, there is only very limited action by local authorities. In Tasmania there is essentially no mosquito control.

In NSW, the state Health Department funds extensive mosquito/arbovirus surveillance, but has no responsibility for mosquito control which is left to local authorities. With a few exceptions there is little action, although a recent government initiative may improve the situation; a discussion paper proposing options for a state strategy for mosquito-borne disease control has been released for public consideration and comment.

The control strategies vary with the above-mentioned programs. There is no routine adulticiding undertaken anywhere in Australia, although ULV fogging against adults is reserved by some authorities as the appropriate intervention for disease outbreaks. In general, it is the larval populations that are targeted for routine control, with both environmental management technologies and control agent applications. The bacterial product *Bacillus thuringiensis israelensis* (*Bti*) and the growth regulator methoprene have been the preferred agents in recent years, although methoprene use is limited by restrictive registration. The organophosphate temephos is no longer used on saltmarsh or in estuarine areas, because of its detrimental effect on development of some crustaceans (Mortimer and Chapman, 1995; Brown *et al*., 1996), but it is used in freshwater habitats in inland regions.

Habitat management has been utilised in saline wetlands, with ‘runnels’ (narrow and shallow spoon-shaped channels that follow natural drainage lines and connect isolated pools to the tidal source) constructed for estuarine saltmarshes. This technique was first implemented in northern NSW (Easton, 1986), and further developed in Queensland where there was minimal impact on the hydrology and plant and animal communities of marshes (Hulsman *et al*., 1989; Dale *et al*., 1993). It has now been used elsewhere in Australia and has often been effective, but it is not suitable for all sites and environmental regulations can restrict its use. Habitat management in freshwater wetlands has received little attention; however, there is an increasing recognition of the need to manage mosquitoes in these habitats, and the recently issued NSW government manual for constructed wetlands contains recommendations and guidelines for mosquito management (Russell and Kuginis, 1998).

When Sydney was awarded the Olympic Games for the year 2000, the major venues were to be included in the redevelopment of an area situated close to saline and freshwater wetlands that produced large numbers of pestiferous mosquitoes affecting surrounding residential suburbs. With no organised mosquito control program for Sydney, there was concern for the nuisance threat and risk of transmission of local and imported pathogens.

MOSQUITOES AND THE OLYMPIC GAMES

The development area. The site for the Olympic (and Paralympic) Games, is at Homebush Bay, on the major tidal river of the Sydney estuary. More than 700 hectares are involved in the development area, and international sporting facilities will share the site with commercial, recreational and residential developments. The area is adjacent to saline (mangrove and saltmarsh) wetlands, and there are also freshwater marshlands associated with two creeks. The wetlands produce large numbers of pest mosquitoes, some of which are important arbovirus vectors, although there is no known activity of mosquito-borne pathogens at the site.

Because the area has remnants of original Sydney ecosystems, the developers are required to rehabilitate degraded land and integrate it with natural and built environments. This has involved remediation of existing wetlands, with saline swamps and marshes being restored and enhanced, and a freshwater reed marsh removed during a floodway reconstruction being replaced by a similar wetland. Freshwater wetlands are also being constructed for control and treatment of storm- and wastewater, for irrigation water storage, for water features that include pools for fountains/cascades, and to provide habitat for a rare species of frog.

A strong suite of environmental guidelines has been formulated for the various developments, and the development of the area and the options and operations for mosquito management are being constrained by a number of environmental considerations.

Environmental constraints. The terrestrial and wetland ecosystems are significant remnants of original habitat of the area and require conservation for the flora and fauna they support. Additionally, a rare and endangered frog (*Litoria* sp.) has been discovered in the area, and there are efforts to preserve its sites, create additional habitats, and provide transit corridors for its dispersal.

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The terrestrial area has a eucalypt forest remnant and other locally rare communities that support a number of regionally rare woodland and grassland birds. The wetlands are direct descendants of original wetlands of the area, support Sydney's most significant populations of waterbirds, and provide for a number of migratory birds, including some from Alaska, Siberia and Scandinavia, covered by international agreements with Japan and China.

The health of the saline wetlands, the mangroves (*Avicennia* sp.) and the saltmarsh (*Sarcocornia* sp.) has been of concern for some years because of continuing degradation. There are other saltmarsh plants, including three (*Halosarcia* sp., *Lampranthus* sp., *Wilsonia* sp.) which are considered uncommon in NSW and are targeted for conservation.

Apart from passive recreation associated with the parkland, the wetlands are destined to have an educative role for school and other community groups. Boardwalks and bird hides, and various instructional features, will bring local, national and international visitors into close and informative contact with the various wetland habitats, and their mosquitoes.

To address the mosquito concerns, surveillance of the habitats was commissioned, with the objective of investigating the local mosquito fauna, providing a risk assessment, and developing environmentally acceptable strategies to minimise mosquito production.

Mosquito pests. Adult mosquito populations have been monitored by weekly trap sampling with dry ice-baited light traps at up to 30 sites from 1993-1999, and larval populations surveyed by weekly dip sampling at 27 saline and 60 freshwater sites. In total, 29 species from eight genera have been recorded from the area: *Aedeomyia* (1 species), *Aedes* (13 species), *Anopheles* (2 species), *Coquillettidia* (1 species), *Culex* (9 species), *Mansonia* (1 species), *Mimomyia* (1 species), *Uranotaenia* (1 species). Seasonal activity and relative abundance profiles have been established for the species of greatest concern as pests or disease vectors.

Four species exploited the saline wetlands and two, *Ae. vigilax* and *Cx. sitiens* Wiedemann, were abundant and major pests. The freshwater wetlands produced *Cx. annulirostris, Cx. australicus* Dobrotworsky and Drummond and *Coquillettidia linealis* (Skuse), and although *Cx. australicus* does not bite humans, the other two species were significant pests when abundant. The constructed wetlands produced various species depending on condition; with little vegetation *Ae. alboannulatus* (Macquart) was dominant, with dense emergent vegetation *Cx. annulirostris* predominated, and when floating vegetation proliferated *An. annulipes* s.l. became abundant. The period of greatest activity by pest species, and of greatest threat of pathogen transmission by vector species, was December through April.

Mosquito vectors. A number of the mosquitoes in the area are important vectors of disease pathogens, especially arboviruses. *Aedes vigilax* and *Cx. annulirostris* are both major vectors of RR and BF, and the latter is the most important vector of MVE and KUN. No viruses have been isolated from the mosquitoes collected at the Homebush sites, although BF virus has been isolated from *Ae. vigilax*, Stratford virus from *Ae. procax* (Skuse) and *Ae. notoscriptus*, and Edge Hill virus from *Ae. notoscriptus* collected in other areas of Sydney in recent years.

There are no confirmed cases of local arboviral infection in humans in urban areas adjoining Homebush, and (despite the above isolates) metropolitan Sydney is generally considered to be free of transmission of mosquito-borne disease. However, RR has been active in semi-rural outer urban areas, and various arboviruses are active in rural areas outside Sydney, and there is concern for introduction of arboviruses to urban Sydney, and for establishment in local mosquito populations through vertical transmission or in local vertebrate reservoirs.

The vertebrate hosts of MVE and KUN are water birds, and although there is suitable habitat in the area (and elsewhere in and near Sydney) for migratory water birds to introduce these (and other) viruses, neither MVE nor KUN has ever been identified from coastal regions in southeastern Australia. RR is associated with native mammals such as kangaroos and wallabies, and although there are no such animals in the area, there is a possibility that the virus could be introduced by viraemic humans acting as vertebrate hosts.

There is a potential for exotic mosquito-borne pathogens to arrive with international visitors. Malaria is not a concern for establishment in Sydney; although local transmission could be possible if a parasitaemic visitor encountered large numbers of *An. annulipes* s.l. during summer months. Of more concern is the potential for introduction of an exotic arbovirus, although appropriate mosquito vectors must be present and abundant to provide a serious risk of transmission. DEN imported with humans from Asia or the Pacific cannot be transmitted in Sydney as the vector *Ae. aegypti* (L.) does not exist outside the northern state of Queensland. However, vectors do exist for other exotic viruses, e.g. *Cx. annulirostris* can transmit JE from Asia, and *Ae. notoscriptus*, *Ae. vigilax* and *Cx. annulirostris* can transmit Rift Valley fever virus from Africa, although these species are abundant in Sydney generally only through the summer months.

For effective transmission of local or exotic pathogens to occur in Sydney, abundance and longevity of the mosquito vectors are critical issues. These relate not only to availability of suitable habitat, but the environmental and seasonal conditions which are limiting in the temperate climate. Notwithstanding that there are various issues involved, vector abundance is an important determinant and is most readily minimised by mosquito control practices.

Mosquito control. Management of the mosquito populations has to be via an 'environmentally friendly' approach to conform to the overall development philosophy. The integrated environmental management strategy that has been proposed and accepted is based on: (i) restoration of tidal flushing of the mangroves providing a regular tidal interchange through the saline wetlands will remove much of the stagnant water; this will improve the health of the mangrove and saltmarsh plant communities, and reduce impounded habitat for the *Ae. vigilax* and *Cx. sitiens* mosquitoes; (ii) runnelling of the saltmarshes; constructing runnels on the saltmarshes (once the impact of the penetrating tides is evident) will allow natural dewatering and entry of predators to the saltmarsh depressions that provide habitat for *Ae. vigilax* and *Cx. sitiens*; (iii) appropriate construction and maintenance of freshwater wetlands; recommending design features such as steep sides and substantial depth, and ensuring management of water and vegetation, along with the establishment of larvivorous fish, will minimise populations of *Cx. annulirostris* and *Cq. linealis*; (iv) judicious use of biorational control agents; applying biorational larvicides will reduce extraordinary populations; *Bti* is the first choice agent; methoprene is an alternative and complementary biorational agent, but it has limited registration and slow release formulations are not available; products of *Bacillus sphaericus* would be useful against *Culex* species in wastewater wetlands but are not registered locally; (v) complementary use of larvivorous fish; establishing predatory fish in the wetlands will supplement environmental control measures; the 'mosquitofish' *Gambusia* sp. is in the area, but is considered a noxious species and its introduction into new sites is not allowed. Native species, such as Blue-eye (*Pseudomugil* sp.) and gudgeons (*Hypseleotris* spp.) are being considered for use in brackish and freshwater habitats, respectively, but exclusion of *Gambusia* may be impossible.

If the above-mentioned strategy is implemented and pursued, there are good prospects that the major pest mosquito populations can be successfully managed and minimised.

Prospects. The Games will be held during September/October 2000, and even without any active mosquito control, it is unlikely that there would be noticeable mosquito activity at that (early Spring) time of the year. The major saline pest *Ae. vigilax* overwinters as eggs and usually does not reach nuisance levels until December and the beginning of summer; the secondary saline pest *Cx. sitiens* disappears over winter and usually does not become abundant before January. Of the freshwater species, *Cx. annulirostris* and *Cq. linealis* are most likely to be pests; the former overwinters as quiescent adults, adults of the latter also disappear over winter, and neither species is common before January. Pest activity has generally ceased by May, with the arrival of cool conditions. Additionally, although there is little evidence of transmission of mosquito-borne pathogens in metropolitan Sydney, the arbovirus season for coastal regions of the state is generally from January through May, months after the Games.

Although the area is being developed as a priority for the Games, the mosquito management proposals have been designed to also provide for users of the area beyond the year 2000. Following the Games, the area will continue to host major sporting and other events, and with the establishment of parklands and other facilities the whole area will be an important recreation destination for the Sydney community. The village that is being constructed on the site for the Games athletes and officials will become a residential area under a municipal authority, and there will be a substantial community within the area. For the local community and adjacent urban areas, a concern over the mosquito threat will continue.

It has been accepted by the responsible government authority that with the preservation of 'natural' wetlands and the construction of 'artificial' wetlands, there will continue to be mosquito production in the area and, notwithstanding the efforts to institute environmental controls, it is likely there will be a requirement for occasional interventions with pesticides. It has been emphasised that mosquito surveillance must be a critical component of the ongoing management program, and the extent of additional anti-mosquito operations (e.g. pesticide applications) will be dependent on the effectiveness of the environmental management strategies, and the continued maintenance of the field operations.

CONCLUSION

With respect to Sydney and the Olympic Games in the Year 2000, there should be little concern for nuisance mosquitoes at the Homebush site, or for the transmission of local or exotic mosquito-borne pathogens imported with international visitors at the time of the Games. However, because of the continuing heavy recreational and residential usage planned for the area, maintenance of the anti-mosquito measures designed for the various habitats, and surveillance of the various mosquito populations, will have to continue in order to sustain the current mosquito minimisation objectives for the years beyond 2000.

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