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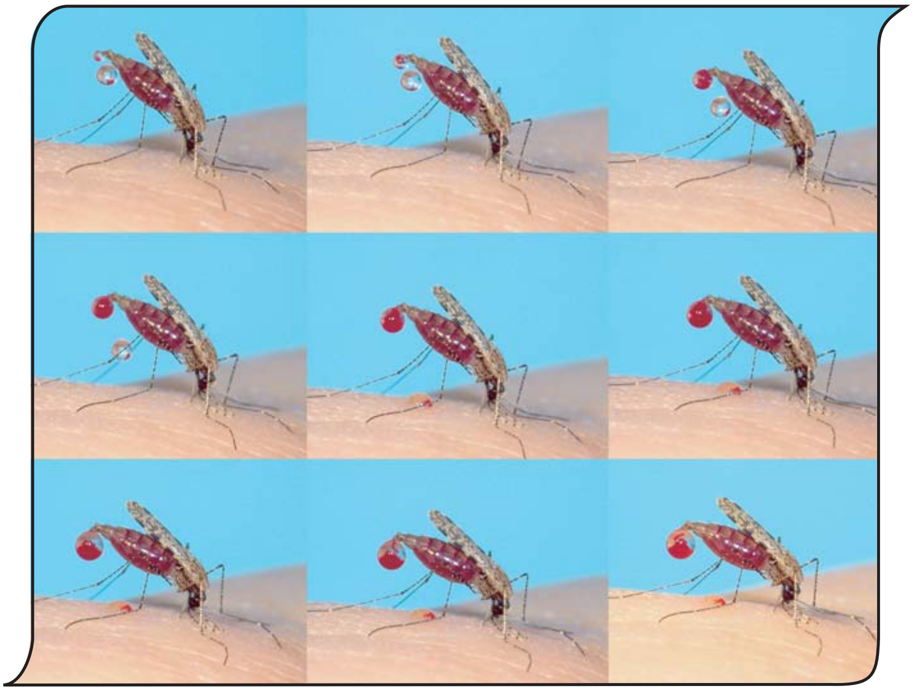
THE NEW SOUTH WALES ARBOVIRUS SURVEILLANCE & MOSQUITO MONITORING PROGRAM

2004-2005 Annual Report



Anopheles annulipes bloodfeeding

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Authorised by
ARBOVIRUS DISEASE CONTROL ADVISORY GROUP, NSW HEALTH.

NSW HEALTH

EXECUTIVE OVERVIEW

- **For the 2004-2005 season**, the NSW Arbovirus Surveillance Program: (i) Monitored mosquito vector populations and undertook surveillance of arbovirus activity on the NSW western slopes and plains, far north coast region and metropolitan Sydney. (ii) Monitored flavivirus transmission through the testing of sentinel chickens across inland NSW. The majority of sites operated between November and May.

- **The dry conditions** during the two previous seasons continued for much of 2004-2005. For most of the NSW inland region, there was only average rainfall during the second half of 2004 and conditions became especially dry in early 2005 for the northwest. The coastal strip suffered from similar low rainfall patterns, although above average rainfall fell during the last quarter of 2004 for the entire strip and during early 2005 for the mid-north coast.

- **For the inland**, the low rainfall patterns meant that mosquito numbers were well below normal. Likewise, there was minimal arbovirus activity; there were neither viral isolates from the mosquitoes nor seroconversions in the sentinel chickens. The total of 110 human case notifications from the inland (87 RRV & 33 BFV) was well down upon the average of 282 (264 RRV & 18 BFV) for the previous ten seasons.

- **Monitoring along the coast** was expanded to include several sites around the Port Macquarie area. These were added due to the recent annual activity of BFV in the region and, for this reason, the mosquitoes were also processed for virus. Mosquitoes, despite being abundant along the coast, were not exceptionally greater than normal. There was however, several viral isolates. These included 1 RRV from Ballina (from *Coquillettidia linealis*), 1 RRV from Port Macquarie (*Ochlerotatus vigilax*) and 11 RRV from Port Stephens (6 from *Ochlerotatus vigilax*, 3 from *Ochlerotatus procax*, and one each from *Culex molestus* and *Ochlerotatus multiplex*).

- **Barmah Forest virus (BFV)** continues to be active along the north coast for the fifth season running, with most disease notifications occurring within the Mid-North Coast (211 cases) and Northern Rivers AHSs (126). These regions produced over 77% of all BFV reports for NSW. The total of 436 BFV notifications for NSW is the greatest number of cases recorded to date within the state, and the 373 cases for the coast north of Sydney represents the second largest documented outbreak of BFV in Australia. RRV was also active along the coast, with a total of 327 cases, slightly down upon the previous ten seasons' average of 377.

- **For the Sydney trapping locations**, mosquito numbers were relatively low with the dry summer. Human notifications from the region were lower than normal (32 compared with the previous ten seasons average of 74), although there was one isolated of Stratford virus made at Wheeney Creek within the Hawkesbury region from *Ochlerotatus procax*.

- **The NSW Arbovirus Surveillance Web Site** http://www.arbovirus.health.nsw.gov.au/ continued to expand and now has over 159MB of information with 1,260+ pages.

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NSW ARBOVIRUS SURVEILLANCE AND MOSQUITO MONITORING PROGRAM 2004-2005

INTRODUCTION

The aim of the Program is to provide an early warning of the presence of Murray Valley encephalitis virus (MVEV) and Kunjin (KUNV) viruses in the state in an effort to reduce the potential for human disease. In addition, the Program compiles and analyses mosquito and alphavirus, especially Ross River (RRV) and Barmah Forest (BFV) viruses, data collected over a number of successive years. This will provide a solid base to determine the underlying causes of the seasonal fluctuations in arbovirus activity and the relative abundance of the mosquito vector species with the potential to affect the well being of human communities. This information can then be used as a basis for modifying existing local and regional vector control programs, and in the creation of new ones.

METHODS

Background

Arbovirus activity within NSW has been defined by the geography of the state and three broad virogeographical zones are evident: the inland, the tablelands and the coastal strip (Doggett 2004). Within these zones there are different environmental influences (e.g. irrigation provides a major source of water for mosquito breeding inland, while saltmarshes along the coast are highly productive), different mosquito vectors, different viral reservoir hosts and even different mosquito borne viruses (e.g. MVEV and KUNV occur only in the inland, while BFV is active mainly on the coast). As a consequence, arboviral disease epidemiology of is often vastly different and thus the surveillance program is tailored around these variables.

Arbovirus surveillance can be divided into two categories: those methods that attempt to predict activity and those that demonstrate viral transmission. Predictive methods include the monitoring of weather patterns, the long-term recording of mosquito abundance, and the isolation of virus from vectors. Monitoring of rainfall patterns, be it short term with rainfall or longer term with the Southern Oscillation, is critical as rainfall is one of the major environmental factors that influences mosquito abundance; generally the more rain, the higher the mosquito numbers. The long-term recording of mosquito abundance can establish baseline mosquito levels for a location (i.e. determine what are normal populations), and this allows the rapid recognition of unusual mosquito activity. The isolation of virus from mosquito vectors can provide the first indication of which arboviruses are circulating in an area. This may lead to the early recognition of outbreaks and be a sign of the potential disease risks to the community. Virus isolation can also identify new viral incursions, lead to the recognition of new virus genotypes and identify new vectors. Information from vector monitoring can also reinforce and strengthen health warnings of potential arbovirus activity.

Methods that demonstrate arboviral transmission include the monitoring of suitable sentinel animals (such as chickens) for the presence of antibodies to particular viruses (e.g. MVEV and KUNV within NSW) and the recording of human cases of disease. Sentinel animals can be placed into potential 'hotspots' of virus activity, and as they are continuously exposed to mosquito bites, may indicate activity in a region before human cases are reported. Seroconversions in sentinel flocks provide evidence that the level of virus in mosquito populations is high enough for transmission to occur.

The monitoring of human cases of arboviral infection has little direct value for surveillance, as by the time the virus activity is detected in the human population, often not much can be done to control the viral transmission. Via the other methodologies, the aim of the surveillance program is to recognise both potential and actual virus activity before it impacts greatly on the human population so that appropriate preventive measures can be implemented. The recording of human infections does however provide important epidemiological data and can define the locations where surveillance should occur.

These methods of surveillance are listed in order; generally with more rainfall comes more mosquito production. The higher the mosquito production, the greater the probability of enzootic virus activity in the mosquito/host population. The higher the proportion of virus infected hosts and mosquitoes, the greater the probability of transmission and thus the higher the risk to the human population. The NSW Arbovirus Surveillance and Mosquito Monitoring Program undertakes the first four methods of arbovirus surveillance and the results for the 2004-2005 season follow.

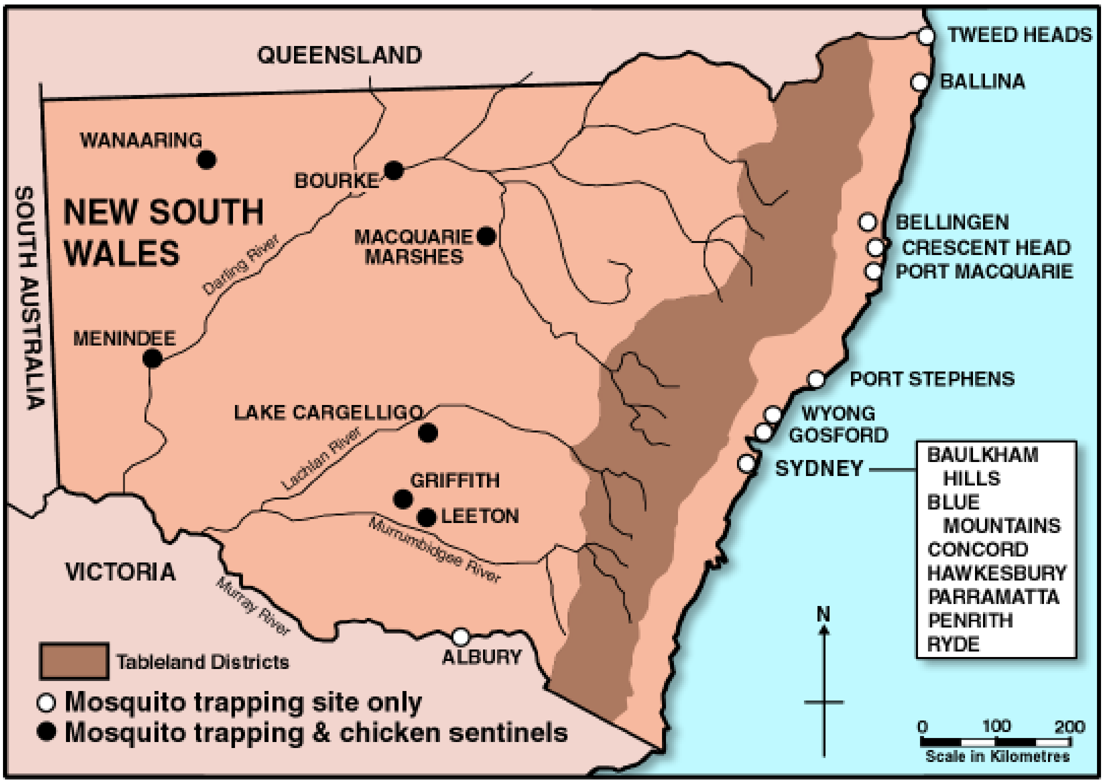


Fig 1. Mosquito trapping locations and Sentinel Chicken sites, 2004-2005.

MONITORING LOCATIONS

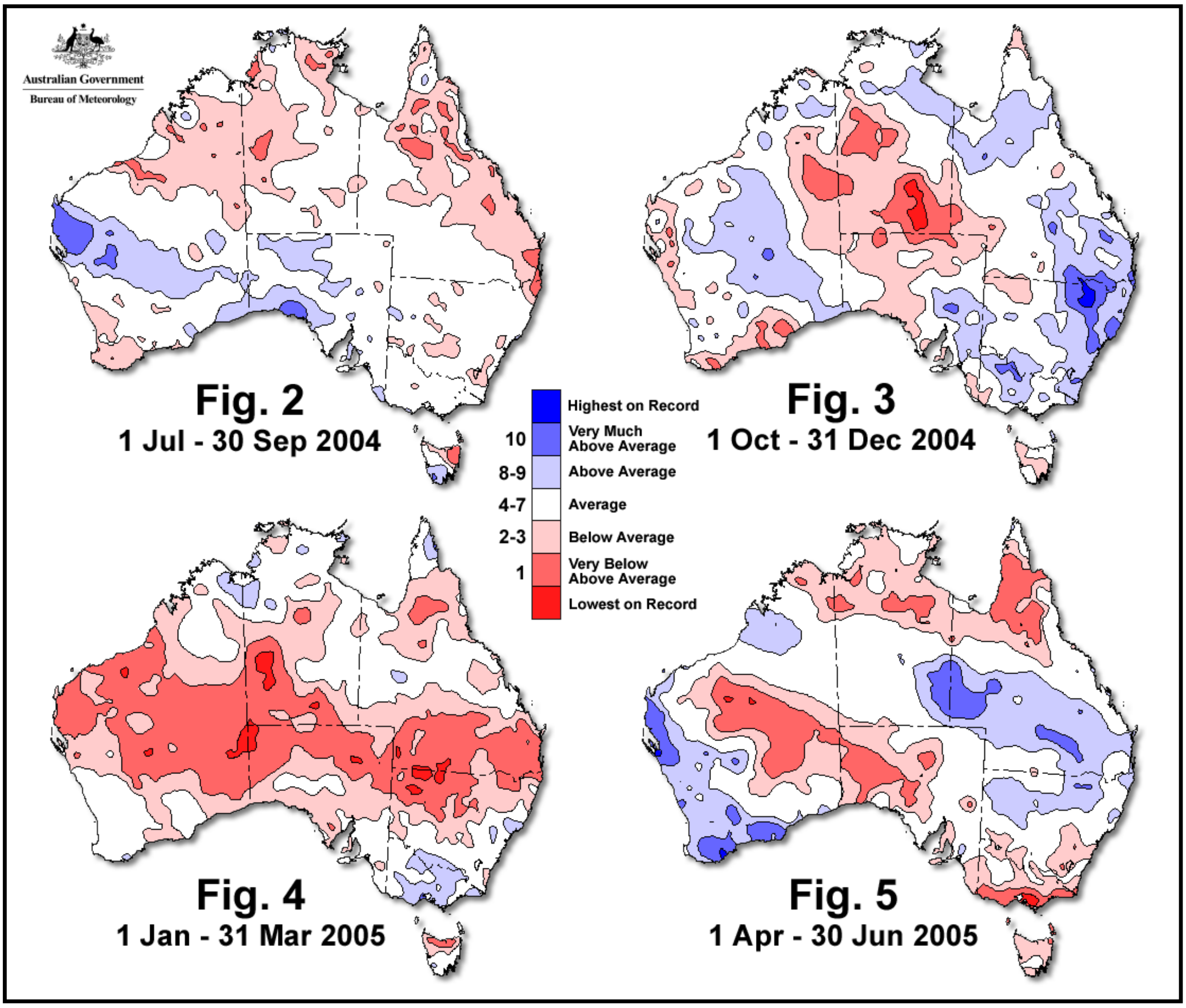
http://www.arbovirus.health.nsw.gov.au/areas/arbovirus/location/locations.htm

For 2004-2005, mosquito-trapping sites were operated at 7 inland, 8 coastal and 7 Sydney locations (Fig 1). Chicken sentinel flocks were located at 7 sites.

WEATHER DATA

http://www.arbovirus.health.nsw.gov.au/areas/arbovirus/climate/climate.htm

Mosquito abundance is dictated principally by rainfall patterns and irrigation practices in inland regions, while in coastal regions tidal inundation along with rainfall is important. Temperature and/or day-length are often critical in determining the initiation and duration of mosquito activity for species in temperate zones. Hence, the monitoring of environmental parameters, especially rainfall, is a crucial component of the Program.



Figures 2-5. Australian Rainfall deciles for the 3 month periods, Jul-Sep 2004, Oct-Dec 2004, Jan-Mar 2005 & Apr-Jun 2005. The stronger the red, the drier the conditions. Conversely, the stronger the blue, the wetter the conditions. *Modifed from the Australian Bureau of Meterology, 2005*.

The conditions leading up to the season of 2003-2004 were of very low precipitation.

These dry conditions were not alleviated during the second half of 2004 for much of the state. The third quarter (i.e. Jul-Sep 2004) of 2004 had average rainfall (Figure 2), and while the last quarter of the year saw some heavy rainfall along the coast, much of the inland stayed relatively dry (Figure 3). The first quarter of 2005 saw a worsening of the drought situation in the northwest inland, with some areas experiencing record low rainfall (Figure 4). These dry conditions extended to the Murray region by the second quarter of 2005 (Figure 5), although pockets in the north received some good rainfall. Some above average rainfall was recorded along the mid-north coast during January, otherwise the coastal strip remained relatively dry during early 2005.

As per 2003-2004, the dry conditions meant that warmer weather prevailed and temperatures were well above average for the entire 2004-2005 season. In fact only December 2004 experienced below average temperatures for the entire state.

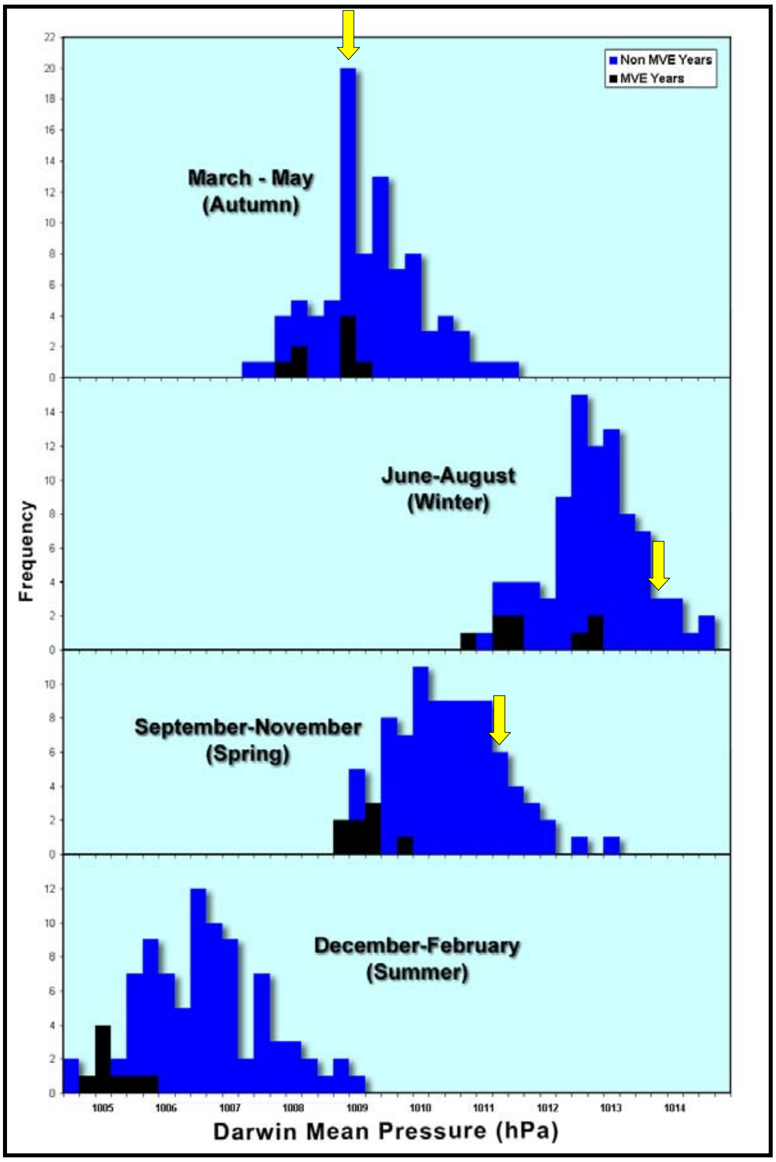


Figure 6. The SO by seasons prior to MVEV active years, according to Nicholls (1986), updated up to Winter 2005. The black bars represent the pre-MVEV active seasons. The yellow arrows indicate the respective seasons SO values relevant to the 2004-2005 season.

MVEV Predictive Models

Two models have been developed for the prediction of MVEV outbreaks in southeastern Australia; the Forbes' (1978) and Nicholls' (1986) models.

Forbes associated rainfall patterns with the 1974 and previous MVEV endemics, and discussed rainfall in terms of 'decile' values. A decile is a ranking based on historical values. The lowest 10% of all rainfall values constitute decile 1, the next 10% make up decile 2, and so on up to the highest 10% of rainfall constituting decile 10. Thus, the higher the decile value, the greater the rainfall.

Forbes' hypothesis refers to rainfall levels in the catchment basins of the main river systems of eastern Australia. These include:

- The Darling River system,
- The Lachlan, Murrumbidgee & Murray River systems,
- The Northern Rivers (that lead to the Gulf of Carpentaria), and
- The North Lake Eyre system.

The hypothesis states that if rainfall levels in these four catchment basins are equal to or greater than decile 7 for either the last quarter of the previous year (eg. October-December 2003) or the first quarter of the current year (January-March 2004) and the last quarter of the current year (October-December 2004), then a MVEV outbreak is probable.

Rainfall was not above decile 7 for all the catchment basins for the last quarter of 2003, the first quarter of 2004 or the last quarter of 2004. Thus, Forbes' hypothesis was not satisfied for the 2004-2005 season. As rainfall was also not above decile 7 in all the catchments for the first quarter of 2005, Forbes hypothesis would suggest that an MVEV outbreak in southeastern Australia would be unlikely for the 2004-2005 season.

Nicholls' hypothesis uses the Southern Oscillation (SO) as a tool to indicate a possible MVEV epidemic. He noted a correlation between past outbreaks of MVEV and the SO (as measured by atmospheric pressures at Darwin in mm) for the autumn, winter and spring period prior to a disease outbreak. For the autumn, winter and spring periods of 2004, the SO values of 1009.20mm, 1013.93mm and 1011.27mm respectively (indicated on Figure 6 by the yellow arrows), were all outside the range of values for the same period of past MVEV outbreak years (Figure 6). Likewise, the summer 2004–2005 SO value of 1007.60mm was also much higher than that experienced during MVEV years. Currently, the autumn and winter Nicholls' values for 2005 are 1010.47mm and 1012.93mm, respectively, and while the winter figure is in the range of past MVEV outbreak years, the autumn value is not.

MOSQUITO MONITORING

Methods

Mosquitoes were collected overnight in dry-ice baited Encephalitis Vector Surveillance type traps. They were then sent live in cool, humid Eskies via overnight couriers to the Medical Entomology Unit, Centre for Infectious Diseases and Microbiology (CIDM), Institute of Clinical Pathology and Medical Research (ICPMR), Westmead for identification and processing for arbovirus isolation. The mosquitoes were identified via taxonomic keys and illustrations according to Russell (1993, 1996), Dobrotworsky (1965) and Lee *et al*. (1980 – 1989). A brief description of the main mosquito species for NSW appears in Appendix 2.

Mosquito abundances are best described in relative terms, and in keeping with the terminology from previous reports, mosquito numbers are depicted as:

- 'low' (<50 per trap),
- 'moderate' (50-100 per trap),
- 'high' (101-1,000 per trap),
- 'very high' (>1,000 per trap), and

- 'extreme' (>10,000 per trap).

All mosquito monitoring results (with comments on the collections) were placed on the NSW Arbovirus Surveillance Web site, and generally were available within 1-2 days of receiving the sample into the laboratory. Access to each location's result is from: **http://www.arbovirus.health.nsw.gov.au/areas/arbovirus/results/results.htm**.

Results

Overall, 121,907 mosquitoes representing 59 species were collected in NSW during the 2004-2005 season. *Culex annulirostris* and *Anopheles annulipes* were the most abundant and most important of the inland mosquito species during the summer months, whereas *Ochlerotatus vigilax*, *Culex annulirostris*, *Culex sitiens, Coquillettidia linealis* and *Ochlerotatus notoscriptus* were the most numerous species on the coast. A full summary of the results on a location-by-location basis is included in Appendix 1 and the complete mosquito monitoring results are available on the NSW Arbovirus Surveillance web site.

Inland

Mosquito populations across the inland continued to be well down with the drought conditions with a total of 23,719 mosquitoes, comprising 20 species. *Culex annulirostris* was the dominant species trapped at most sites and comprised 78% of the total inland collections. *Anopheles annulipes* (10%) was the next most common species.

Coastal

This season included additional trapping sites around the Port Macquarie region and the overall mosquito collections were similar in abundance to the previous season. In total, 83,175 mosquitoes comprising 54 species were collected from coastal NSW. The most common species collected were *Ochlerotatus vigilax* (31.3% of the total coastal mosquitoes trapped), *Culex annulirostris* (12.6%), *Coquillettidia linealis* (8.3%) and *Culex sitiens* (7.8%).

Metropolitan Sydney

Mosquito collections from Sydney totalled around double that of the previous season, mainly due to the additional sites at Baulkham Hills, which had several 'high' collections and a broad species diversity (28 species). A total of 20,978 mosquitoes, comprising 37 species, was collected from metropolitan Sydney. *Culex annulirostris* (25.5% of the total Sydney mosquitoes trapped) was the most common species followed by *Ochlerotatus vigilax* (25.3%) and *Ochlerotatus notoscriptus* (22.3%).

ARBOVIRUS ISOLATIONS FROM MOSQUITOES

http://www.arbovirus.health.nsw.gov.au/areas/arbovirus/about/methods.htm

Methods

Only mosquitoes collected from the inland and some Sydney sites were processed for viruses. Viral isolation methods were as per earlier annual reports (Doggett *et al*., 1999a, 2000). Assays were used to identify any suspected viral isolate, and can identify the alphaviruses - BFV, RRV and Sindbis (SINV), and the flaviviruses - MVEV, KUNV, Alfuy (ALFV), Edge Hill (EHV), Kokobera (KOKV) and Stratford (STRV). Any isolate that was not identified by the assays was labelled as 'unknown'. A short description of the various viruses and their clinical significance is detailed in Appendix 3.

Positive results were sent to Dr Jeremy McAnulty, Director, Communicable Diseases Branch, NSW Health, to the relevant Public Health Unit, and posted on the NSW Arbovirus Surveillance Web Site (under 'Mosquito/Chicken Results') and under each locations' surveillance results.

Results

http://www.arbovirus.health.nsw.gov.au/areas/arbovirus/results/virusisolates.htm

Of the mosquitoes processed, there were 17 viral isolates. These are listed in Table 1.

Table 1. Arbovirus Isolates, 2004-2005.

LOCATION - Site	Date Trapped	Mosquito Species	RRV	STRV	Virus?	TOT
BALLINA – Lennox Heads	8/Mar/05	*Coquillettidia linealis*	1			**1**
PORT STEPHENS - Karuah	8/Mar/05	*Ochlerotatus vigilax*	1			**1**
PORT STEPHENS - Heatherbrae	8/Mar/05	*Ochlerotatus procax*	3			**3**
HAWKESBURY – Wheeney Ck	17/Mar/05	*Culex annulirostris*			1	**1**
PORT STEPHENS - Saltash	22/Mar/05	*Ochlerotatus vigilax*	1			**1**
PORT STEPHENS - Karuah	22/Mar/05	*Ochlerotatus vigilax*	2			**2**
PORT STEPHENS - Heatherbrae	22/Mar/05	*Ochlerotatus vigilax*	1			**1**
PORT STEPHENS - Karuah	5/Apr/05	*Culex molestus*	1			**1**
PORT STEPHENS - Karuah	5/Apr/05	*Ochlerotatus multiplex*	1			**1**
PORT STEPHENS - Karuah	5/Apr/05	*Ochlerotatus vigilax*	1			**1**
HAWKESBURY – Wheeney Ck	7/Apr/05	*Ochlerotatus procax*		1		**1**
PORT MACQUARIE – Lord St	19/Apr/05	*Ochlerotatus vigilax*	1			**1**
PORT STEPHENS - Heatherbrae	3/May/05	*Ochlerotatus multiplex*			1	**1**
PORT STEPHENS - Saltash	24/May/05	*Ochlerotatus multiplex*			1	**1**
TOTAL			**13**	**1**	**1**	**17**

RRV = Ross River virus, STRV = Stratford virus, Virus? = unknown (not MVEV, KUNV, EHV, STRV, KOKV, RRV, BFV or SINV)

SENTINEL CHICKEN PROGRAM

http://www.arbovirus.health.nsw.gov.au/areas/arbovirus/about/chickenmethods.htm

Location of flocks

The 2004-2005 season began on November 12th 2004 with the first bleed and ended on April 19th 2004 with the last. For 2004-2005, seven flocks each containing 15 Isa Brown pullets were deployed at Bourke Griffith, Lake Cargelligo, Leeton, Macquarie Marshes, Menindee and Wanaaring (Figure 1).

Methods

The NSW Chicken Sentinel Program was approved by the WSAHS Animal Ethics committee. This approval requires that the chicken handlers undergo training to ensure the chickens are cared for appropriately and that blood sampling is conducted in a manner that minimises trauma to the chickens. The chickens are cared for and bled by local council staff and members of the public. Laboratory staff, under the supervision of a veterinarian, are responsible for training the chicken handlers. A veterinarian (usually the Director of Animal Care at Westmead, Dr Ross Mathews) must inspect all new flock locations prior to deployment to ensure animal housing is adequate. Existing flocks are inspected approximately every two years. The health of each flock is reported weekly, and is independently monitored by the Animal Ethics Committee via the Director of Animal Care.

Full details of the bleeding method and laboratory testing regimen were detailed in the 2003-2004 NSW Arbovirus Surveillance Program Annual Report (Doggett *et al*. 2004).

Results are disseminated via email to the relevant government groups as determined by NSW Health and are placed on the NSW Arbovirus Surveillance website. Confirmed positives are notified by telephone to NSW Health and Communicable Diseases Network, Australia (CDNA).

Results

The season began with 105 pullets. The flocks at Leeton and Griffith recorded 17 deaths through the season. The chickens in these locations were meat producing birds rather than layers, which are the preferred bird. Birds grown for meat production are selected to rapidly gain weight and so require a different diet to layer hens. The average life span for a meat producing bird is 12 weeks. If these birds are kept longer they will continue to put on weight causing damage to legs and joints. An autopsy demonstrated that the birds diet was inappropriate and it was suffering was various deficiencies. It was also noted that it was a meat producer had had been kept for 6 months (twice its normal life span). This was the first time that meat producers had been used and only two locations used these birds – both locations sustained significant losses. Both locations fed the birds layer pellets rather than a suitable feed for meat producers, which would have contributed, to dietary deficiencies. Veterinary advice indicates that these birds are not suitable for the programme and that in future only layer hens should be used. The Isa Brown birds have been successfully used elsewhere in the state and where possible these should be used.

A total of 1,899 samples were received from the seven flocks in NSW over the six-month period in 2004-2005. This represented 3,798 ELISA tests (excluding controls and quality assurance samples), with each specimen being tested for MVEV and KUNV antibodies.

There were no seroconversions to MVEV or KUNV. Likewise, no cases of MVEV or KUNV disease were detected in humans in NSW, Victoria or South Australia in 2004-2005.

HUMAN NOTIFICATIONS

http://www.arbovirus.health.nsw.gov.au/areas/arbovirus/human/human.htm

Table 2 contains the number of laboratory notifications of human RRV and BFV disease by former Area Health Service (AHS) for NSW. The former AHSs data were used, rather than the current, to allow for a comparison of notification trends over time. Note that these are laboratory notifications based on a single IgM positive specimen, and may not always represent infections from this season, as IgM may persist for long periods.

The total number of notifications for the period July 2004 to June 2005 was 919 (including 436 BFV, 437 RRV and 46 'other' arboviral notifications) and this was very close to the average for the previous five seasons of 923, and not dissimilar to the ten-year average of 986 notifications. The coastal region accounted for 790 (86%) of the BFV and RRV notifications, which was slightly above the average (729) for the previous five seasons. The 127 notifications (14%) from the inland were well below the previous five year seasonal average of 195. Within the Sydney region there were 52 cases reported, again below the five-seasonal average of 64.

The Mid-North Coast Area Health Service received the highest number of notifications (358) with the Northern Rivers Area Health Service having 216 reports. Combined, these two areas accounted for over 62% of all the arbovirus notifications for the state.

Table 2. Arbovirus disease notifications according to former Area Health Service, July 2004 - June 2005.

Month	CS	NS	WS	WE	SW	CC	HU	IL	SE	NR	MN	NE	MA	MW	FW	GM	SA	Total
RRV	2	2	1	9	3	9	73	3	6	84	146	33	12	8	14	20	12	**437**
BFV	1	3	2	2	0	4	41	5	1	126	211	14	2	0	1	16	7	**436**
Other	3	4	2	1	3	0	3	0	7	6	1	2	0	2	0	3	7	**46**
Total	**6**	**9**	**5**	**12**	**6**	**13**	**117**	**8**	**14**	**216**	**358**	**49**	**14**	**10**	**15**	**39**	**26**	**919**

CS = Central Sydney, NS = Northern Sydney, WS = Western Sydney, WE = Wentworth, SW = South Western Sydney, CC = Central Coast, HU = Hunter, IL = Illawarra, SE = South Eastern Sydney, NR = Northern Rivers, MN = Mid North Coast, NE = New England, MA = Macquarie, MW = Mid Western, FW = Far Western, GM = Greater Murray, SA = Southern Area.

DISCUSSION

The dry conditions that began in the summer of 2000-2001 continued through into the 2004-2005 season. Rainfall was around above average in the second half of 2004 for inland NSW, however the northwest became exceptionally dry during the first quarter of 2005. Not surprisingly, mosquito numbers across the inland were again low, with minimal arboviral activity as shown by the lack of mosquito isolates and sentinel chicken seroconversions. Human notifications were reflected in the low mosquito and arboviral activity; the total of 120 cases (Table 4) was less than half that of the previous ten seasons' average of 281.5. Over the last decade there has been a general decline in arboviral notifications across the inland with the ongoing drought conditions. From 1994/95 to 1998/99 there was a seasonal average of 369.8, whereas during 1999/2000 to 2003/04 this had dropped to 193.2.

Table 4. Notifications of BFV & RRV disease per virogeographic regions of NSW, per season from 1994/95 to 2004/05 (*after Doggett 2004 & Doggett & Russell 2005*).

Season	BFV				RRV			
	Coastal Cases[1]	Inland Cases[2]	Sydney[3]	Total	Coastal Cases[1]	Inland Cases[2]	Sydney[3]	Total
94/95	233	8	7	**248**	163	45	14	**222**
95/96	141	9	3	**153**	399	511	32	**942**
96/97	155	19	16	**190**	731	566	250	**1547**
97/98	103	14	2	**119**	162	129	41	**332**
98/99	208	26	8	**242**	575	522	117	**1214**
99/00	158	22	6	**186**	359	341	43	**743**
00/01	367	18	3	**388**	432	218	115	**765**
01/02	371	14	11	**396**	135	73	6	**214**
02/03	407	21	6	**434**	395	57	10	**462**
03/04	303	26	6	**335**	417	176	41	**634**
04/05	394	33	9	**436**	327	87	23	**437**
Total	**2840**	**210**	**77**	**3127**	**4095**	**2725**	**692**	**7512**
Ave[4]	244.6	17.7	7	**269.1**	376.8	263.8	66.9	**707.5**

[1]Represents the former AHSs of CC, HUN, ILL, MNC, NR and SA.
[2]Represents the former AHSs of FW, GM, MAC, MW and NE.
[3]Represents the former AHSs of CS, NS, SES, SWS, WEN and WS.
[4]This is the ten season average from 1994/95 – 2003/04.

It was noted in last season's report (Doggett *et al*. 2004) that there had been four consecutive years of BFV activity along the north coast, centred in and around the Mid North Coast AHS. In response to this ongoing disease activity and due to the fact that current knowledge on BFV natural history is notably lacking, several new trapping sites were initiated. The new sites included two within Port Macquarie and one site each in the nearby towns of Bellingen, Crescent Head and Wauchope. The mosquitoes trapped at these sites and several other coastal localities were not only identified to species but also tested for virus. In the long term it is hoped that by undertaking virus isolation, insights will be provided into the local BFV vectors and the traps may, if appropriately located, act as an early warning system for future activity.

The end of 2004 saw heavy rainfall along the entire coast, although this occurred mainly in October. Summer was mostly dry, although the mid-north coast recorded above average rainfall. Mosquito numbers from the coast were not extraordinary high; nevertheless there were several isolates of RRV. This included 11 from Port Stephens (from three different sites) and one each from Ballina and Port Macquarie. Most of the isolates were from *Ochlerotatus vigilax* (7), but also included *Ochlerotatus procax* (3), *Coquillettidia linealis* (1), *Culex molestus* (1) and *Ochlerotatus multiplex* (1).

There were again many notifications of human disease attributed to BFV and RRV from the north coast. Combined from the Mid North Coast and the Northern Rivers AHSs, there were 337 BFV cases and 230 RRV. The total (567) represented almost 60% of all BFV/RRV reports from the state for the 2004-2005 season, and over the last five seasons, these AHSs have accounted for close to 60% of all the state wide BFV/RRV disease notifications (Table 5).

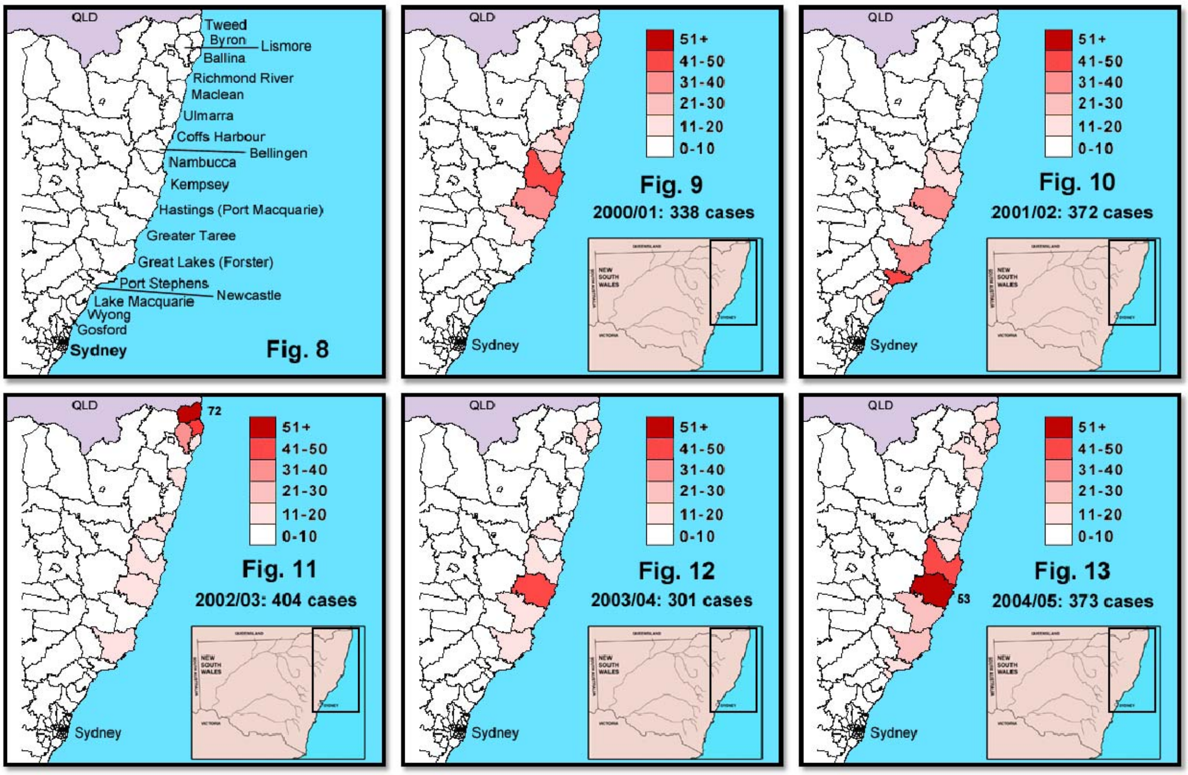
Table 5. Notifications of BFV & RRV disease from the Northern Rivers & Mid North Coast AHSs, over the last five mosquito seasons.

Virus	2000-01	2001-02	2002-03	2003-04	2004-05	Total
BFV	307	250*	350	274	337	1518
RRV	215	82	347	305	230	1179
Total	**522**	**332**	**697**	**579**	**567**	**2697**
NSW Total	1161	711	901	988	873	4634

The BFV activity for 2004-2005 was the fifth consecutive annual outbreak for the north coast. Prior to 2000, outbreaks of BFV disease in humans had been confined to a single season, with little activity in the following year (Doggett *et al*. 1999a), which is in stark contrast to what has occurred since. There have however, been some differences in the outbreaks. In 2000-2001, activity was mainly confined to the Kempsey region on the mid-north coast and followed upon heavy flooding as a result of record rainfall, along with high spring tides. The 2001-2002 activity was more diffuse along the coast, with the first ever cases being reported in western Sydney. However, the mid-north coast region again experienced the largest number of cases. It is suggested that this outbreak may have had a greater involvement of freshwater vectors, as there were several isolates from species such as *Culex annulirostris*, *Ochlerotatus notoscriptus* and *Ochelerotatus procax*. As these vectors vary in their habitat and geography, there may have been a demographically different human population exposed to the virus in the 2001-2002 outbreak compared with the prior season. For 2002-2003, the far north coast had most activity, although the mid-north coast had 136 cases, and for the 2003-2004 season the mid-north coast was again the most active BFV region. During 2004-2005, the outbreak again focused on the mid-north coast especially around Port Macquarie. The question with no answer yet is, why has BFV all of a sudden become so active in the mid-north coast of NSW? Clearly, the disease must be considered to be an emerging problem in NSW, and warrants further investigation.

To further examine this recent trend of BFV activity for the north coast and to demonstrate localities of greatest risk, the disease notifications of BFV per Statistical Local Area (SLA) over the five consecutive outbreaks are presented in Figures 8-13. The highest number of BFV disease notifications occurred in the Hastings SLA (Port Macquarie being the major city), with 187 cases and almost continual activity from 2000-

2005. The next highest was in the adjoining SLA of Kempsey, with 136 cases, while further north (but in the same AHS), Nambucca SLA had 65, Bellingen SLA with 60 and Coffs Harbour with 72. Immediate to the south of Hastings SLA is Greater Taree SLA and then Great Lakes SLA, which had respectively, 83 and 93 cases of BFV disease over the last five seasons. For the far north coast, Byron SLA peaked with 121 BFV disease cases, with the Tweed SLA having 118. These figures show that Port Macquarie and its immediate surrounds are the current 'hot-spot' for BFV activity in NSW, although why this should be so is unknown. Certainly the Hasting area is a region comprising numerous and diverse waterways, with many native animals that may act as viral reservoir and amplifying hosts. Despite this, mosquito habitat mapping to identify high-risk areas is yet to be undertaken, the local mosquito species that are transmitting BFV are unknown, and the native vertebrate hosts for the virus are yet to be identified. This lack of information means that it is impossible to accurately target disease reduction efforts, and the human population in the region will remain at risk from this emerging disease.



Figures 8-13. BFV notifications for the NSW North Coast. Fig 8. List of Statistical Local Areas (SLA), the name in the bracket is the largest urban centre for the area, if that name is different to the SLA name. **Fig 9.** BFV notifications for 2000-2001. **Fig 10.** BFV notifications for 2001-2002. **Fig 11.** BFV notifications for 2002-2003. **Fig 12.** BFV notifications for 2003-2004. **Fig 13.** BFV notifications for 2004-2005. **Note that the numbers on Figs. 11 & 13 show the cases of BFV disease when >51 were reported**.

In a recent review of the epidemiology of BFV and RRV disease in NSW (Doggett & Russell 2005), the disease notifications over ten seasons were combined and plotted to show seasonal trends between the major virodemographic regions of the coast and inland. The resulting graph (Figure 14), which attempted to demonstrate when patients were acquiring the virus, showed a stark difference between the regions. For the inland, peak virus acquisition occurred during February, while for the coast it was some two months later, namely April. Over the last decade for the inland, the series of dry summers have meant that notifications have started to decline by early spring, while along the coast, summer rainfall supplementing spring tides have provided plenty of water for mosquito breeding, allowing the season of virus activity to extent much longer.

It was noted in the review that as the seasonal trend between the coast and inland is markedly different then mosquito educational campaigns must be tailored for the region. Most health programs currently focus their mosquito/arbovirus warnings late in the calendar year and during mid-summer, which is well short of the peak notifications for the coastal region. Health warnings in this case should continue well into April.

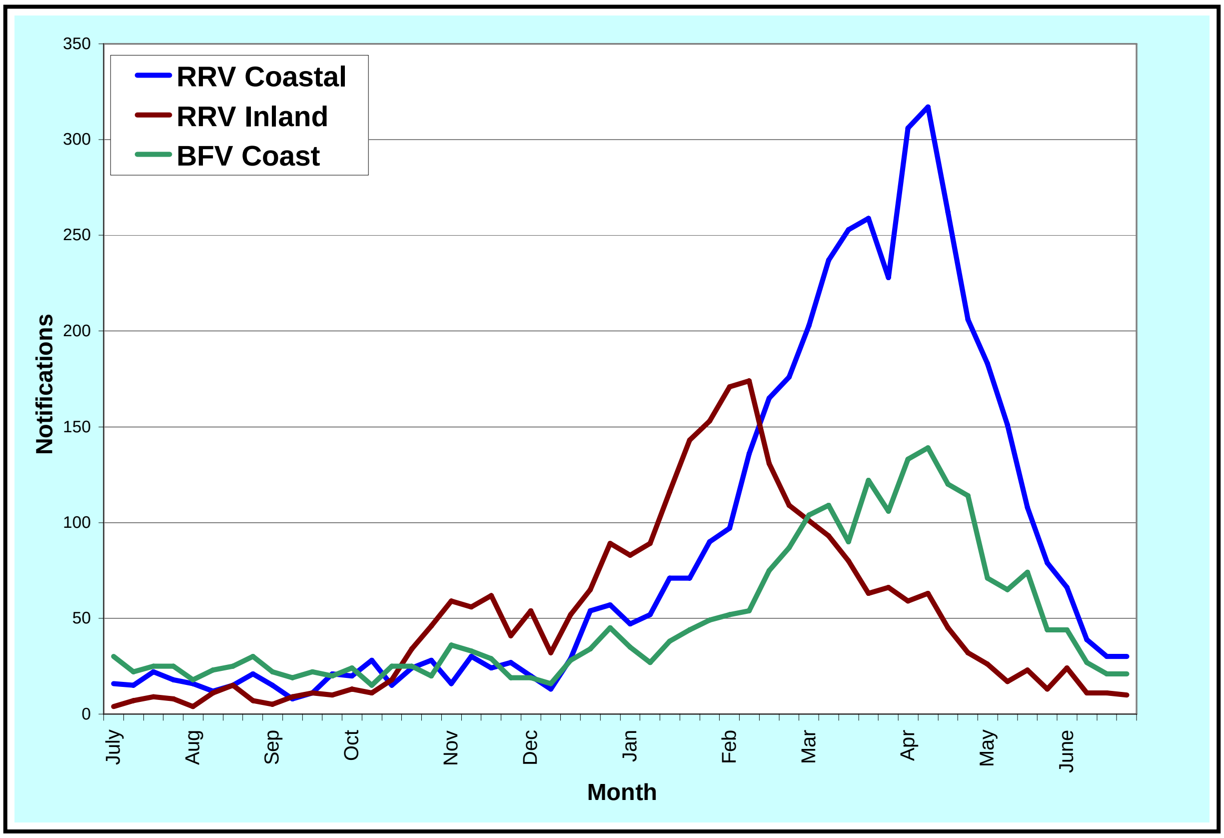


Figure 14. Seasonal notifications of RRV disease for the coast (—) and inland (—), and for BFV disease for the coast (—) only (inland not included due to low numbers), combined for 1994/95 - 2003/04. Note that the date represents virus acquisition, i.e. when the patient was bitten by the viraemic mosquito (*after Doggett & Russell 2005*).

For the south coast, there was again no monitoring of mosquito populations or virus activity and fortunately few notifications were reported (12 BFV &15 RRV).

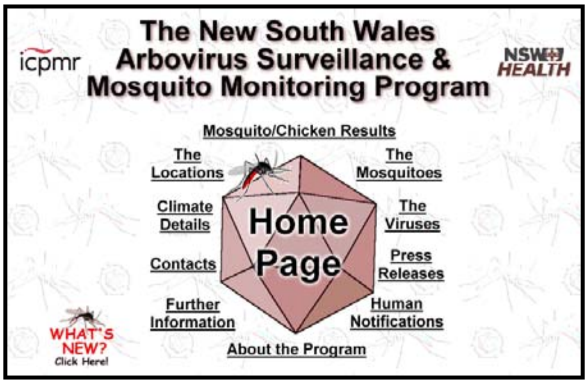
In Sydney, the relatively dry conditions meant that mosquito collections were around average. The new trapping location at Baulkham Hills was the most productive of the Sydney sites, trapping around one third of the mosquitoes. This site had high densities of the noted vector *Culex annulirostris*, suggesting a high risk factor for the local community. There was one isolate of Stratford virus, which was made at Wheeney

Creek from the Hawkesbury area from the mosquito *Ochlerotatus procax* collected on 17/Mar/2005. Human notifications within the Sydney Region continued to be down; the 32 reported cases (9 BFV and 23 RRV) were less than half the previous ten seasons' average of 73.7.

THE NEW SOUTH WALES ARBOVIRUS SURVEILLANCE WEB SITE

http://www.arbovirus.health.nsw.gov.au/

The NSW Arbovirus Surveillance web site was established in early 1999 to facilitate the rapid dissemination of surveillance results (Doggett *et al.*, 1999b). An additional important function is to provide information on mosquitoes and the arboviruses they transmit. Over the last year, the site has continued to grow to the current size of 159MB, and has 1,260+ pages of information.



Added to the site since the last annual report include:

- Archived data for the 2004-2005 season.
- Weekly rainfall summaries,
- Monthly rainfall summaries, with long-term averages,
- Monthly rainfall and temperatures maps,
- Monthly SOI updates.

Appendix 1. LOCATION-BY-LOCATION SUMMARY

http://www.arbovirus.health.nsw.gov.au/areas/arbovirus/results/results.htm

Inland Locations

Albury: collections were well below average for most of the trapping season and 'high' on only two occasions; in both cases from the Sewerage Treatment Works trapping site. No viruses were isolated.

Bourke: nine collections were made this season with mainly 'high' collections being yielded. Mosquito numbers peaked during mid-January with one collection of 979, which was strongly dominated by *Culex annulirostris*. There were no viral isolates or any seroconversion to MVEV or KUNV in the sentinel chickens.

Condobolin: no mosquito collections were made or sentinel chickens operated this year.

Forbes: no mosquito collections were made or sentinel chickens operated this year.

Griffith: as per the previous two seasons, mosquito numbers were well below average through the entire 2004-2005 season. Hanwood had three 'very high' collections with numbers peaking during mid-January. Willbriggie had a maximum of only 'high' numbers mainly due to the swamp drying out. There were no viral isolates or any seroconversion to MVEV or KUNV in the sentinel chickens.

Lake Cargelligo: no mosquito collections were undertaken this season and there were no seroconversion to MVEV or KUNV in the sentinel chickens.

Leeton: mosquito numbers were well down from last season, with only the one 'very high' collection, which was made during mid-January at Farm 347. There were no viral isolates or any seroconversion to MVEV or KUNV in the sentinel chickens.

Macquarie Marshes: mosquito numbers were 'low' for the entire season. There were no viral isolates or any seroconversion to MVEV or KUNV in the sentinel chickens.

Menindee: mosquito numbers were mostly 'low' to 'medium', with the occasional 'high' collection during March. There were no viral isolates or any seroconversion to MVEV or KUNV in the sentinel chickens.

Tamworth: no mosquito collections were undertaken this season.

Wanaaring: no mosquito collections were undertaken this season and there were no seroconversion to MVEV or KUNV in the sentinel chickens.

Coastal Locations

Ballina: mosquito numbers were continually around average for the season from the Greenfield Road site, whereas collections were more abundant from North Creek Road, with ‘very high’ collections in early January and again in late April. *Verrallina funerea*, *Culex sitiens* and *Ochlerotatus notoscriptus* were the dominant species at this site. One RRV was isolated at the North Creek Road site from *Coquillettidia linealis* on 8/Mar/2005.

Batemans Bay: no mosquito collections were made this year.

Gosford: two sites at Gosford were being monitored this year; Empire Bay and Killcare Heights. The latter was included due to recent concerns over mosquitoes by the local residents. For Empire Bay, mosquito numbers were mostly ‘low’ to ‘medium’ until the end of January, with some ‘high’ collections in early February and later in mid-March. Killcare Heights continually trapped greater mosquito numbers; with ‘high’ numbers for most weeks from December through until late April, including one ‘very high’ collection in mid-February. These collections were strongly dominated by *Ochlerotatus vigilax.* No viruses were isolated from the mosquitoes.

Port Macquarie: in response to the ongoing BFV activity in the region and that the mid-north coast tends to have greater number of RRV disease than other regions, several new sites began trapping around the Port Macquarie region. These included two sites within Port Macquarie itself; Lord Street and Partridge Street, and one site each at Wauchope, Crescent Head and Bellingen. These sites began trapping late in the season (mid-April), with mostly low collections yielded at Lord Street. Despite this, the first trapping week yielded one RRV isolate at this site, which was from *Ochlerotatus vigilax* trapped on 19/Apr/2005. At Partridge Creek, mosquito abundances were ‘high’ until early May and thereafter mainly ‘low’. Wauchope and Bellingen tended to have ‘low’ trap counts. Collections from Crescent Head were mostly ‘high’, dominated by *Ochlerotatus notoscriptus* and *Culex australicus*.

Port Stephens: the collections varied substantially in mosquito abundance and species composition between the sites, which reflected the diverse mosquito breeding habitats within the region. Some trapping sites are near freshwater habitats, while others are near saltmarsh environments. Gan Gan had mostly ‘high’ collections from January to late March, with *Coquillettidia linealis* and *Coquillettidia variegata* dominant. Mosquito numbers were more abundant at Saltash and ‘high’ throughout most of the season with one ‘very high’ collection in mid-April. The main species collected included *Ochlerotatus vigilax, Ochlerotatus procax* and *Culex annulirostris*. Medowie had ‘medium’ to ‘high’ numbers from January until the end of the season, with *Culex annulirostris* being the main species captured. As usual, Karuah was strongly dominated by *Ochlerotatus vigilax* and collections were mostly ‘high’ throughout the season, with one ‘very high’ yield in late January. Heatherbrae continued to trap the most mosquitoes for any site within NSW and mosquito numbers tended to be being ‘high’ from early December to mid-January and thereafter ‘very high’ until early May. *Ochlerotatus vigilax* was the most common species trapped at Heatherbrae, although freshwater species including *Culex annulirostris, Culex orbostiensis*, *Coquillettidia linealis* and *Ochlerotatus procax* were also trapped in ‘high’ numbers. There were a series of arboviral isolates from Port Stephens; RRV was isolated from Karuah (1RRV from *Ochlerotatus vigilax* trapped 8/Mar/2005; 1RRV from *Ochlerotatus vigilax* trapped 22/Mar/2005; 3RRV from mosquitoes trapped on 5/Apr/2005, including one isolate each from *Culex molestus*, *Ochlerotatus multiplex* and *Ochlerotatus vigilax*), Heatherbrae (3RRV from *Ochlerotatus procax* trapped 8/Mar/2005; 1RRV from *Ochlerotatus vigilax* trapped 22/Mar/2005), and Saltash (1RRV from *Ochlerotatus vigilax* trapped 22/Mar/2005).

Tweed Heads: collections were mostly 'low' and below average from Piggabeen Road, with one 'high' trap number in mid-February, which was dominated by *Culex sitiens*. Beltana Road consistently yielded greater mosquito densities, and trap numbers were generally 'high' from December to late February. Collections here also trapped *Culex sitiens* as the main species. No virus isolation was undertaken.

Wyong: except for one 'medium' collection of mosquitoes during mid-March, numbers remained 'low' for the entire season. No viruses were isolated.

Sydney Locations

Baulkham Hills: this new trapping location consistently produced 'high' mosquito numbers throughout the season from the three sites, with *Culex annulirostris* being the main species captured. The site at Cliftonville tended to catch the greatest numbers, with some collections of over 500 mosquitoes. No viruses were isolated.

Blue Mountains: only five collections were made this season. From the first week of February, both sites trapped 'high' numbers, dominated by *Ochlerotatus notoscriptus*. Virus isolation was undertaken from the mosquitoes but no isolates were yielded.

Concord: mosquito numbers were mostly 'low' throughout the season, although there were two 'high' collections during mid to late February, dominated by *Ochlerotatus vigilax*. No virus isolation was undertaken.

Hawkesbury: mosquito collections were consistent from mid-January until the end of the season. The sites tended to have 'low' to 'medium' numbers, with 'high' traps produced at both Yarramundi and McGraths Hill in late February/early March. There was one isolate of Stratford virus made from *Ochlerotatus procax* trapped on the 7/Apr/2005.

Parramatta: the ongoing mosquito management program at Homebush continues to ensure that mosquito numbers have not reached 'very high' levels in Parramatta (or Concord and Ryde) this season. Due to its close proximity to saltmarsh habitat, the George Kendall Reserve site was the most productive, with consistently 'high' numbers dominated by *Ochlerotatus vigilax.* The only other site that had numbers 'medium' or higher was Eric Primrose Reserve, which had three 'high' collections over a four week period beginning mid-February. Virus isolation was undertaken from the mosquitoes but no isolates were yielded.

Penrith: only limited collections were made with traps set on eight occasions. Mosquito collections were mostly 'low' with one 'high' trap yield in late January. Virus isolation was undertaken from the mosquitoes but no isolates were yielded.

Ryde: the majority of the trapping yielded 'low' to 'medium' mosquito densities, although there were three ‘high’ collections from Wharf Road during January to February. Lambert Park produced the largest collection with ‘high’ mosquito numbers being trapped from late November through until mid March. *Ochlerotatus notoscriptus* and occasionally *Culex annulirostris*, dominated at this site. Only the Lambert Park collections were processed for viruses and none were isolated.

Appendix 2. THE MOSQUITOES

The following briefly details the main mosquito species collected in NSW.

	**The Common Australian Anopheline,** ***Anopheles annulipes*.** A mosquito collected throughout NSW, although is most abundant in the irrigated region of the Murrumbidgee where it can be collected in the 1000's. Despite its abundance, it is not thought to be a serious disease vector.
	**The Common Marsh Mosquito**, ***Coquillettidia linealis*.** Found throughout NSW but especially in areas with freshwater marshes such as the Port Stephens area. Both BFV & RRV have been isolated from this species and is probably involved in some transmission.
	**The Common Banded Mosquito**, ***Culex annulirostris*.** The species is common in the NSW inland regions that have intense irrigation. This species is highly efficient at transmitting most viruses and is responsible for the spreading of most of the arboviruses to humans inland.
	**The Brown House Mosquito**, ***Culex quinquefasciatus*.** A common species throughout Australia and tends to breed in polluted ground pools. While this species is an important nuisance biter, it appears to be a poor vector of most of the arboviruses.
	**The Common Domestic Mosquito**, ***Ochlerotatus notoscriptus*.** A common species that breed in a variety of natural and artificial containers around the home. It is the main vector of dog heartworm and laboratory studies shows it be an excellent transmitter both of RRV and BFV.
	**The Northern Saltmarsh Mosquito**, ***Ochlerotatus vigilax*.** The most important species along coastal NSW. This species breeds on the mud flats behind saltmarshes and can be extremely abundant and a series nuisance biter. It is the main vector for RRV and BFV along the coast.

Appendix 3. THE VIRUSES

Alphaviruses

Barmah Forest virus (BFV): disease from this virus is clinically similar to that of RRV disease although BFV disease tends to be associated with a more florid rash and a shorter duration of clinical severity. This is an emerging disease and is increasingly becoming more common in NSW, with around 3-400 cases annually. Despite being first isolated from an inland region, cases of BFV disease tend occur mainly in coastal regions. The main vector in NSW is *Ochlerotatus vigilax*.

Ross River virus (RRV): this virus causes RRV disease and is the most common arbovirus affecting humans in NSW and Australia. For the state, there are around 800 cases per season. A wide variety of symptoms may occur from rashes with fevers, to arthritis that can last from months to occasionally years. The virus occurs in both inland and coastal rural regions. The main vectors are *Culex annulirostris* (inland) and *Ochlerotatus vigilax* (coast), although other species are undoubtedly involved in the transmission of the virus.

Sindbis virus (SINV): this is an extremely widespread virus throughout the world and occurs in all mainland states of Australia. In contrast with Africa and Europe where outbreaks have been reported, disease from SINV is relatively uncommon; only 24 cases were notified in NSW from Jul/1995-Jun/2003 (Doggett 2004). Symptoms of disease include fever and rash. Birds are the main host, although other animals can be infected such as macropods, cattle, dogs and humans. The virus has been isolated from many mosquito species, but most notably *Culex annulirostris* in south eastern Australia.

Flaviruses

Alfuy virus (ALFV): no clinical disease has been associated with this virus and it has not been isolated from south-eastern Australia.

Edge Hill virus (EHV): a single case of presumptive infection with EHV has been described, with symptoms including myalgia, arthralgia and muscle fatigue. *Ochlerotatus vigilax* has yielded most of the EHV isolates in south east Australia, although it has been isolated from several other mosquito species. The vertebrate hosts may be wallabies and bandicoots, however studies are limited.

Kokobera virus (KOKV): only three cases of illness associated with KOKV infection have been reported and all were from south east Australia. Symptoms included mild fever, aches and pains in the joints, and severe headaches and lethargy. Symptoms were still being reported by the patients five months after onset. *Culex annulirostris* appears to be the principal vector.

Kunjin virus (KUNV): disease from this virus is uncommon, with only two cases were notified from 1995-2003 (Doggett 2004). Activity is confined to the inland region of NSW where it is detected every few years. *Culex annulirostris* appears to be the main vector.

Murray Valley Encephalitis (MVEV): activity of this virus is rare in south-eastern Australia and the last clinical cases of MVEV disease occurred in 1974. The virus occurs only in inland regions of the state and the last major activity was in the summer/spring of 2001, although no human cases were reported. Symptoms are variable, from mild to severe with permanent impaired neurological functions, to sometimes fatal. *Culex annulirostris* is the main vector.

Stratford virus (STRV): there have been very few documented symptomatic patients, only three described to date and symptoms included fever, arthritis and lethargy. The virus has mostly been isolated from coastal NSW, particularly from the saltmarsh mosquito, *Ochlerotatus vigilax*, although recent isolates from the Sydney metropolitan area include *Ochlerotatus notoscriptus* and *Ochlerotatus procax*.

ACKNOWLEDGMENTS

This project is funded and supported by the Environmental Health Branch of NSW Health. The following are acknowledged for their efforts in the Arbovirus Program:

Glenis Lloyd (Environmental Health Branch, NSW Health, Gladesville); Tony Kolbe & Terry Carvan (Centre for Public Health, Albury); Dr Jeanine Liddle & Peter Tissen (Mid Western NSW Public Health Unit, Bathurst); Bill Balding (Far West Population Health Unit, Broken Hill); Dr Peter Lewis, Sam Curtis, John James, Adam McEwan (Central Coast Public Health Unit, Gosford); Kerryn Allen, Paul Corben and David Basso (Mid-North Coast Public Health Unit), Christine Robertson, Greg Bell, K. Taylor, Charles Rablin (New England Public Health Unit, Tamworth); John Simpson & Geoff Sullivan (Northern Rivers Institute of Health and Research, Lismore); Tony Brown (Macquarie Centre for Population Health, Dubbo); Dr Krishna Hort & Helen Ptolomy(Wentworth Population Health Unit, Kingswood); Bhram Deo & Lauriston Muirhead (Albury City Council); Graham Plumb, Kerri Watts, Rachael Currie, Mary & Don Apps, Janice & Bill McMillan (Ballina Shire Council, Ballina); Lisa Kennedy (Baulkham Hills Shire Council), Grant Ashley (Bellingen); Graham Liehr (Blue Mountains City Council); Linda George (Bourke Shire Council); Colleen Allen (Crescent Head); David Sanders & Pauline Porter (Griffith Shire Council, Griffith); Dianne Tierney, Edward White, Andrea Horan & Christine Mitchell (Hawkesbury Council); John Reberger (Lake Cargelligo); Ben Lang (Leeton Shire Council, Leeton); the McLellan family (especially Linda) (Macquarie Marshes); Ivan Cowie (Menindee); Mike Randall, Haley Lloyd, Amanda Monaco (Parramatta Council); Belinda Comer & Kelly Demattia (Penrith City Council); Cheyne Flanagan & Thor Aaso (Port Macquarie); Graeme Pritchard, Bruce Peterson, & Leigh Ernst (Port Stephens Shire Council, Raymond Terrace); Gith Striid (Ryde Council); Clive Easton (Tweed Shire Council, Murwillumbah).

The chicken handlers included; David Sanders (Griffith), Ivan Cowie (Menindee), Linda George (Bourke), Ben Lang (Leeton), Linda McLellan (Macquarie Marshes) and John Reberger (Lake Cargelligo) & Andy Lawrance (Wanaaring).

The laboratory staff within CIDM are acknowledged including; Jennifer Goder and Eric Kapsalis.

Our apologies to anyone inadvertently omitted.

Human case numbers and epidemiological information were obtained through the NSW Health Department and the NSW Notifiable Diseases database. The input of Dr Ross Mathews, Director of Animal Care, Westmead Hospital in the implementation & continuation of the chicken surveillance program is greatly appreciated. We are grateful to the Arbovirus Laboratory, Department of Microbiology, University of Western Australia, particularly Dr Annette Broom, for the supply of monoclonal antibodies for antigen detection.

REFERENCES

Bureau of Meteorology, Australia. (2005). Rainfall Maps. http://www.bom.gov.au/cgi-bin/climate/rainmaps.cgi, *accessed 17Aug/2005.*

Dobrotworsky N.V. (1965). **The Mosquitoes of Victoria**. *Melbourne University Press, Carlton*.

Doggett S.L., Russell R.C., Clancy J., Haniotis J. and Cloonan M.J. (1999a). **Barmah Forest virus epidemic on the south coast of New South Wales, Australia, 1994-1995: Viruses, Vectors, Human Cases, and Environmental Factors**. *Journal of Medical Entomology*, 36: 861-868.

Doggett S., Russell R. and Dwyer D. (1999b). **NSW Arbovirus Surveillance Web Site**. *NSW Public Health Bulletin,* 10: 7.

Doggett S. (2004). **Population health aspects of mosquito-borne disease in New South Wales**. *NSW Public Health Bulletin*, 15: 193-199.

Doggett S., Clancy J., Haniotis J., Russell R.C., Hueston L., Marchetti M. and Dwyer D. (2004). **The New South Wales Arbovirus Surveillance & Mosquito Monitoring Program. 2003 – 2004 Annual Report**. *Department of Medical Entomology, Westmead*. 23pp.

Doggett S.L. and Russell R.C. (2005). **The epidemiology of Ross River and Barmah Forest viruses in New South Wales.** *Arbovirus Research in Australia*, 9: 86-100.

Forbes J.A. (1978). **Murray Valley encephalitis 1974 - also the epidemic variance since 1914 and predisposing rainfall patterns**. *Australasian Medical Publishing Co., Glebe*. 20pp.

Lee D.J., Hicks M.M., Griffiths M., Russell R.C., Geary M. and Marks E.N. (1980 – 1989). **The Culicidae of the Australian Region. Vols. 1 - 11**. *Australian Government Publishing Service, Canberra*.

Nicholls N. (1986). **A method for predicting Murray Valley encephalitis in southeast Australia using the Southern Oscillation**. *Australian Journal of Experimental Biology and Medical Science,* 64: 587-94.

Russell R.C. (1993). **Mosquitoes and mosquito-borne disease in southeastern Australia**. *Department of Medical Entomology, Westmead, NSW*, 310pp.

Russell R.C. (1996). **A Colour Photo Atlas of Mosquitoes of Southeastern Australia**. *Department of Medical Entomology, Westmead, NSW*, 193pp.