

ROSS RIVER VIRUS TRANSMISSION IN DARWIN, NORTHERN TERRITORY, AUSTRALIA

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INTRODUCTION

The alphavirus Ross River virus (RR) is responsible for most of the confirmed cases of arbovirus disease in Australia and is responsible for periodic outbreaks of arbovirus disease in the NT (Whelan et al. 1994, Merianos et al. 1992, Tai et al. 1993).

A mosquito monitoring program utilising CO₂ baited traps has been in place in Darwin since 1979. There are currently 17 traps set weekly in various positions in the Darwin suburban area between sources of mosquitoes and urban areas. The usual pattern of adult abundance is high *Ae. vigilax* (Skuse) numbers from September to January and high *Cx. annulirostris* Skuse numbers from January to June.

There have been 6 isolates of RR from 4 species of mosquitoes in the Darwin area from 1982 to 1992 (Whelan and Weir 1993). Two isolates each were made from *Cx. annulirostris* in February and March and *Ae. vigilax* in January, with 1 isolate each from *Ae. phaeasiatus* Marks in March and *Ae. notoscriptus* (Skuse) from pooled collections made from January to March. *Aedes vigilax* and *Cx. annulirostris* have been considered the principal suspected vectors of RR in the Darwin area (Whelan et al. 1993).

An arbovirus disease surveillance program was established in the NT in 1980 to monitor the number of laboratory confirmed cases of RR infection. The aim was to utilise this data to identify vector control requirements by the timely detection of geographical and temporal clusters of arbovirus infections (Whelan et al. 1993).

The largest number of confirmed cases in the Darwin region occurred in 1990/91 when there was a large outbreak over a wide area of the NT (Tai et al. 1993). During the outbreak the highest attack rate (cases per 100,000 population) in the general Darwin area was in the surrounding rural Litchfield shire (886) followed by Darwin urban (228) and the satellite city of Palmerston (165). In this outbreak *Ae. vigilax* was regarded as the probable vector in the early part of the outbreak, with *Cx. annulirostris* the probable additional vector during the peak of the outbreak (Whelan et al. 1993).

There have been consistent numbers of laboratory confirmed cases of RR infection in Darwin over the last 10 yrs. The usual pattern of RR infection in Darwin has been for most cases to occur between December and March with a January peak (Tai et al. 1993).

Darwin, together with the satellite city of Palmerston and the extensive rural shire of Litchfield, has a large proportion of the population of the NT. Most mosquito control efforts are centred around urban Darwin which has a number of northern residential suburbs relatively close to an extensive seasonally brackish swamp. There is little organised or regular mosquito control in Palmerston because it was regarded as having relatively little proximal mosquito breeding places after the storm water drainage system and water features were constructed to specifically reduce mosquito problems. The Litchfield shire has no organised mosquito control program and has variable sources of mosquitoes from small seasonally inundated areas to extensive wetlands.

It was decided to investigate the incidence of RR cases in the 3 residential regions of Darwin and within the various suburbs of urban Darwin to determine whether the pattern of disease indicated a need for more focused mosquito control and mosquito awareness resources. This paper outlines the annual incidence of RR disease in the 3 residential regions of Darwin and examines the vector and environmental variables in various suburban groupings of urban Darwin to determine if they could help explain the distribution of cases and hence assist in the prediction of risk periods for proactive mosquito control or disease awareness programs.

METHODS

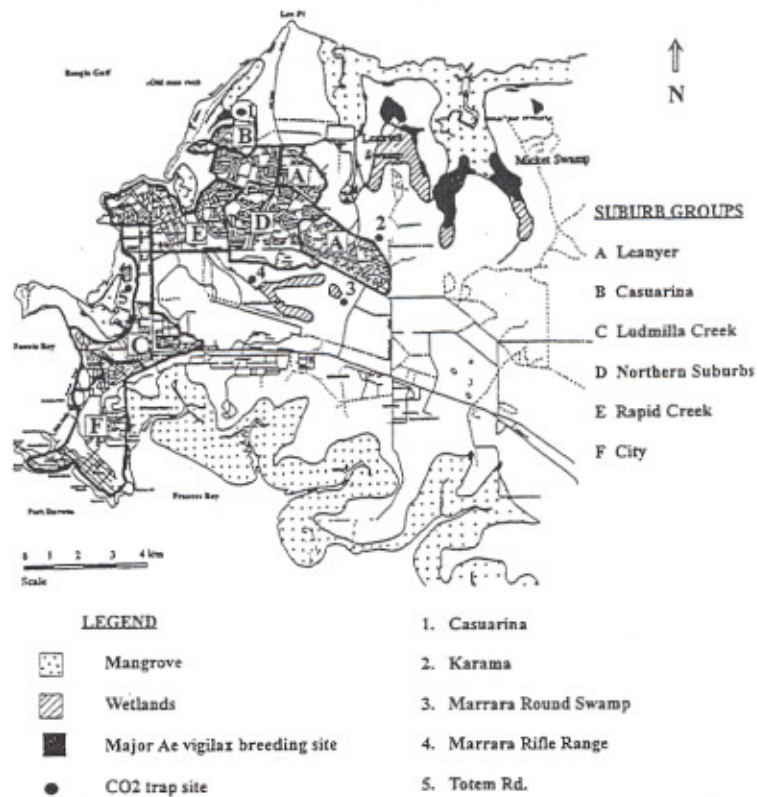
Ross River virus cases

Laboratory confirmed cases of RR notified to the arbovirus disease surveillance program were tabulated for the general Darwin area for the financial years from 1990/91 to 1995/96. The cases were tabulated by residential address recorded on the pathology forms for the urban Darwin, Palmerston and Litchfield shire (Fig 1). In the Darwin urban area, the cases were recorded for 6 suburb groupings based on the proximity of each suburb to a swamp or tidal creek system (Fig 2).



Figure 1. Darwin regional boundaries.

Figure 2. Darwin suburban groupings.



Residential addresses recorded as Darwin only, without a clear indication of suburb location, were recorded in the totals for the Darwin region but were not assigned a suburb grouping and were excluded from the analysis by suburb. Cases with suburban addresses of Berrimah, Coonawarra and Winnellie were excluded from the suburban grouping because of the variable and small number of residents in these areas over the period.

Mosquito vector data

Weekly mosquito monitoring over the period was conducted with CO₂ baited modified EVS mosquito traps (Rohe and Fall 1979). There were no specific trap results available for Palmerston or Litchfield for the study period. For the Darwin suburb groupings, a single trap was used as follows: Darwin City (none), Ludmilla Creek (Totem Road), Leanyer (Karama), Northern Suburbs (Marrara Round Swamp), Casuarina (Casuarina), and Rapid Creek (Marrara Rifle Range). Traps were generally positioned between urban areas and the nearest significant swamp or creek system. Traps were set weekly before sunset and collected after sunrise the following day.

The collections of *Ae. vigilax* and *Cx. annulirostris* from each suburban group indicator trap were tabulated for the whole year and for the November to February period. The Karama site was selected to represent the mosquito population fluctuation for the Leanyer suburb group because it consistently showed the highest number of the 2 main suspected vector species and was closest to a suburban area.

Tide data

The tide data were obtained from the tide prediction charts for Darwin Harbour from 1992 to 1996 (Department of Defence). The number of tides over 7.6 m between September and March each year was tabulated from the tide charts.

Rainfall data

Rainfall data were obtained from the official rainfall records for Darwin (Bureau of Meteorology). The site for the official rainfall data was Darwin Airport. Total rainfall was tabulated weekly for the whole year and for the period from September to March and January in each year.

Mosquito control effort

The indicator for mosquito control effort was obtained from the Medical Entomology Branch figures for the number of hectares sprayed in the late dry season/early wet season each year under the helicopter applied insecticide control program over the large brackish swamps of Leanyer, Holmes Jungle and Mickett Creek. These swamps were regarded as the major sources of vector mosquitoes for the Leanyer and Northern suburb groupings.

Analysis of Ross River virus cases

A logistic regression model was used to determine the predictors of RR incidence over the period of observation. The outcome variable was case numbers, and the group size was set by the 1995 Australian Bureau of Statistics population denominators for Darwin residents ≥ 20 yr in the region and suburban groupings. The denominators were adjusted by published age specific prevalence rates of RR seropositivity to estimate the susceptible population (Tai 1992). Financial years rather than calendar years were used for each yearly calculation so that the entire wet season and seasonal mosquito vector variables were included in the 1 yr. Predictor variables included hectares sprayed for vector control, rainfall, tides over 7.6 m, and average numbers of *Ae. vigilax* and *Cx. annulirostris* trapped at 5 indicator sites.

RESULTS

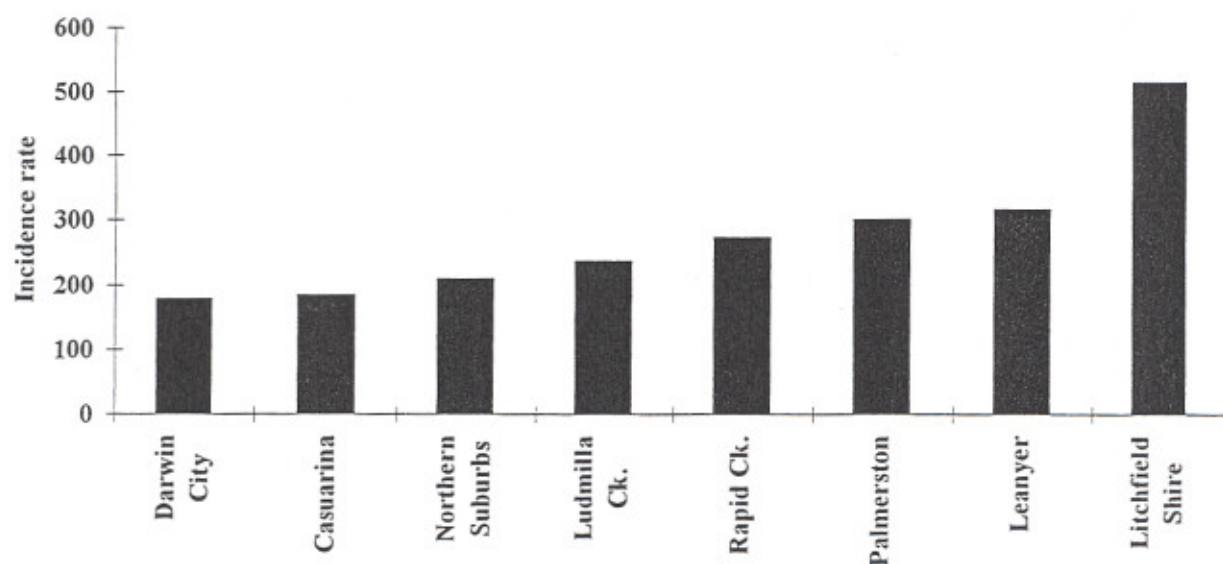
Ross River virus cases

The total number of RR cases for the 3 general areas and for the Darwin suburban groups reached a peak in 1990/91, with the least number of cases in 1995/96 (Table 1).

Table 1. Number of Ross River virus cases with tide, rainfall and control effort, Darwin, NT 1990-96.

	YEAR					
	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96
No. cases RR Darwin, Palmerston & Litchfield	249	89	130	222	202	56
RR cases Darwin only	165	55	88	146	118	27
No. tides over 7.6 m Sep-Mar	4	3	3	5	8	6
Rainfall (mm) Sep-Dec	454	212	579	606	462	491
Rainfall (mm) Sep-Mar	2140	823	1513	1687	2253	1329
Rainfall (mm) January	922	318	494	277	940	292
No. ha sprayed (Leanyer)	423	405	1190	1160	1337	1683
<i>Ae. vigilax</i> Av/Trap (Nov-Feb) (5 indicator sites Darwin)	57	15	12	269	135	21
<i>Ae. vigilax</i> Av/Trap (Nov-Feb) Karama	166	60	48	710	119	69
<i>Cx. annulirostris</i> Av/Trap (Nov-Feb) (5 indicator sites)	61	5	16	64	33	35
<i>Cx. annulirostris</i> Av/Trap (Nov-Feb) Karama	177	15	30	217	60	82

The highest average incidence rates of RR per 100,000 for the population ≥ 20 yr was recorded in the Litchfield shire (512), followed by the Leanyer suburb group (314), Palmerston (298), and Rapid Creek (271). Lower incidence occurred in Ludmilla Creek (235), Northern Suburbs (208), Casuarina (183) and Darwin City (177) (Fig 3).

**Figure 3.** Ross River virus average incidence rate per 100,000 population 20 yr and over. Darwin 1990/91-1995/96.

Vector numbers

The average number of *Ae. vigilax* per trap for the 5 indicator sites for November to February was highest in 1993/94, with 269/trap night, followed by 1994/95 with 135/trap night, with relatively low numbers in 1991/92, 1992/93, and 1995/96 (Table 1). The average number of *Ae. vigilax* per trap for the Karama indicator site followed a similar pattern, although at higher numbers per trap, except for a reversal of order in 1990/91 and 1994/95 (Table 1).

The average number of *Cx. annulirostris* for the 5 indicator sites and for the Karama site for November to February showed a similar pattern of abundance each year to that for *Ae. vigilax* (Table 1).

The average number of *Ae. vigilax* for the 5 indicator sites was approximately 4 times higher than the numbers of *Cx. annulirostris* for 1993/94 and 1994/95 when *Ae. vigilax* was most abundant. The order of magnitude of catches of *Ae. vigilax* and *Cx. annulirostris* at the Karama site was similar over most years except for 1993/94 (Table 1).

There was a similarity in the order of magnitude of RR cases in Darwin alone with *Ae. vigilax* numbers at Karama except in 1993/94 (Table 1).

The weekly trap results for *Cx. annulirostris* and *Ae. vigilax* for the Karama trap site and the monthly number of cases of RR in the Leanyer suburb group from 1993/94 to 1995/96 indicated that high numbers of *Ae. vigilax* preceded the increase in RR cases, while cases continued when *Ae. vigilax* numbers were low to very low and *Cx. annulirostris* numbers were relatively high or at moderate levels (Figs 4-5).

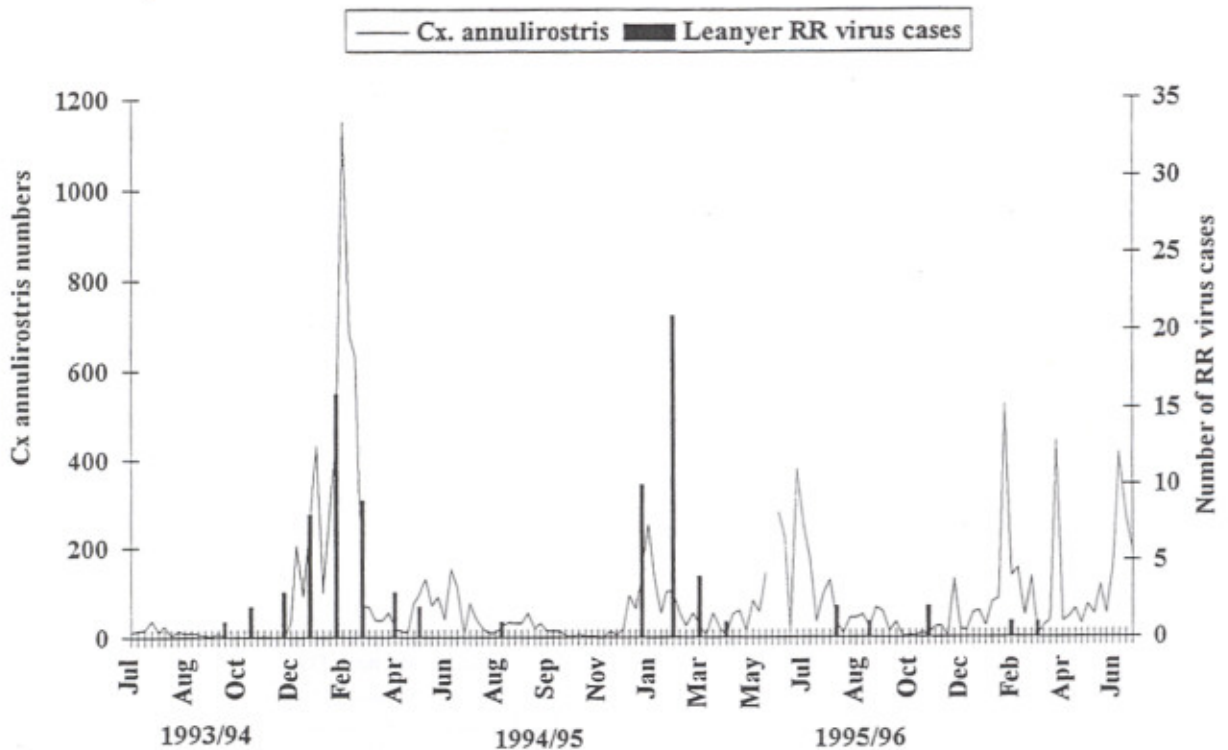


Figure 4. *Cx. annulirostris* numbers per trap per week for Karama versus Ross River virus cases per month for the Leanyer suburb group, July 1993 to June 1996.

Tides

The number of tides over 7.6 m in the September to March period reached a peak in 1994/95 with 8 tides, followed by 1995/96 with 6 and 1993/94 with 5 (Table 1).

Rainfall

The highest total rainfall for the September to December period occurred in 1993/94 (606 mm), followed by 1992/93 (579 mm). The highest rainfall for the September to March period occurred in 1994/95 (2253 mm), followed by 1990/91 (2140 mm). The pattern of the magnitude of rainfall for January over the years generally followed the pattern for the September to March period (Table 1).

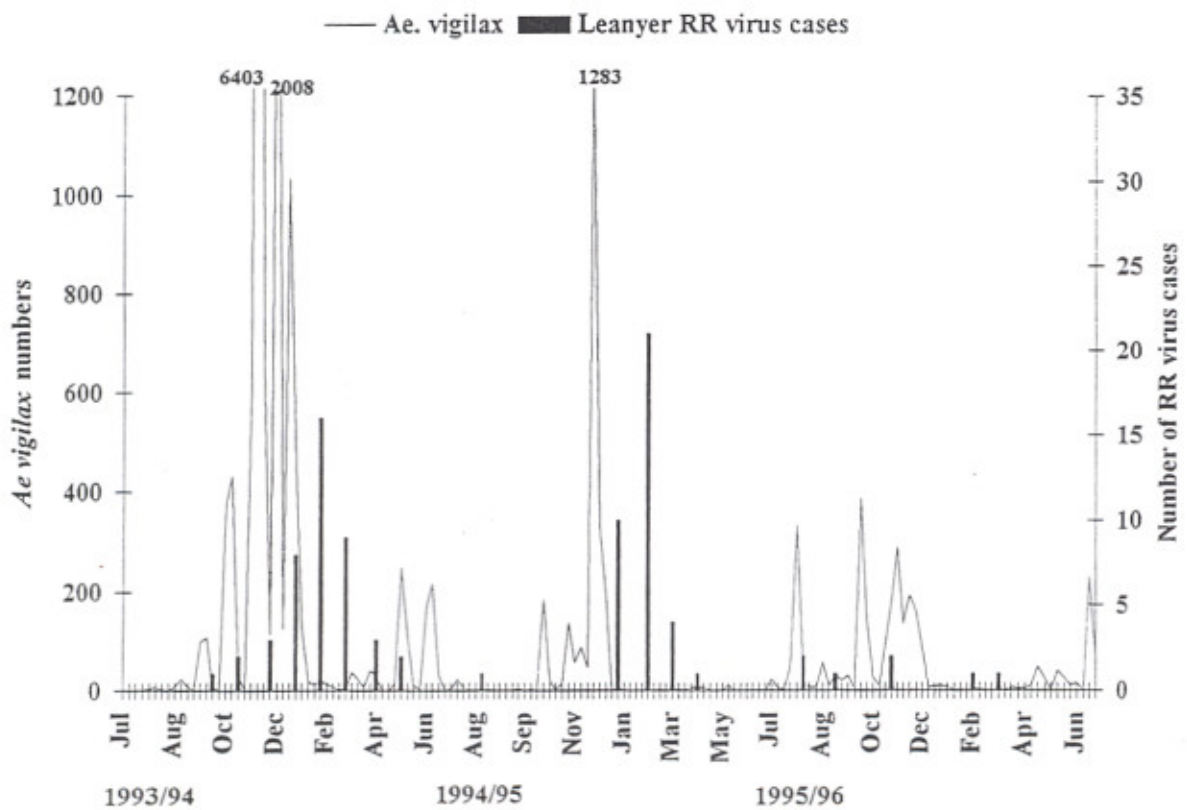


Figure 5. *Ae. vigilax* numbers per trap per week for Karama versus Ross River virus cases per month for the Leanyer suburb group, July 1993 to June 1996.

Mosquito control

The numbers of hectares (ha) sprayed for mosquito control increased by almost 3 times in 1992/93 from the previous 2 yr and reached a peak of 1683 ha. in 1995/96 (Table 1).

Analysis of Ross River virus cases

The logistic regression model of the incidence of RR cases in and near Darwin by suburban and area groups, and financial year of diagnosis, showed that Litchfield shire had almost three times the relative risk of RR disease compared to the referent city group, with the Leanyer suburb group closely followed by the Palmerston area having relatively high risks (Table 2). Rapid Creek also significantly differed from the city group and the remaining suburb groups.

There was no statistically significant association between the incidence of RR and rainfall or mosquito control effort.

There was a small but significant association between the incidence of RR cases and the mean *Ae. vigilax* numbers in November to February. A similar association was also found with the mean *Cx. annulirostris* numbers over the same period of time. However the trend of mean *Ae. vigilax* and *Cx. annulirostris* numbers each year were closely correlated.

There was an apparent reduction in the incidence of RR cases with tides over 7.6 m in the September to December period (Table 2).

Table 2. Logistic regression model of the incidence of Ross River virus in Darwin by suburban divisions and (financial) year diagnosis.

Term	Odds Ratio (Relative risk)	95% Confidence Limits		P Value
Suburban Divisions				
City (referent)	1.0000			
Casuarina	1.0360	0.6857	1.5650	0.8670
Northern Suburbs	1.1770	0.8322	1.6630	0.3570
Ludmilla Creek	1.3290	0.9383	1.8810	0.1090
Leanyer	1.7770	1.3050	2.4190	<0.0010
Rapid Creek	1.5340	1.1210	2.0990	0.0070
Palmerston	1.6850	1.2170	2.3340	0.0020
Litchfield	2.9060	2.1490	3.9290	<0.0010
Tides above 7.6 m (Sept-Dec)	0.7918	0.7300	0.8588	<0.0010

DISCUSSION

Ross River virus cases

The 4 areas that had significantly different RR incidence from the referent city group included 2 areas where mosquito control was not carried out. The highest incidence was in the Litchfield shire. A high incidence was also found in this area in the 1990/91 outbreak (Tai et al. 1993). This is a large and diverse area, with some locations relatively close to small inner harbour breeding sites of *Ae. vigilax* and other areas close to large tidally influenced coastal flood plain sources of this species. There is also a variable proximity to various sources of *Cx. annulirostris*, with various fresh water streams, swamps and seasonally inundated flood plains. The network of vegetated streams through the area also enables close proximity with various marsupials such as the agile wallaby which may be significant and relatively mobile reservoirs of RR in the general area.

The housing and lifestyle of many of the residents in the Litchfield shire is different from urban areas in Darwin, with less sophisticated houses, less insect screening, more outdoor evening relaxation and consequently more exposure to vector mosquitoes in the rural areas.

The high incidence in the Leanyer suburb group is likely to be due to the proximity to the large coastal flood plains and mangrove areas. These are large seasonal sources of a range of mosquito species. Most of the mosquito control effort in Darwin is aimed at *Ae. vigilax* larvae in these coastal swamps within 3 km of the edge of the Leanyer suburbs.

The highest incidence of RR was in the first year of the study. In that year there was significant, although less, control effort in Leanyer swamp compared with the latter years. The average number of *Ae. vigilax* for the 5 indicator sites was relatively low in that year compared to other years, indicating either or both relatively low populations of *Ae. vigilax* and good larval control. However the average number of *Ae. vigilax* and *Cx. annulirostris* for the Karama site alone was the second highest, indicating that the high RR incidence for this year could have been due to the high number of vectors arising from Leanyer swamp, with relatively few vectors in other suburban areas.

The high incidence in the Palmerston area was possibly related to both the absence of organised mosquito control in the area, and the presence of a number of semi rural residential and recreation areas in the general Palmerston area. There are a number of small localised sources of vectors close to some of the urban areas of Palmerston that could be enough to maintain transmission of RR. *Aedes vigilax* has also been recorded dispersing in relatively high numbers to Palmerston from the coastal Howard swamp to the north east where no regular mosquito control has been carried out (Liehne et al. 1985). The high incidence indicates that either minor sources of vectors relatively close to urban Palmerston or dispersal of vectors from relatively distant sources may be sufficient to maintain considerable RR transmission. There is also a possibility that there was differential contact with the Litchfield shire by Palmerston residents compared with other suburban Darwin residents, thereby resulting in greater non residence vector exposure for the Palmerston residents.

There appeared to be an increased incidence of RR in the Palmerston area in latter years compared to that in the 1990/91 outbreak (Tai et al. 1993). The recent development of semi rural residential development between the urban

areas and the mangrove margins in Palmerston could have resulted in more overall exposure to vectors in latter years.

The relatively high incidence in Rapid Creek was unexpected. While this area has a few small sources of *Ae. vigilax* and *Cx. annulirostris*, it was thought that they were relatively well controlled by ground larval control operations, and there were relatively small populations of vectors in this area compared to other areas. This group of suburbs are relatively old, and contain a large proportion of public housing without outdoor storage, which increases the probability for a greater number of accumulated rain filled containers and hence higher *Ae. notoscriptus* (Skuse) populations. *Aedes notoscriptus* has been suggested as a possible vector of RR in Darwin with the isolation of the virus at some time between January and March (Whelan and Weir 1993). There have been indications of an appreciable number of *Ae. notoscriptus* adults present within the Rapid Creek area. *Aedes notoscriptus* may thus be playing a part in urban RR transmission in at least this area of Darwin and this aspect should be further investigated.

The lower incidence in the Northern Suburbs indicated that suburban areas up to a kilometre in width offer significant protection as buffers against RR infection for other urban areas. This apparent reduction is probably due to the diversion of vector mosquitoes by the competing lights and human and non human blood sources in the buffer suburbs between the sources of mosquitoes and the shielded Northern Suburbs urban areas.

The reduction in vector numbers with distance over an open forest buffer from a coastal swamp has been shown for *Cx. annulirostris*, although there was little reduction with *Ae. vigilax* (Whelan et al. 1989). However most mosquito complaints regarding *Ae. vigilax* in the urban areas have been recorded within a 200 m urban strip nearest to Leanyer swamp (Whelan 1989). The principle of buffering urban areas with less populated rural or semi rural areas has been a standing recommendation by Health authorities in Darwin and has been incorporated in the design of some Darwin urban and rural areas.

The low incidence in the Casuarina area was also unexpected, as there were years of relatively high *Ae. vigilax* numbers in this area. However the numbers of *Ae. vigilax* at the Casuarina trap have been highly variable over the study period. They were relatively low in the early years and have been greatly reduced in the final year. In addition there are relatively few *Cx. annulirostris* in this area compared with the Leanyer area. There is also an open mown park between the urban area and the densely forested mosquito breeding and harbouring sites. This may act as a buffer and reducing the degree of people/vector contact. One or more of these aspects could be responsible for the relatively low incidence in this area.

Vector numbers

The lack of a significant correlation of RR cases with the average number of *Cx. annulirostris* at the 5 indicator sites suggests that this species does not play an important part in RR transmission in Darwin. However the 2 yrs with the highest numbers of RR cases in the Darwin urban area were the years with the highest average numbers of *Cx. annulirostris* per trap at the Karama trap site. Other investigations in Darwin and Nhulunbuy have shown RR transmission during periods of relatively high *Cx. annulirostris* populations, both with and without appreciable numbers of *Ae. vigilax* (Merianos et al. 1992, Whelan et al. 1993). The probable role of *Cx. annulirostris* as a vector of RR is supported by the data presented here for the Leanyer suburb group (Fig 4). This is also supported by the months of isolation of RR from *Cx. annulirostris* in the Darwin area (Whelan and Weir 1993).

A small but significant association was found between the incidence of RR and the average numbers of *Ae. vigilax* in the November to February period. A similar result was found with *Cx. annulirostris*. The trend in *Cx. annulirostris* and *Ae. vigilax* numbers was closely correlated, resulting in problems with co-linearity when both variables were added to the model at the same time. Similarly other investigations in the Top End have shown RR transmission began with high *Ae. vigilax* numbers in the early wet season when there were very few other mosquitoes present. The case data for the Leanyer suburb group and the prevalence of *Ae. vigilax* at the Karama site supports the suggestion that *Ae. vigilax* is an important vector (Fig 5). This is also supported by the month of isolation of RR from *Ae. vigilax* in the Darwin area (Whelan and Weir 1993).

The method of analysis used above averaged the vector numbers for a number of sites over a number of months and years. This has probably hidden the relationship between vector numbers and disease. It is probable that an analysis of RR incidence with *Ae. vigilax* and *Cx. annulirostris* numbers for specific months and individual suburbs would reveal a significant relationship between vectors and disease. The method of analysis used in this investigation is thus probably not useful for determining these relationships.

Rainfall and Vector control effort

There were variable amounts of rain in different localities in the early wet season, variable effects of the rain on vector numbers in the various localities, and variable amounts of vector control in each area. When using yearly totals and averaging in the methodology of analysis above, the relationship between these variables and RR cases could be hidden. This uncertainty is compounded with the uncertainty of the site of transmission for each of the RR cases, and whether there is a difference in non residence mosquito exposure with the different suburb groups. The data presented

in Table 1 indicated some association between the total rainfall in September to March and mosquito numbers, and may explain the apparent lack of association between incidence of RR and rainfall due to this co-linearity. Again it is possible that an analysis of the RR incidence and these variables over shorter periods of time (months or weeks), and for each suburb, or a separate model examining *Ae. vigilax* and *Cx. annulirostris* numbers independently could reveal a relationship between these variables and RR transmission.

Tides

The higher number of spring tides in the September to December period appeared to reduce the incidence of RR. We feel that this is an artefact, as tides are a proxy measure of the effect of vector control. The major vector control activities of both ground and aerial operations are timed according to tidal predictions. The effect of tides on *Ae. vigilax* adult numbers is highly variable in the different areas, but control of larvae after tide alone episodes in the late dry season and early wet season near Darwin has been very successful in preventing high adult numbers of *Ae. vigilax*.

Tides after December or January generally have little effect on *Ae. vigilax* numbers if preceding rainfall has filled the large brackish swamps and hence flooded oviposition sites. Widespread rain in January can result in large hatches of *Ae. vigilax* in the coastal marshes but the ensuing population is very dependent on the level of preceding vector control, and rain and tide variables. With these large hatches, an appreciable amount of vector control may destroy large numbers of *Ae. vigilax* larvae but may still not be sufficient to prevent large numbers of adults invading the residential areas and transmitting RR. Hence the amount of vector control may not necessarily be a good indicator of reduced *Ae. vigilax* numbers. *Cx. annulirostris* numbers are not affected by tides and they do not begin to breed in appreciable numbers until after considerable rainfall in December or January.

REFERENCES

- Bureau of Meteorology. Monthly Weather Review, Northern Territory Regional Office, Darwin, Northern Territory.
 Department of Defence. Australian National Tide Tables. Australian Hydrographic, Commonwealth of Australia.
 Liehne PF in consultation with the Medical Entomology Branch (1985) Mosquito and Biting Midge Investigations, Palmerston 1982-85. Palmerston Development Authority.
 Merianos A, Farland AM, Patel M, Currie B, Whelan P, Dentith M and Smith D (1992) A concurrent outbreak of Barmah Forest and Ross River virus diseases in Nhulunbuy, Northern Territory. Commun Dis Intell (Aust) 16: 110-111.
 Rohe DL and Fall RR (1979) A miniature battery powered CO₂ baited light trap for mosquito borne encephalitis virus surveillance. Bull Soc Vector Res 4: 24-27.
 Tai KS (1992) Epidemic polyarthrititis in the Northern Territory. Masters thesis, Menzies School of Health Research, Darwin, Northern Territory.
 Tai KS, Whelan PI, Patel MS and Currie B (1993) An outbreak of epidemic polyarthrititis (Ross River virus disease) in the Northern Territory during the 1990-1991 wet season. Med J Aust 158: 522-525.
 Whelan PI (1989) Integrated mosquito control in Darwin. Arbovirus Res Aust 5: 178-185.
 Whelan PI, Barker-Hudson P, Morgan B, Ebery B and Gee K (1989) Mosquito control measures in Darwin, Task Force review. NT Dep Hlth Comm Serv.
 Whelan PI, Merianos A, Patel MS, Tai KS and Currie B (1993) The epidemiology of arbovirus infections in the Northern Territory 1980-92. Arbovirus Res Aust 6: 266-269.
 Whelan PI and Weir RP (1993) The isolation of alpha and flaviviruses from mosquitoes in the Northern Territory, 1982-1992. Arbovirus Res Aust 6: 270-277.