

## GEOGRAPHIC VARIATION OF NOTIFIED ROSS RIVER VIRUS INFECTIONS IN QUEENSLAND, AUSTRALIA, 1985–1996

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**Abstract.** The spatial and temporal variations of Ross River virus infections reported in Queensland, Australia, between 1985 and 1996 were studied by using the Geographic Information System. The notified cases of Ross River virus infection came from 489 localities between 1985 and 1988, 805 between 1989 and 1992, and 1,157 between 1993 and 1996 ( $\chi^2_{(df=2)} = 680.9$ ;  $P < 0.001$ ). There was a marked increase in the number of localities where the cases were reported by 65 percent for the period of 1989–1992 and 137 percent for 1993–1996, compared with that for 1985–1988. The geographic distribution of the notified Ross River virus cases has expanded in Queensland over recent years. As Ross River virus disease has impacted considerably on tourism and industry, as well as on residents of affected areas, more research is required to explore the causes of the geographic expansion of the notified Ross River virus infections.

### INTRODUCTION

Ross River (RR) virus, an alphavirus, causes a syndrome known as epidemic polyarthritis.<sup>1,2</sup> Epidemic polyarthritis, a debilitating and frequently persistent disease characterised by arthritis, fever, rash, and fatigue, is the most prevalent vector-borne disease in Australia and hundreds to thousands of such cases are reported annually.<sup>2,3</sup> In general terms, RR virus activity appears to have increased in Australia in the past decade<sup>3</sup> but its causes remain largely unknown.<sup>4</sup> It was proposed that the economic cost of RR virus is approximately US\$1,300 (i.e., A\$2,500) per case,<sup>5</sup> and the economic impact of this disease is thought to cost a minimum of tens of millions of dollars annually in direct and indirect health costs nationally.<sup>4–6</sup>

The disease caused by RR virus has been known since the late 1920s, although the virus and its association with the disease were not identified until the early 1960s.<sup>7</sup> Ross River virus was first isolated by Doherty and colleagues from *Aedes vigilax* mosquitoes trapped in 1959 near Townsville in Queensland at the Ross River, after which the virus was named.<sup>7</sup> However it was not until the single largest reported outbreak in the South Pacific islands in 1979–1980 that the virus was isolated from the serum of a patient suffering from epidemic polyarthritis.<sup>8</sup> More than 50,000 people were affected in that epidemic event. In Australia, it was not until 1985 that RR virus was isolated from a patient with epidemic polyarthritis.<sup>9</sup>

A range of mosquito species has been implicated as vectors of RR virus.<sup>10</sup> Tidal-breeding *Aedes vigilax* and *Aedes camptorhynchus* are important in coastal regions, as are floodwater *Aedes* species in many inland areas. *Culex annulirostris*, which breeds in vegetated semi-permanent and permanent fresh water, is important in areas of the tropics and temperate regions that are subject to flooding or irrigation during summer. Species such as *Aedes notoscriptus* may be important in semi-rural and urban areas. Macropods and other marsupials are thought to be important vertebrate hosts.<sup>1,2,4,10</sup>

Queensland is one of the major Australian States where the transmission of RR virus occurs.<sup>3</sup> It has been suggested that the geographic range of the RR virus infection may have

changed.<sup>11</sup> Therefore, it is important to determine the geographic variation of the disease over recent years. The aim of this study is to examine the geographic distribution of notified cases of the RR virus infection in Queensland between 1985 and 1996.

### METHODS

**Study area.** Queensland is the second largest of the six Australian States and has the largest habitable area.<sup>12</sup> It occupies the northeastern quarter of the continent (Figure 1) and covers approximately 1,727,000 square meters, with 7,400 km of mainland coastline (9,800 km including islands). Lying generally between 10° and 29° south of the equator, it ranges from the temperate and densely populated southeast to the tropical, sparsely populated Cape York Peninsula in the north. There were 3,401,232 residents in Queensland on June 30, 1997.

**Data sources.** We have obtained the computerized data set on the notified RR virus cases in Queensland for the period of 1985 to 1996 and their key sociodemographic information from the Queensland Department of Health. This data set was also used by the National Notifiable Diseases Surveillance System (NNDSS) which is conducted under the auspices of the Communicable Diseases Network Australia New Zealand. The reported place of onset for each case was used to characterise the geographic distribution of the RR virus infection within Queensland.

**Geographic mapping.** The Geographic Information System (GIS) that we used to display the spatial and temporal distributions of RR virus cases was MapInfo Professional.<sup>13</sup> The digital base map data sets used for constructing the GIS were obtained primarily from the Queensland Department of Natural Resources. Administrative boundary data were procured from a commercial source. The base-map data were manipulated to facilitate the accurate identification of the spatial locations of suburbs and townships and their linkages with the other data layers. Therefore, according to the digital base map data sets provided by the Queensland Department of Natural Resources, the location in this study is defined as the locality of a suburb (e.g., in Brisbane and other major cities) or a township. The basic premise underlying the geo-

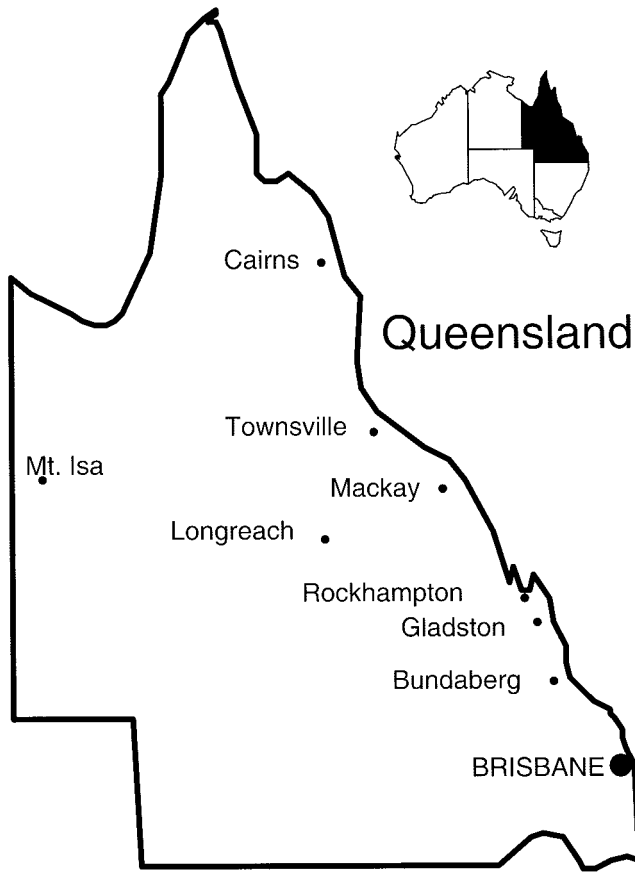


FIGURE 1. A map of Queensland, Australia, showing the location of major cities.

graphical mapping is the localities where the cases were notified.

The onset places in the data set were geo-coded to the digital base maps of localities utilizing MapInfo and Microsoft Access software (US Microsoft Corporation, 1997). The location for each notified case of the RR virus infection was then obtained by overlaying the database of the onset places of notified RR virus infections with the digital base maps. The software automatically links the onset places of the notified RR virus cases from the data set to the digital base-map database if there is an exact locality match. Places that could not be automatically geo-coded were matched interactively, using post code as a secondary search criterion to reduce potential assignment errors. Cases that could not be geo-coded (< 1%) were excluded from the spatial analysis.

**Statistical analysis.** Annual variation of localities where RR virus cases were notified was examined and the data set was then grouped into three categories (each for a four-year period) to visualize the temporal and spatial distributions of notified RR virus infections between 1985 and 1996 in Queensland. The Chi-square test of homogeneity was used to examine whether the differences in the localities where RR virus cases were notified in different years were the random variation.<sup>14,15</sup>

RESULTS

The number of notified RR virus cases in Queensland varied between 1985 and 1996, and reached a record high

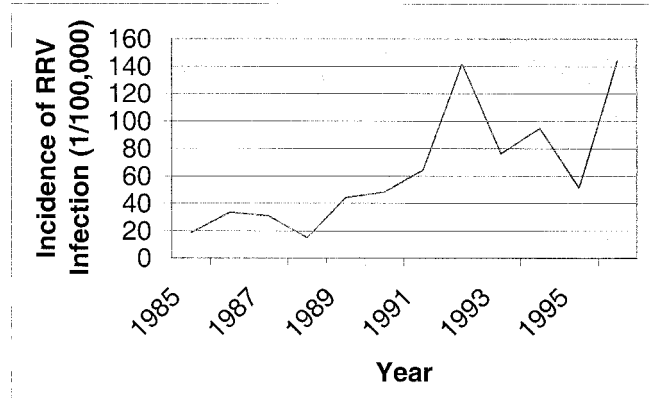


FIGURE 2. Incidence of notified Ross River virus infections in Queensland, 1985–1996.

(4,815 cases) in 1996. The incidence of the RR virus infection ranged from 15.0 per 100,000 in 1988 to 144.2 per 100,000 in 1996 (Figure 2).

The total number of the localities where RR virus cases were notified each year varied over time and there is a remarkable increase in the number of localities where RR virus infections were reported. In the meantime, the number of “new” sites of RR virus cases notified on more than one occasion increased steadily since 1988 (Figure 3).

The spatial analyses show that the cases came from 489 locations between 1985 and 1988, 805 between 1989 and 1992, and 1,157 between 1993 and 1996. Clearly, there was a statistically significant increase in the number of localities where RR virus cases were notified ( $\chi^2_{(df=2)} = 680.9; P < 0.001$ ). The increase of the number of localities was also seen across the majority of categories (Figures 4–6).

Table 1 shows that the total number of locations where the RR virus cases were reported increased by 65% for the period of 1989–1992 and 137% for 1993–1996, compared with that for 1985–1988.

DISCUSSION

This is the first detailed report of apparent geographic expansion of notified Ross River virus infections in Queensland, using the spatial analytical method. Our results indicate that routinely-collected NNDSS program data coupled with

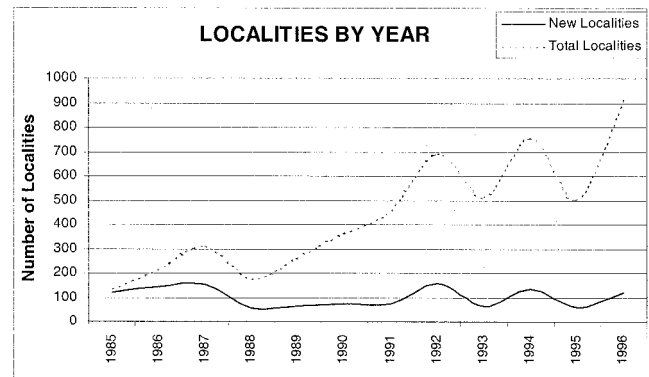


FIGURE 3. Number of localities by type and year.

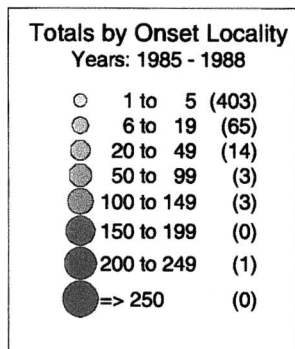
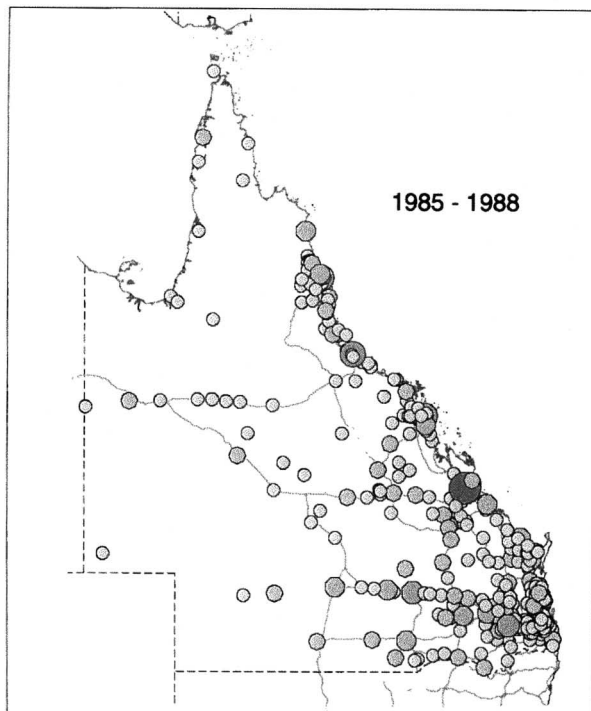


FIGURE 4. Total number of onset localities where Ross River virus cases were notified between 1985 and 1988.

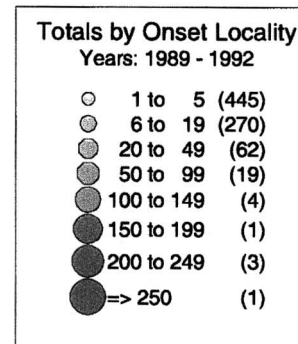
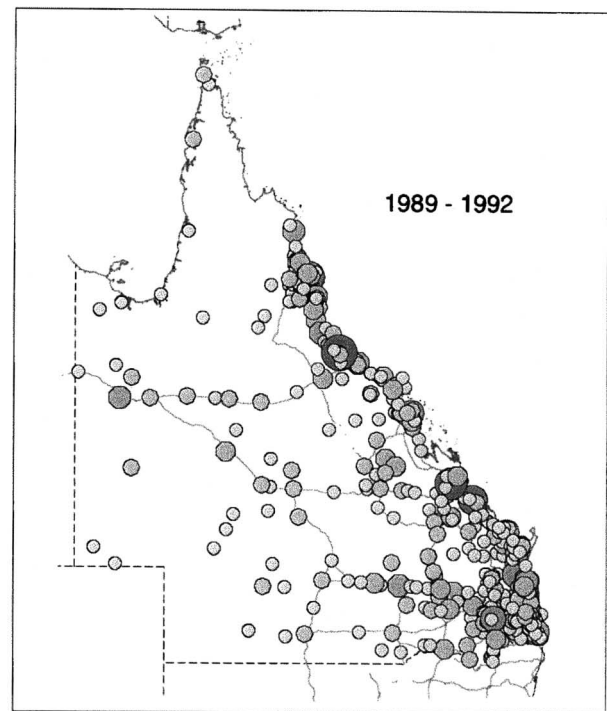


FIGURE 5. Total number of onset localities where Ross River virus cases were notified between 1989 and 1992.

an adaptable GIS system can be used to define the geographic patterns of communicable diseases.

The Geographic Information System is particularly well-suited for studying associations between location, environment, and disease because of its spatial analysis and display capabilities.<sup>16</sup> Recently GIS has been used in the surveillance and monitoring of vector-borne diseases,<sup>17-19</sup> waterborne diseases,<sup>20</sup> and sexually transmitted diseases;<sup>21</sup> and in environmental health,<sup>22,23</sup> injury control, and prevention;<sup>24</sup> and in the analysis of disease control policy and planning.<sup>25</sup> It is envisaged that GIS will play an increasingly important role in medical and public health research. As an introductory study, our research shows that the operational utility of integrating a local health-department disease database with a GIS system can facilitate disease surveillance and development of preventive strategies. Additional reports will be forthcoming as more GIS and epidemiological data are collected and analysed.

**Disease transmission.** The transmission cycles of RR vi-

rus are complex.<sup>1</sup> Many factors, including virus, vector, and host or environmental variations, may contribute to its geographic variation. Several studies have shown that vertical transmission of RR virus is possible, which indicates that the virus may be able to persist in the environment for a long period in desiccation-resistant mosquito eggs; therefore, a rapid onset of cases could occur if conditions become suitable.<sup>26,27</sup> A molecular epidemiological study has recently shown that the E2 and E3 genes of 5 isolates of RR virus isolates exhibited remarkable conservation between 1959 and 1989.<sup>28</sup> Sequence data from a region within the E2 gene of 51 additional isolates showed that RR virus has diverged genetically into three distinct topotypes (or geographically-distinct genetic types), each predominating in particular regions of Australia. Thus one topotype was found in Western Australia and one in Eastern Australia, with an overlap in the Northern Territory and northwestern Australia. A third topotype had been prevalent in northeastern Australia, but no isolates of this topotype have been observed since 1977.

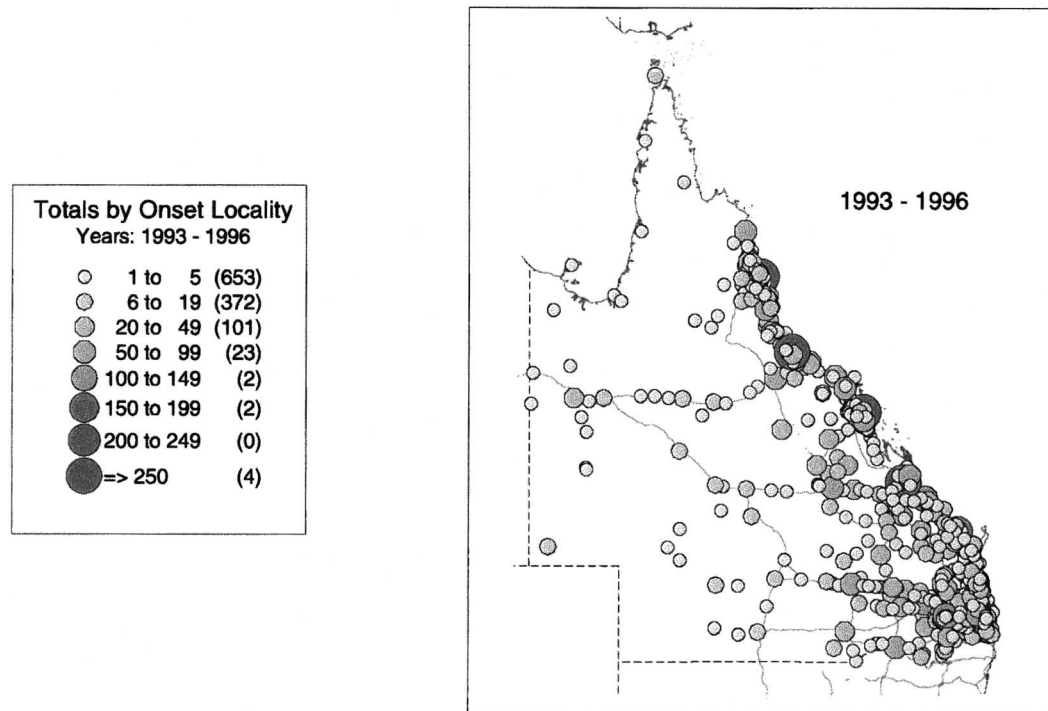


FIGURE 6. Total number of onset localities where Ross River virus cases were notified between 1993 and 1996.

However, some RR virus isolates of the Eastern toptype have been found in Western Australia, and the reverse has also been observed, with the Western toptype in Eastern Australia, indicating movement of virus by the travel of viremic humans or livestock across the continent. It remains unclear how much impact the movement of RR virus has exhibited on its geographic variation in Queensland, although evidence has suggested it may have had a major influence on epidemic activity in Western Australia.<sup>28</sup>

Ross River virus has been isolated from more than 30 species of mosquito belonging to six genera in Australia.<sup>2</sup> Two salt marsh-breeding mosquito species are probably the major vectors in coastal regions, *Aedes vigilax* in northern and eastern Australia and *Aedes camptorhynchus* in cooler areas of southern and southwestern Australia. Some freshwater breeding species, such as *Cx. annulirostris*, *Cq. linealis*, and *Aedes normanensis*, are also vectors of RR virus. These freshwater mosquito species are closely associated with human habitation.<sup>29</sup> Further research is needed to examine whether there has been any change in the geographic distribution of these mosquito species in Queensland.

Marsupials such as the Western grey kangaroo, wallabies, and euros are believed to be the major vertebrate hosts of

RR virus, but other species may also play a role.<sup>1,2</sup> Recent evidence suggests that fruit bats may act as vertebrate hosts in some areas, thus providing a means of virus dispersal.<sup>30,31</sup>

The incidence of RR-virus infection fluctuates with the seasons and is usually associated with warmer and more humid weather. In general, epidemic activity is more often observed in temperate areas with heavy rainfall, flooding or high tides, whereas in tropical Australia transmission occurs throughout the year.<sup>31</sup> Nevertheless, distinct epidemics do occur in northern Australia, especially associated with heavy monsoonal rainfalls. Although RR virus infection occurs in all Australian States, the majority of reported cases (e.g., 63.1% in 1996) have been from Queensland.<sup>3</sup> Over the past decade, major outbreaks caused by heavy rainfall and/or high tides have been reported from several States, including Western Australia in 1988–1989, 1991–1992, and 1995–1996, Victoria and South Australia in 1993 and 1997, New South Wales in 1996–1997, and Queensland in 1996.<sup>4,31,32</sup> Clearly, temperature, humidity, virus strain, mosquito population densities and survival, human behaviour, and housing characteristics, all contribute and interact in determining RR virus transmission.

The geographic distribution of RR virus can also be affected by many other factors, such as population growth, urbanisation, increased travel, and environmental or ecological change. For example, the Queensland population increased from 2,625,000 to 3,390,000 between 1986 and 1996,<sup>12</sup> and more people may have moved into endemic areas or into areas with increased potential for exposure to RR-virus infection. Indeed there has been a significant increase in the potential for exposure to virus through injudicious urban expansion into areas close to wetlands and salt marshes or through the establishment of canal developments,

TABLE 1

Number of localities where the Ross River virus cases were notified in Queensland, Australia, 1985–1996

| Time      | Number of cases |       |         |         |      | Total |
|-----------|-----------------|-------|---------|---------|------|-------|
|           | 1–49            | 50–99 | 100–149 | 150–199 | ≥200 |       |
| 1985–1988 | 482             | 3     | 3       | 0       | 1    | 489   |
| 1989–1992 | 777             | 19    | 4       | 1       | 4    | 805   |
| 1993–1996 | 1,126           | 23    | 2       | 2       | 4    | 1,157 |

leading to either increased mosquito populations, or to increased contact between humans and existing vector populations.<sup>2,4</sup> Furthermore, the possible variation in the quality of the NNDSS data (e.g., notification rates) might affect the assessment of the geographic distribution of RR virus as well. For example, prior to the end of 1991, arboviral infections were reported by medical practitioners. From 1992, infections became notifiable by confirming laboratories.<sup>4</sup> A series of clinical and serological definitions, with guidelines for testing and reporting, was only proposed for national use by testing laboratories in 1993.<sup>33</sup> Furthermore, both under-reporting and over-diagnosis are possible in the NNDSS data. Under-reporting might occur when most of the people infected by RR virus were not clinically apparent; patients who were aware of current infections did not present to physicians because they knew there was no specific treatment or cure; and when physicians increasingly diagnosed cases based on clinical symptoms rather than sending blood samples for serological testing (e.g., some patients may be misdiagnosed as having other diseases if they don't have typical clinical symptoms). Therefore, the notified cases may only reflect the tip of iceberg.<sup>2,4</sup> On the other hand, uncertainty must exist in reporting RR virus cases in endemic situations when based on an IgM response in a single serum specimen because the IgM may represent past infection in a person who currently has another disease.<sup>31</sup>

It may also be worth noting that the premise underlying the geographical mapping in this study is the place of onset—i.e., locality where the RR virus case was notified. The place of onset is presumed as the place of acquisition of infection under the NDDSS. Some studies indicate that the geographical distribution of cases reflects fairly accurately the locations in which RR virus infections actually occur.<sup>11,34</sup> However, there may be differences between these two places, particularly in holiday seasons. In addition, we have examined the proportion of “new” sites of notified cases on more than one occasion (Figure 3). These new sites may have important implications for public health intervention.

**Prospects for control and prevention.** Outbreaks of RR virus impact considerably on tourism and industry, as well as on residents of affected areas. The public health response to the threat of increased virus activity must include further research into the ecology of the virus, its known and potential vectors and hosts, the impact of environmental change, and the interactions of these factors.<sup>35,36</sup>

The importance of an effective surveillance and monitoring system cannot be over-emphasized; it will provide not only forewarning of outbreaks of disease but also valuable information on which to base public-health decision-making. Computer models need to be developed to predict possible epidemic activity under different environmental conditions, and as a means of predicting future consequences of environmental change.<sup>37–40</sup> Due to the high costs required for vaccine development and licensing, and the relatively small population at risk (on a global scale), it is difficult to envisage the economic viability of a vaccine to RR virus. Indeed it may be more effective economically to investigate appropriate personal protective measures against mosquitoes and the better use of anti-arthritic therapies, and to increase research into vector control strategies and into improved town planning and urban development. The latter is of growing

importance as people seek life-style changes and urban spread impinges on wetlands.

There has been global resurgence of arboviral diseases.<sup>41</sup> Ecologic changes and human behavior are important in the spread of these diseases.<sup>42</sup> At present, the transmission of RR virus can only be reduced by mosquito control and community education. Outbreak control remains a problem in rural areas where it is generally impossible to control widespread breeding of very large populations of vector species.<sup>34</sup> In urban areas, biological control strategies should be developed to minimize the impact of vector control programs on the environment. Effective and sustainable control and prevention of RR virus outbreaks must include the community's participation. As the geographic expansion of RR virus transmission is likely to continue, with a concomitant increase in disease incidence, it is essential that public health resources are directed into these areas.

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