An Ecological Approach to Public Health Intervention: Ross River Virus in Australia

Philip Weinstein

Wellington School of Medicine, University of Otago, Wellington South, New Zealand

A detailed look at the ecology of a disease can lead to recommendations for public health interventions that are not otherwise obvious. To illustrate this point, this paper discusses the ecology and control of infection with the Australian arbovirus Ross River virus (RRV). The traditional insecticidal approach to mosquito control is recommended when an outbreak of RRV results from the expansion of an area endemic for the disease to include a population of previously unexposed (nonimmune) people. In contrast, if an outbreak results from the expansion of a nonimmune population into an endemic area, an insecticidal approach can lead to an increased incidence of the disease. Education about antimosquito measures is more appropriate in the latter situation; the differing applicability of these intervention strategies is highlighted. Both strategies could be more scientifically applied if endemic areas were clearly defined by modeling ecological variables and if intervention were more closely linked to improved surveillance systems. An ecologically based control strategy must be developed for RRV to manage the disease appropriately when faced with its probable ecological changes brought about by global warming, increased rainfall, and demographic change. *Key words:* arbovirus, ecology, endemic, epidemic, global change, intervention. *Environ Health Perspect* 105:364-366 (1997)

Historically, the term ecological has been applied to a variety of constructs within the framework of public health. Dubos (*1*) had an ecological view of health—he described health as a mirage that could not be obtained by medical means alone. McKeown (*2*) went on to list the additional components of human ecology that had been responsible for improvements in health, such as sanitation and nutrition. More recently, McMichael (*3*) used the term ecosystem disruption to describe how the same improvements in health will be undermined by the impact of man on the environment. Despite these authors' landmark contributions to our ecological thinking about public health, they have overlooked the practical contribution that an ecological analysis can provide in attempting to solve public health problems. Public health management practices are too often out of touch with the ecology of their target diseases, as is illustrated by a discussion of Ross River virus (RRV) infection in Australia. In the management of this disease, an ecological approach could improve the rationality and efficiency of public health interventions.

The Disease

Ross River virus is a mosquito-borne virus (arbovirus) that circulates enzootically in reservoir populations of kangaroos and other marsupials in Australia. Infection is asymptomatic in host animals and leads to long-term immunity, but while they are viremic, host animals can infect mosquitoes that feed upon them. In susceptible species of mosquitoes, virus particles infect the gut lining, from which the hemolymph and, ultimately, the salivary glands are also infected. After a variable period of time (the extrinsic incubation period), virus particles replicate to the point where the mosquito's saliva is infective to the mosquito's next nonimmune vertebrate host. *Culex annulirostis, Aedes vigilax,* and *Aedes camptorhynchus* are the major vectors, although more than a dozen others are known (*4*). The viral lifecycle is unobtrusively completed if the next host is a member of the reservoir population. However, if a human is bitten instead, clinical disease may result. At least 20% of infected individuals develop an acute disease, characterized by severe joint pains (*5*) and often accompanied by rash, fever, fatigue, and/or myalgia. Most cases resolve within 6 weeks, but recent research suggests that symptoms may often last longer, sometimes relapsing for years (*6*). Because symptoms are nonspecific, diagnosis usually relies on serological evidence of IgM antibodies to RRV (presumptive case) or a fourfold rise in antibody titer between acute and convalescent sera (confirmed case) (*7*). Laboratory notification to public health authorities of positive cases is a statutory requirement in all states and territories of Australia, and approximately 5,000 cases are reported per year.

Epidemiological knowledge of the disease has been reviewed by several authors (*8,9*) but only two points are of major importance in the context of this paper. First, the disease demonstrates a tropical pattern (endemic, averaging about 300 notifications per 100,000 people) and a temperate pattern (epidemic, averaging less than 10 cases per 100,000 in nonepidemic years) (*10*). Second, the age distribution of cases peaks among young and middle-aged adults, presumably reflecting the extent to which these groups are exposed to mosquitoes during outdoor activities. Children are also infected, but for immunological reasons that remain ill understood, symptomatic disease rarely develops before the teenage years. Complete recovery occurs in all cases and infection results in long lasting immunity.

The Ecology of Outbreaks

In attempting to dissect and understand the relationships between those factors that lead to outbreaks, it is useful to consider the following four components separately: the virus and its reservoir, the vector, the human population, and the climate.

The virus and its reservoir. As we have seen, the virus is dependent on the continuing presence of nonimmune hosts in the reservoir population. The distribution and abundance of the reservoir population will thus affect the availability of viremic individuals to mosquitoes and a young (nonimmune) reservoir population leads to increased virus activity.

The vector. A number of vector-related factors also influence the level of RRV activity in a given area. Susceptibility (the ease with which the virus infects and replicates to infective levels in the mosquito) differs between species, as does the degree of host-specificity. The mosquitoes listed above are efficient vectors of the disease both because of their susceptibility to the virus and the readiness with which they bite reservoir as well as human hosts. The age and abundance of mosquitoes affects their ability to transmit the virus; older female mosquitoes are more likely to seek the protein of a second or subsequent blood meal to mature additional eggs and are thus more likely to bite after completion of the extrinsic incubation period of the virus. The greater the abundance of mosquitoes, the greater the probability of being bitten and the greater the probability that the mosquito population will include old females that have bitten both a reservoir host and a human.

Address correspondence to P. Weinstein, Department of Public Health, Wellington School of Medicine, University of Otago, P.O. Box 7343, Wellington South, New Zealand.

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The human population. The human population is susceptible to RRV infection if individuals are nonimmune and are exposed to the virus at the reservoir/mosquito/human interface. Such exposure is enhanced by human intrusions into native ecosystems by the expansion of agriculture, forestry, tourism, or similar activities. Human awareness of the disease, with use of appropriate antimosquito measures, has been shown to reduce the probability of infection (*11*).

The climate. Andrewartha and Birch (*12*) identified temperature and water availability as the most important determinants of the abundance and distribution of animals, mosquitoes being no exception. At higher temperatures, mosquito larvae complete their development faster, allowing more generations to fit into a finite period; given that larvae are aquatic, they obviously also require water. Further, and important in this context, the extrinsic incubation period is decreased at higher temperatures and high relative humidities increase the proportion of old mosquitoes in the population (in low relative humidities, the high surface area to volume ratio of adult mosquitoes renders them susceptible to death through desiccation). Thus, climate directly affects not only the abundance of mosquitoes but the level of virus activity within that population. The reservoir population and virus activity therein are also affected by climate. In seasons with high temperatures and rain fall, the vegetation upon which kangaroos depend will flourish, and more young (nonimmune) reservoir hosts will be added to the temporally and spatially expanding population. Clearly climate also affects the nature and extent of human activity outdoors, completing the final link in the ecological chain of interaction between the components of the cycle that has been discussed. Where this chain of interactions remains complete and the cycle is continuous, we have an area endemic for RRV disease in humans. How can an understanding of these interactions help to improve public health interventions aimed at reducing morbidity from RRV?

Outbreak Control

It is possible for an outbreak to occur when, under favorable climatic conditions, an area endemic for RRV expands to include a previously unexposed nonimmune population. Such an expansion results from the dispersal of infected vectors, reservoirs, and/or hosts, and is likely to have been responsible for the record number of cases [over 800 (*13*)] in Adelaide, South Australia, in 1993. The Central geographic region, which contains the city of Adelaide, abuts onto the Riverland region, which is endemic for RRV (*14*). In this situation, traditional mosquito control at the interface between the endemic and nonendemic areas is appropriate: aerial insecticide sprays (usually malathion- or pyrethrin-based) to control adult mosquitoes and larvicides (e.g., temephos) in bodies of water. However, there is another mechanism by which an outbreak can result. When nonimmune populations enter an endemic area because of urban or agricultural expansion or in relation to tourism, cases of RRV can occur in outbreak proportions. Under these conditions, the traditional insecticide control methods are inappropriate for four principal reasons. First, the endemic areas involved are likely to be large, and the widespread application of insecticides is therefore not cost-effective in the long term. Second, there is justifiable and increasing opposition to widespread environmental contamination by insecticides. Third, the application of insecticides in areas where the target mosquito is unlikely to be eradicated will inevitably result in the development of a resistant mosquito population. Finally, and more subtly, mosquito control in areas endemic for RRV can create disease by delaying the exposure of children to the virus until such a time as they are likely to show symptomatic disease. Residents of such areas are therefore less prone to disease if the natural mosquito populations are left to play out their natural role in the ecology of the virus. Conversely, the invading nonimmune populations would benefit by practicing antimosquito measures such as the use of protective clothing, personal repellents, and house screens, as well as modifying their behavior to avoid peak biting times and areas of high mosquito abundance. Thus, in the former outbreak (resulting from the expansion of an endemic area), traditional mosquito control is appropriate; in the latter outbreak (resulting from nonimmune populations entering an endemic area), public health education is more appropriate. This is a distinction in vectorborne disease control strategies that has not been made before in Australia, despite the direct funding implications of the differing strategies. Every year in Australia, it is likely that many thousands of dollars are wasted on inappropriate mosquito control as well as on poorly targeted public health education campaigns.

The Future

To increase the effective implementation of the differing control strategies for RRV, it is necessary both to define endemic areas with greater resolution and to determine the optimal timing of intervention by linking control implementation to surveillance systems. Seroepidemiological studies have been used to define endemic areas for RRV on the basis of a linear relationship between seroprevalence and age (*14,15*). To improve resolution in mapping such areas, current research is focusing on the application of geographic information systems technology to superimpose the temporal and spatial distributions of the ecological determinants of endemicity (landscape ecology, climate, reservoir and vector populations, and human presence and activity). It is hoped that such modeling will provide answers to the questions of location for control strategies. Improved surveillance systems for RRV activity, such as the use of human blood donors as sentinels (*14*), should in turn provide the answers to the question of timing for control strategies and lead to an integrated management model for public health intervention based on a sound ecological understanding of the disease. It is essential to establish a baseline for such a model for RRV control before our disease management problems are compounded by the predicted effects of global warming, increased rainfall, and demographic change. It is likely that endemic areas of RRV would expand in both time (length of season) and space (geographic area) under greenhouse conditions, with case rates in temperate areas approaching those currently reported in the Australian tropics, and affecting more people in highly urbanized areas. Similar changes in the ecologies of other diseases undoubtedly contribute to their appearance as emerging diseases, and the lack of an ecological basis in the approach to their management may lead to suboptimal intervention, which enhances this appearance. Only with a baseline for management of a disease based on its current ecology can we hope to deal with changes to this ecology that are likely to occur with future global change.

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