MAXIMISING THE VALUE OF OUR ARBOVIRUS NOTIFICATION AND SEROPREVALENCE DATA

L.A. Kelly-Hope, D.M. Purdie and B.H. Kay

Queensland Institute of Medical Research and University of Queensland Tropical Health Program, PO Royal Brisbane Hospital, Qld 4029, Australia

INTRODUCTION

In Queensland (Qld), Ross River virus (RR) and Barmah Forest virus (BF) notification data are routinely presented as a two-weekly indicator of cases testing positive in major local government areas. However, major heterogeneity in RR incidence has been demonstrated in Maroochy Shire by Ryan et al. (1999), and age, sex, seasonal and immunity-adjusted data by Kelly-Hope et al. (submitted) demonstrated that the magnitude, geographical and seasonal patterns of RR and BF disease differed from each other in major urban populations throughout Qld. Significant differences were also evident between age groups, and males and females both within and between populations. In view of the considerable expense associated with the collection and maintenance of notification data, it is likely that its usefulness could be maximised by presenting more detailed information to the local governments responsible for the control and public health awareness of these pathogens. In addition, more accurate and specific estimates of RR and BF disease risk could provide practitioners with useful travel medicine information, similar to that given for Malaria.

In Qld, individuals at greatest risk of mosquito-borne epidemic polyarthritis (EP) disease, are migrants and visitors from interstate and overseas, who have most likely had little or no previous exposure to RR and BF, and may be unaware of the associated risks. However, it is the transient viraemic individuals or groups, who potentially act as migratory hosts, facilitating the spread and maintenance of these viruses to other populations, where favourable environmental conditions, efficient vectors and vertebrate hosts prevail (Bres 1988, Service 1989, Gratz 1999). Similar antibody titres found in clinical and subclinical RR infections (Aaskov et al. 1981a, b), suggest that subclinical infections are also important, and that seroprevalence data could be better utilised to estimate rates of seroconversion among individuals living in or visiting Qld, particularly among transient visitor groups to highly endemic areas.

Qld has high levels of migration and visitation. Over the past decade, Qld has been the fastest growing State in Australia with a 12.5% increase between 1992-1997. The State's growth is chiefly due to interstate migration, but has also recorded net gains of overseas migrants similar to other States and Territories, with an average of around 50,000 individuals from interstate and 20,000 from overseas, moving to Qld each year (Australian Bureau of Statistics [ABS] 1999a, Barker et al. 1999). The State's high level of visitation is primarily driven by the tourist industry, and its wide range of popular tourist destinations and their diverse range of natural attractions, which include beaches, national parks, tropical rainforests and reefs, are considered to be the main attributes responsible for attracting around 4 million interstate and up to 2 million international visitors each year (Statistics Queensland 1999, Tourism Queensland 2000). This paper describes the associated risks and potential outcomes of large groups of individuals moving to and through RR and BF endemic areas in Qld.

METHODS

We present four case studies that focus on interstate and international migrant and visitor groups to selected urban tropical and subtropical populations in Qld. For each group, the risk of mosquito-borne EP disease, and rate of subclinical infection are determined using specific RR and BF notification and seroprevalence data.

Migrant and visitor groups

Interstate and international migrant groups, their numbers and age structure, ie 0-29, 30-59, 60+ were based on published and unpublished data from the ABS 1996 Census of Population and Housing (ABS 1999a, b, Barker et al. 1999). For visitor groups, their numbers, age structure, ie 15-29, 30-59, 60+ as well as air travel (%) were based on visitor survey data (excludes individuals < 15 years), collected in major tourist regions by Bureau of Tourism Research (Tourism Queensland 2000). For each case study, data apropos to 1996 were primarily used, as they were the most comprehensive and readily available, and largely reflected Qld migrant and visitor trends between 1991-98.

Qld populations

The populations to be considered (1998 Estimated Resident Population), included the tropical populations of Cairns (118,834), Townsville/Thuringowa (135,099), Rockhampton (64,437), and the subtropical populations of Maroochy Shire (115,490), Brisbane City (848,741), the Gold Coast (380,270) and Toowoomba (86,968) (ABS 1999b). These populations represent the largest and most centralised urban populations of their regions (Fig 1).

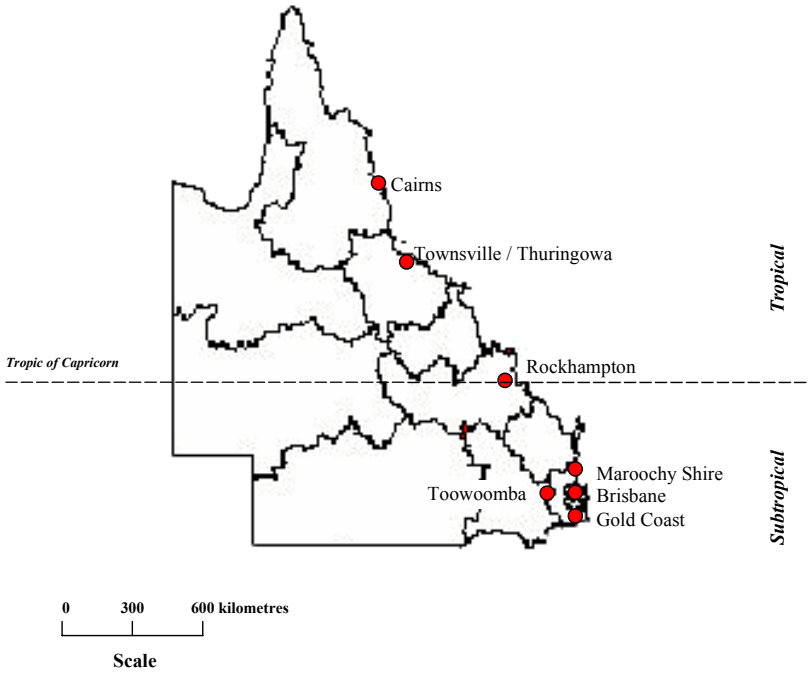

Figure 1. Queensland populations and their governmental regions or Statistical Division (SD) boundaries.

Risk of EP disease

To determine the risk of EP disease, RR and BF annual and seasonal age-specific incidence rates of each population were adjusted for level of immunity using seroprevalence data from a large statewide survey (Phillips et al. 1990, Kelly-Hope et al. submitted). RR and BF immunity-adjusted rates were then aggregated to obtain an annual and seasonal estimate of EP disease per 100,000 population for the 0-29 (for migrants), 15-29 (for visitors), 30-59 and 60+ age groups, in each study population (Table 1).

From these specific EP rates, the number of clinical infections during the first year of residency or period of visitation, the most likely time of infection, ie summer/autumn (SA) versus winter/spring (WS), and the age group at greatest risk were determined for each group. Specific rates were used in preference to standardised rates due to the varying age structure of migrant and visitor groups to Qld.

In addition, human serological studies undertaken throughout Australia were reviewed, with the aim of obtaining an estimate of immunity among interstate groups. From this, we estimated that between 0-30% were potentially immune, and in order to reflect this range, interstate groups were adjusted for three levels of immunity, ie. 0%, 15% and 30%.

The level of immunity among international groups was considered to be negligible, ie. unlikely to exceed 5%, and thus, not taken into account, despite a proportion (~17%) of the overseas migrants to Qld between 1991-96 being Australian-born residents returning long term (Barker et al. 1999), ie. 30% immunity among this Australian group accounts for 5% immunity for the whole international migrant group.

Table 1. Annual and seasonal age-specific EP rates per 100,000 adjusted for immunity.

Age† group	Cairns	Townsville / Thuringowa	Rockhampton	Maroochy Shire	Brisbane	Gold Coast	Toowoomba
0-29	109.8	290.6	146.9	49.4	33.1	19.7	35.6
SA/WS*	95.3 / 14.5	243.8 / 46.8	119.1 / 27.8	40.6 / 8.8	29.5 / 3.6	17.6 / 2.1	27.0 / 8.6
15-29	182.9	495.4	258.6	95.2	54.4	34.0	65.0
SA/WS*	159.2 / 23.7	414.5 / 80.9	209.8 / 48.8	79.3 / 15.9	48.3 / 6.1	30.3 / 3.7	49.5 / 15.5
30-59	313.8	678.3	530.3	258.0	120.0	87.3	124.0
SA/WS*	262.4 / 51.4	571.5 / 106.8	409.9 / 120.4	213.6 / 44.4	105.4 / 14.6	75.9 / 11.4	102.0 / 22.0
60 +	180.0	269.0	228.3	175.8	82.2	50.7	91.9
SA/WS*	127.9 / 52.1	204.5 / 64.5	173.2 / 55.1	128.4 / 47.4	62.8 / 19.4	37.9 / 12.8	64.3 / 27.6

† 0-29 age group rates were used for migrants and 15-29 rates were used for visitors.
* SA = summer/autumn, WS = winter/spring age-specific immunity-adjusted rates.

Rate of subclinical infection

To determine the rate of subclinical infection, all human serological studies undertaken in Qld were reviewed, with the aim of obtaining an annual seroconversion rate from the available age-specific data, using linear regression. From this, we estimated that the annual seroconversion rate ranged between 0.8% and 1.9% [~ 0.2% BF virus] (Doherty 1973, Phillips et al. 1990), and in order to determine the number of subclinical infections, these rates were applied to the first year of residency or period of visitation of each group. As no current regional seroprevalence data exists, these rates were unable to be more specifically applied to the distinct regions of Qld, and thus only produced broad estimates of subclinical infection. However, we speculate that 0.8% is more likely to reflect seroconversion rates in the subtropical populations, whereas 1.9% is more likely to reflect those in tropical populations.

Again interstate groups were adjusted for 0%, 15% and 30% levels of baseline immunity, while international groups were unadjusted for immunity.

RESULTS

Case study 1. Interstate migration

In 1996, 4,305 individuals, whose usual place of residence was interstate, migrated to Townsville/ Thuringowa, over half were from the populous east coast States of New South Wales (NSW) (1,575) and Victoria (Vic) (1,002), and around 57%, 40% and 3% were in the 0-29, 30-59 and 60+ age groups, respectively.

From the annual and seasonal age-specific EP rates for Townsville/Thuringowa (Table 1), between 13–19 (or 1 in 232-227) interstate migrants (~ 8-11 from NSW / Vic) were estimated to develop EP disease during their first year of residency, depending upon the group's level of immunity (Table 2). The majority of cases were estimated to occur during the summer and autumn months (81-85%), and among adults in the 30-59 year age group (62-63%).

Depending on the annual seroconversion rate, between 24-82 (1 in 125-53) individuals from interstate (~ 14-49 from NSW / Vic) were estimated to develop subclinical infection during their first year of residency (Table 3).

Table 2. Estimated number of EP cases among interstate migrants to Townsville/Thuringowa, for age groups and seasons based on baseline level of immunity.

Age group and seasons	Level of immunity 0%	15%	30%
0-29	7	6	5
30-59	12	10	8
60 +	0	0	0
Total	19	16	13
Summer / Autumn	16	13	11
Winter / Spring	3	3	2

Table 3. Estimated number of subclinical among interstate migrants to Townsville/ Thuringowa, for different seroconversion rates and baseline level of immunity.

Seroconversion rate	Level of immunity 0%	15%	30%
0.8 %	34	29	24
1.9 %	82	69	57

Case study 2. International migration

In 1996, 22,576 individuals, whose usual place of residence was overseas, migrated to the southeast Qld populations of Maroochy Shire (919), Brisbane (14,866), Gold Coast (5,974) and Toowoomba (817), accounting for around 63% of all overseas immigrants to Qld. The most common countries of origin (by birthplace) of overseas migrants to this region between 1991-96, included New Zealand (20%), Australia (17%), United Kingdom (UK) / Ireland (13%), Northeast (NE) Asia (14%) and Southeast (SE) Asia (10%), with individuals born in NE, SE and Southern Asia making up around one-quarter (27%). Approximately 50%, 43% and 7% of migrants were in the 0-29, 30-59 and 60+ age groups, respectively.

From the annual and seasonal age-specific EP rates for each population (Table 1), around 15 (1 in 1,505) international migrants (~ 3 from NZ, ~ 2 UK / Ireland and ~ 4 Asia) were estimated to develop EP disease during their first year of residency, with most infections occurring among migrants to Brisbane and the Gold Coast (Table 4). For Australian-born residents returning from overseas, approximately two individuals were estimated to develop disease. Overall, the majority of cases were estimated to occur during the summer and autumn months (91-100%), and among adults in the 30-59 year age group (67-100%).

Based on the annual seroconversion rate range, a total of between 181-429 (1 in 125-53) individuals from overseas (~ 36-86 from NZ, ~ 31-73 Australian-born residents, ~ 24-56 UK / Ireland and ~ 49-116 Asia) were estimated to develop subclinical infection during their first year of residency in this southeast Qld region (Table 5).

Table 4. Estimated number of EP cases among international migrants to southeast Qld populations, for age groups and seasons.

Age group and seasons	Region Maroochy Shire	Brisbane	Gold Coast	Toowoomba	Total
0-29	0	2	1	0	3
30-59	1	8	2	0	11
60+	0	1	0	0	1
Total	1	11	3	0	15
Summer/Autumn	1	10	3	0	14
Winter/Spring	0	1	0	0	1

Table 5. Estimated number of subclinical cases among international migrants to southeast Qld populations, for different seroconversion rates.

Seroconversion rates	Region Maroochy Shire	Brisbane	Gold Coast	Toowoomba	Total
0.8 %	7	119	48	7	181
1.9%	17	282	1141	16	429

Case study 3. Interstate visitation

In 1996, around 410,000 individuals from interstate visited the Cairns region, 80% were from NSW and Vic, predominantly Sydney (105,000) and Melbourne (113,000) and approximately 26%, 63% and 11% were in the 15-29, 30-59, 60+ age groups, respectively. The average length of stay was 7 days, and around 35% of interstate visitors were estimated to travel to the region by air, as part of domestic airline package deals.

From the annual and seasonal age-specific EP rates for Cairns (Table 1), between 15-21 (1 in 19,133-19,524) interstate visitors (~ 8-11 from Sydney / Melbourne) were estimated to develop EP disease during their period of visitation, depending upon the group's level of immunity (Table 6). Again, most cases were estimated to occur during the summer and autumn months (80-88%), and among adults in the 30-59 year age group (73-76%).

Depending on the annual seroconversion rate, between 44-150 (1 in 6,523-2,733) visitors (~ 23-80 from Sydney / Melbourne) were estimated to develop subclinical infection during their stay, depending upon the group's level of immunity (Table 7).

Taking both clinical and subclinical infections into account, we estimated that between 59-171 (1 in 4,864-2,398) interstate visitors potentially developed viraemia after 1 week holiday in the Cairns region, of whom approximately 38-111 moved on to other destinations by rail or road, and between 21-60 (~ 11-32 from Sydney / Melbourne) returned home by air.

Table 6. Estimated number of EP cases among interstate visitors to Cairns, for age groups and for seasons based on baseline level of immunity.

Age group and seasons	Level of immunity 0%	15%	30%
15-29	3	3	3
30-59	16	13	11
60 +	2	1	1
Total	21	17	15
Summer/Autumn	17	15	12
Winter/Spring	4	2	3

Table 7. Estimated number of subclinical cases among interstate visitors to Cairns, different seroconversion rates and baseline level of immunity.

Seroconversion rate	Level of immunity 0%	15%	30%
0.8 %	63	54	44
1.9 %	150	127	105

Case study 4. International visitation

In 1996, around 647,261 and 950,500 individuals from overseas visited Cairns and the Gold Coast, the two most popular tourist regions of Qld. Around 33% (215,299) and 45% (396,774), respectively, were from Japan, representing the two largest visitor groups to Qld from a single international source. In Cairns, Europeans 22% (140,558), and on the Gold Coast, New Zealanders 10% (91,616) accounted for the second highest proportion of international visitors. Of all the international visitors, approximately 36%, 48% and 16% to Cairns and 32%, 57% and 11% to the Gold Coast were in the 15-29, 30-59, 60+ age groups, respectively.

The average length of stay in each region was 5 days, and around 48% of visitors to Cairns and 21% to the Gold Coast were estimated to travel to the region by air. The close proximity (~1 hour drive) of Brisbane International Airport, where 43% of international visitors travel by air, may account for the Gold Coast's lower percentage of air travel, and higher percentage of coach travel of 40%.

From the annual and seasonal age-specific EP rates for Cairns and the Gold Coast (Table 1), around 22 (1 in 29,421) and 9 (1 in 105,611) international visitors, respectively (~ 7 and 4 from Japan respectively, ~ 5 Europe to Cairns, ~ 1 NZ to Gold Coast), were estimated to develop EP disease (Table 8).

Similarly, most cases were estimated to occur during the summer and autumn months (82-89%), and among adults in the 30-59 year age group (60-78%).

Depending on the annual seroconversion rate, between 71-169 (1 in 9,116-3,830) visitors to Cairns (~ 23-56 from Japan, ~ 16-37 Europe) and between 104-247 (1 in 9,139-3,848) to the Gold Coast (~ 47-111 from Japan, ~ 10-25 NZ) were estimated to develop subclinical infections (Table 9).

Taking both clinical and subclinical infections into account, we estimated that between 93-191 (1 in 6,960-3,389) international visitors to Cairns and between 113-256 (1 in 8,412- 3,713) to the Gold Coast, potentially became viraemic after their short holiday, with approximately 45-92 to Cairns, and 24-54 to the Gold Coast (or 49-110 from Brisbane International Airport) leaving either for home or other destinations by air.

Table 8. Estimated number of EP cases among International visitors for age groups and seasons.

Age group and seasons	Region	
	Cairns	Gold Coast
15-29	6	1
30-59	13	7
60 +	3	1
Total	22	9
Summer/Autumn	18	8
Winter/Spring	4	1

Table 9. Estimated number of Subclinical cases international visitors, for different sero-conversation rates.

Seroconversion rates	Region	
	Cairns	Gold Coast
0.8 %	71	104
1.9 %	169	247

DISCUSSION

Our use of age-specific incidence rates and seroprevalence data illustrates how we may obtain more accurate and specific estimates of EP disease and subclinical infection occurring among migrant and visitor groups to Qld. This is of particular importance in Qld, where RR and BF endemicity prevails, and many populations continue to rapidly grow as popular settlement and tourist destinations.

The risk of EP disease among both migrants and visitors varied depending upon age, season and destination, however, the number of cases was dependent upon both this risk and the number of migrants and visitors to each population. In general, the high risk tropical populations, accounted for a higher proportion and number of EP cases among migrant and visitor groups, despite attracting smaller numbers overall. For instance, we estimated that between 13-19 cases among the 4,305 interstate migrants to Townsville/Thuringowa and around 15 cases among the 22,576 international migrants to the southeast Qld region occurred during each group's first year of residency. Similarly, over twice as many cases were estimated to occur among international visitors to Cairns than the Gold Coast, despite the Gold Coast receiving over 300,000 more visitors.

The high-risk summer / autumn period accounted for the majority of EP cases in all four case studies. This has implications for migrants moving to Qld at the beginning of each calendar year, who are more likely to be develop EP disease in their first six months of residency, than those who move midyear. Similarly, visitors taking holidays during this high-risk period are at greater risk of disease. In general, visitors may be viewed as a high-risk group, as they may be more likely to participate in popular recreational outdoor activities, such as bushwalking, and visiting Wildlife/National Parks, in close proximity to epizootic cycles and important local vectors, and less likely to be aware of the associated risks and appropriate precautions, particularly those with limited English language skills. This points to the importance of delivering timely and well-targeted local public health messages and mosquito control programs to meet local needs, with specific focus on residential and tourist areas commonly used by migrants and visitors. Furthermore, active communication between local authorities and tourism companies could, for instance, provide over 50% of international visitors to Cairns and the Gold Coast with multilingual information just by targeting the most popular accommodation and recreational sites of Japanese and European visitors alone.

In all populations, adults in the 30-59 year age group were found to be at greatest risk of EP disease. This has social and economic ramifications for both working migrants and visitors to Qld as both mild and severe EP disease, lasting several weeks or months, may easily impair an adult's ability to earn an income and subsequently provide for their family. To date, no study has specifically examined the socioeconomic impact of disease burden on individuals and their families, despite the annual cost of EP disease to Australia being estimated at tens of millions of dollars (Russell 1998). Migrants, however, are more likely to have their illness correctly diagnosed, adequately treated and notified to local authorities, than transient visitors, particularly those who return overseas, where practitioners may be unaware of, and unable to test for Australian arboviruses.

Currently, there are a range of countries that have the appropriate technology to test for antibodies, which include New Zealand (NZ), Fiji, Papua New Guinea, Israel, the Netherlands, Germany, France and the United States of America (USA) (Kapeleris J [PanBio Pty Ltd Brisbane, Qld], and Mitchell CJ [Centres for Disease Control Fort Collins, USA] personal communications 2000). However, Australia has no centralised system whereby serology or identified cases from overseas may be sent for testing or notification**.** The fact that a positive association between RR infection and travel to Australia has been found among individuals from the USA (Hueston et al. 1997, Mitchell CJ, personal communications 2000), NZ (Maguire 1994) and other parts of the world (Aaskov JG [Queensland University of Technology, Brisbane, Qld], Emmerich P [Bernhard Nocht Institute for Tropical Medicine, Hamburg, Germany] and Kapeleris J, personal communications 2000), has major

implications for international health and travel medicine. It raises the question as to whether there is a need for an increased international awareness of these viruses, as well as more adequate national and international facilities to better cater for international serological tests and data collection.

Due to the transitory nature of both interstate and international visitors, it is possible that many clinical infections acquired in Qld were not notified to local authorities, if at all. However, the extent to which EP disease among visitors leads to incomplete notification data, lower incidence rates and conservative risk assessments in Qld, is difficult to establish, but may be more evident among highly transient tourist populations such as Cairns and the Gold Coast (Tourism Queensland 2000). Some insight to this may be illustrated by our studies of visitors to Cairns, where we estimated that up to 21 interstate and 22 international visitors became infected whilst on holiday, but due to their short stay, are unlikely to have had their illness detected and notified in this population. Thus, potentially resulting in a loss of some 43 notifications or around 30% of all notifications for that year (Queensland Health 1999).

Visitors infected in Qld but notified elsewhere in Australia, results in the overestimation of incidence in other populations. This highlights the importance of practitioners obtaining travel histories, particularly those working in epidemic-prone regions, or regions with minimal or no arboviral activity such as Sydney and Melbourne. A national or State data collection centre where indeterminate notifications could be sent, may identify popular high-risk travel destinations like tropical Qld, help to minimise the misclassification of notifications and subsequently improve risk assessments. Further, it may help to identify the most likely time and route in which either virus may be introduced or re-introduced into vulnerable populations or regions.

Highly endemic Qld areas may be significant sources from where RR and BF are disseminated. Humans have previously been implicated as migratory hosts (Doherty et al. 1970, Seglenieks and Moore 1974, Mudge 1977, Marshall and Miles 1984, Lindsay et al. 1995), and in the Pacific during the 1979–1980 RR epidemics, humans were found to develop titres as high as 10^6 $CCID_{50}$/ml, more than sufficient to infect mosquitoes (Rosen et al. 1981, Tesh et al. 1981). Therefore, it is possible that many viraemic visitors take part in the dissemination of these viruses throughout Australia and elsewhere, facilitated by rapid, affordable and accessible road and air transport. Yet, visitors with subclinical infections may be deemed the most effective and elusive carriers, as they continue to move about freely, undetected, and quite unaware of their viraemic status or the risk they pose to others.

High levels of human air traffic to and from Qld could result in outbreaks of EP disease in other countries, but particularly those throughout the Asian Pacific region, where favourable environmental conditions and mosquito vectors are more likely to prevail. However, RR and BF are unlikely to be maintained in many Asian Pacific countries due to an overall lack of suitable vertebrate hosts, as found with the Pacific outbreaks of RR (Marshall and Miles 1984). Currently, NZ is the country most vulnerable to the importation and maintenance of EP disease with the recent discovery of the efficient RR mosquito vector *Aedes camptorhynchus* (Thomson) in the Hawkes Bay region (Hearnden 1999), together with the already established *Aedes notoscriptus* (Skuse) and an estimated 60 million brush tail possums (Weinstein et al. 1995, Watson and Kay 1999, Boyd and Kay 2000). The close proximity of the two countries and the high levels of migration and visitation could readily introduce RR or BF into NZ from Australia. This has considerable socioeconomic implications for NZ, and the most likely time, route and place in which either virus could be introduced, via viraemic travellers from Qld, needs to be identified.

Clearly, the rate in which visitors develop subclinical infections is important, however, there is a pressing need for current age-specific seroprevalence data in the different regions of Qld, so that better seroconversion rates may be estimated not just for visitors, but for those living in and migrating to endemic populations. While transient visitors may play a role in the dissemination of these viruses, large influxes of non-immune migrants could readily increase the number of infections, boost arboviral activity and subsequently leave populations susceptible to outbreaks of EP disease. In serological studies in Vic, higher RR seroconversion rates were found among individuals who entered endemic populations from risk free populations (Fraser et al. 1986), and the length of residency was positively associated with seroprevalence (Fraser et al. 1986, Wolstenholme 1993). Therefore, interstate and international migrants to endemic Qld populations could potentially have, and contribute to, both higher rates of disease and subclinical infection, than long-term residents.

The examination of notification data with respect to migration in the future could provide better estimates of risk associated with migration and length of residency. It may also point to high-risk locations within populations. Population growth is frequently accompanied by an increase in urbanisation, with the building of homes and housing estates on the outskirts of towns and cities, in the more semi-rural, bushland areas. Migration and urbanisation have shown to be important determinants of arboviral disease throughout the world (Monath 1993). Thus, it would be necessary to determine if high incidence rates found within populations were attributed to the overall low immune status among local residents, or the close proximity in which they live to epizootic cycles, or both. This matter has previously been raised by Ryan et al. (1999), who defined heterogeneity in RR disease in different statistical districts of Maroochy Shire, and suggested that differences in demographics, immunity and relative proximity to important local vectors was responsible.

Our estimates of clinical and subclinical infection among migrant and visitor groups also highlight the importance of communicating the specific risks more effectively to the general public. One way this may be

achieved, is by expressing incidence rates as probabilities or an individual's chance of disease. Chance is a commonly used and widely understood term, and may help local authorities in high-risk populations such as Townsville/Thuringowa, to inform 30-59 year old residents or prospective migrants for example, of their annual 1 in 147 chance of disease. This is likely to be more meaningful to residents, and may produce better outcomes than the use of their annual immunity-adjusted, age-specific rate of 678.3/100,000 population in public health campaigns.

We took a similar approach in expressing the estimated number of clinical and subclinical cases in each group, which may be viewed as an alternative way to communicate risk, particularly to visitors in popular tourist regions, such as Cairns, where 22 of the 647,261 international visitors, or 1 in 29,420 were estimated to developed EP disease. Such an approach may also be useful for health authorities, tourism operators and travel medicine companies overseas, where the risk of tourists returning from Qld with either EP disease or subclinical infection is of concern.

The above cases studies illustrate how we may exploit both notification and seroprevalence data to obtain a better understanding of the associated risks and potential outcomes of human migration and mobility in RR and BF endemic areas. However, the on-going collection, maintenance and practical use of these arbovirus data is imperative, so that progressive risk assessments, up to date public health messages and more specific studies may be carried out with respect to migration and visitation, in particular tourism. This could help to identify and appropriately manage high-risk populations, as well as facilitate better personal protection, prevent infection and subsequently reduce the passage of these viruses elsewhere.

REFERENCES

Aaskov JG, Fraser JRE and Dalglish DA (1981a) Specific and non-specific immunological changes in epidemic polyarthritis patients. Aust J Exp Biol Med Sci 59: 599-608.

Aaskov JG, Mataika JU, Lawrence GW, Rabukawaqa V, Tucker MM, Miles JA and Dalglish DA (1981b) An epidemic of Ross River virus infection in Fiji, 1979. Am J Trop Med Hyg 30: 1053-1059.

Australian Bureau of Statistics (1999a) 1996 Census of Population and Housing – Basic Community Profiles. Commonwealth of Australia. Available at: http://www.abs.gov.au

Australian Bureau of Statistics (1999b) Unpublished population data. Commonwealth of Australia. Available from: Client and Information Services, Brisbane, Queensland.

Boyd AM and Kay BH (2001) Solving the urban puzzle of Ross River and Barmah Forest viruses. Arbovirus Res Aust 8:14-22.

Barker R, Gillam E and Taylor A (1999) Migration Queensland 1991-1996. Queensland Department of Communication and Information, Local Government and Planning.

Bres P (1988) Impact of arboviruses on human and animal health. In The Arboviruses: Epidemiology and Ecology, (Ed. Monath TP) Vol 1. CRC Press Inc. Boca Raton, Florida.

Doherty RL, Wetters EJ, Gorman BM and Whitehead RH (1970) Arbovirus infection in Western Queensland: serological studies, 1963-1969. Trans R Soc Trop Med Hyg 64: 740-747.

Doherty RL (1973) Surveys of haemagglutination-inhibiting antibody to arboviruses in Aborigines and other population groups in Northern and Eastern Australia, 1966-1971. Trans R Soc Trop Med Hyg 67: 197-205.

Fraser JR, Christie DG, Gust ID, White J, Leach R, Macaulay ED, Ahern AP, Alexander J, Jones JM, Lung DYL,

Moore FM, Moysey CD, Phillips PJ and Pryor I (1986) Arbovirus infection in a Murray Valley community. Med J Aust 1: 257-259.

Gratz NG (1999) Emerging and resurging vector-borne diseases. Ann Rev Entomol 44: 51-75.

Hearnden MN (1999) A health risk assessment for the establishment of the exotic mosquitoes *Aedes camptorhynchus* and *Culex australicus* in Napier, New Zealand. Report to the Coordinator, Environmental Health Programme, Community Healthcare Hawkes Bay.

Hueston L, Yund A, Cope S, Monteville M, Marchetti M, Haniotis J, Clancy J, Doggett S, Russell R, Dwyer D and Parker G (1997) Ross River virus in a joint military exercise. Comm Dis Intell 21: 193.

Kelly-Hope LA, Kay BH, Purdie DM and Williams GM (2001) Defining the risk of Ross River and Barmah Forest virus disease in Queensland. Aust NZ J Public Health.

Lindsay MDA, Johansen CA, Broom AK, Smith DW and Mackenzie JS (1995) Emergence of Barmah Forest virus in Western Australia. Emerg Infect Dis 1:22-26.

Maguire T (1994) Do Ross River and dengue viruses pose a threat to New Zealand? NZ Med J 107: 448-450.

Marshall ID and Miles JAR (1984) Ross River virus and epidemic polyarthritis. In: Current Topics in Vector Research, vol 2 K.F. Harris, Ed. Praeger, New York.

Monath TP (1993) Arthropod-borne viruses. In Emerging Viruses, S. Morse Ed. Oxford University Press, New York.

Mudge PR (1977) A survey of epidemic polyarthritis in the Riverland area, 1976. Med J Aust 1: 649-951.

Phillips DA, Murray JR, Aaskov JG and Wiemers MA (1990) Clinical and subclinical Barmah Forest virus infection in Queensland. Med J Aust 152: 463-466.

Queensland Health (1999) Unpublished Ross River and Barmah Forest virus notification data. Communicable Disease Unit, Public Health Services, Queensland Health Department, Queensland Government, Brisbane

Rosen L, Gubler DJ and Bennett PH (1981) Epidemic polyarthritis (Ross River) virus infection in the Cook Islands. Am J Trop Med Hyg 30: 1294-1302.

Russell RC. (1998) Vectors vs. humans in Australia – who is on top down under? An update on vector-borne disease and research on vectors in Australia. J Vector Ecol 23: 1-46.

Ryan PA, Do KA and Kay BH (1999) Spatial and temporal analysis of Ross River virus disease patterns at Maroochy Shire, Australia: association between human morbidity and mosquito (Diptera: Culicidae) abundance. J Med Entomol 36: 515-521.

Seglenieks Z and Moore BW (1974) Epidemic polyarthritis in South Australia: report of an outbreak in 1971. Med J Aust 2: 552-556.

Service MW, Ed. (1989) Demography and Vector-Borne Diseases. CRC Press Inc. Boca Raton, Florida.

Statistics Queensland (1999) Regional profiles (April edition). Queensland Treasury Office of Economic and Statistic Research, Queensland Government. Available at: http://www.statistics.qld. gov.au

Tesh RB, McLean RG, Shroyer DA, Calisher CH and Rosen L (1981) Ross River virus (Togaviridae: Alphavirus) infection (epidemic polyarthritis) in American Samoa. Trans R Soc Trop Med Hyg 75:426-31.

Tourism Queensland (2000) Research and Statistics, Queensland Government. Available at http://www.qttc.com.au

Watson TM and Kay BH (1999) Vector competence of *Aedes notoscriptus* (Diptera: Culicidae) for Barmah Forest and of this species and *Aedes aegypti* (Diptera: Culicidae) for dengue 1-4 viruses in Queensland, Australia. J Med Entomol 36: 508-514.

Weinstein P, Laird M and Calder L (1995) Australian arboviruses: at what risk New Zealand? Aust NZ J Med 25: 666-669.

Wolstenholme J, Aldred J (1993) Ross River virus disease in 3 Murray River towns. Arbovirus Res Aust 6: 64-68.