Pest and Vector Control: Badu, Torres Strait Australia

Sinclair F *RN*

Corresponding Author: Fiona Sinclair fionaksinclair@hotmail.com

Abstract

The objective of the case study was to investigate and identify environmental health related concerns and possible causes of the incursion of Japanese Encephalitis on Badu Island, Torres Strait. The arbovirus was identified in Australia in 1995. Five cases, including two deaths, occurred between 1995 and 1998 with one of these becoming infected on the Mitchell River, Cape York Peninsula. Investigations ensued including serological study of pigs and humans, entomological studies, community interviews and wind/vector studies. The major issues identified included close proximity of domestic pigs (effective amplifying host) to residential premises, and high larval numbers in the environment surrounding dwellings including waterholes, blocked drains and rubbish waste. Computer simulated studies revealed the possibility that a viraemic JE mosquito was windblown from Papua New Guinea to Australia. Management action included attempts at environmental clearance for vector control, wide vaccination campaign, and further enforcement of quarantine requirements, public education and the deployment of sentinel surveillance pigs on Cape York Peninsula. The virus continues to be controlled at this point but lingers as a constant threat and efforts to contain it outside of mainland Australia remain considerable, to protect mortality and morbidity of those living in the Torres Strait and northern Australia.

Key words: Japanese encephalitis, Badu Island, vector control, environmental health

Introduction

Environmental health is an important aspect of modern public health. There is an increasing awareness of the importance of disease surveillance related to pests and vectors, particularly in points of entry to Australia from the rest of the world. Much of this takes place in sea ports, airports or at international mail centres, all of which have strict custom and quarantine regulations. Stringent requirements and enforcement have enabled successful containment and eradication of some pests, although it is an ongoing battle against those that will not respect international boundaries and government quarantine regulations - not foreign asylum seekers, but birds and insects! Pest and vector control, particularly in Australia's north (Fig 1) is of utmost importance in protecting the country's health. Small islands dotted between Australia and Papua New Guinea (PNG) provide natural stepping stones for pests and vector visitors that come bearing disease. Saibai, the most northern part of Australia is a mere 3.6 kilometres from PNG (AQIS 2003).

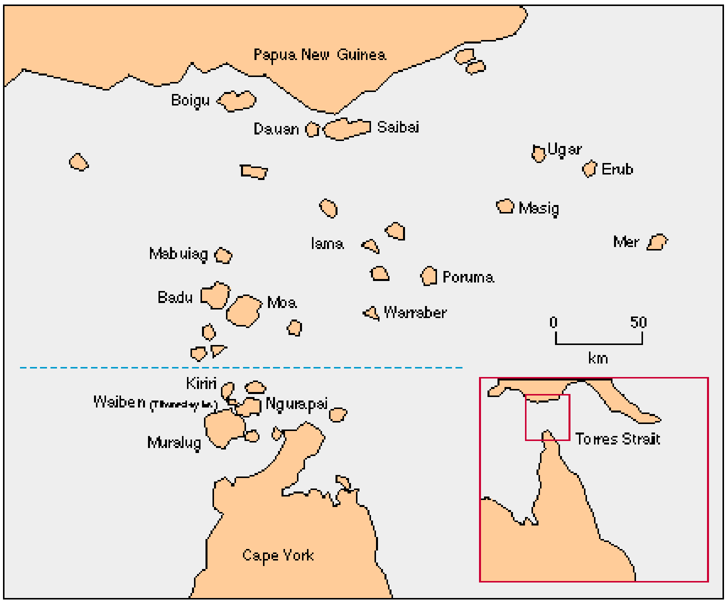


Figure 1: Australia and Torres Strait Islands. © MJA 1996 - reproduced with permission.

The case study presented here concentrates on the island community of Badu, in Australia's Torres Strait and the environmental health problems related to pest and vector managements associated with the Japanese Encephalitis (JE) virus. Badu is a small granite island in the central west Torres Strait (Johansen et al, 2001). The community is on the west coast of the island. It is flat; however it has a perched watertable that creates many swampy areas in the wet season (Ritchie et al, 1997 in Johansen et al, 2001). Badu has a population of approximately 950 people (local census, Badu Island Health Clinic, 1999 in Johansen et al, 2001).

The virus made its debut in March-April, 1995 when three Badu residents contracted the virus. Two of these cases died - a 45 year old and a 15 year old (Russell and Doggett, 2006). Initially it was thought that the cause was Murray Valley encephalitis (the major cause of arbovirus encephalitis in Australia), but laboratory testing identified it as JE (Hanna et al., 1996). Since, there has been another incursion on Badu with infection of another Badu resident and another on the Australian mainland – the west coast of Cape York Peninsula in 1998, a total of five cases (Ritchie, 2005). Following the 1998 incursion, measures were stepped up to address the issues. The identification of a second genotype in another incursion (without human infection) in 2000 suggests a different source (van den Hurk et al, 2001).

JE was first described in Japan as early as 1871 (Dept of Health and Ageing 2004), and now extends from Pakistan, throughout Asia, east to the West Pacific Islands, and from Korea in the north down to northern Australia. It is the chief cause in the world of epidemic viral encephalitis (WHO 2006). Disease transmission occurs via mosquitoes and propagates at the bite site and lymph nodes, invading the central nervous system to produce subclinical disease. Some symptoms include: headache, fever, disorientation, paresis, and coma, but is not distinguishable from other infections of the central nervous system (Dept of Health and Ageing, 2004). Case fatality of those with symptoms is 25-30% and there are 30-50% of neuropsychiatric sequelae in survivors (McCormick and Allworth 2002).

The virus is preserved in a cycle that involves water birds (egrets and herons) and other invertebrates. Most large invertebrates such as humans are poor amplifying hosts and thus are dead ends. Pigs however, are very proficient amplifiers and have been closely linked with the disease occurrence (Hanna et al, 1996).

Following the outbreaks, serological studies found that humans and pigs on other Torres Strait Islands had antibodies to the virus and JE was isolated from the strand of mosquito *Culex annulirostris* on Badu. There is evidence to suggest that the virus has been in PNG since at least 1989 and thus infiltrated into the Torres Strait (Hanna et al, 1996).

The objective of this work was to explore environmental health issues related to the outbreaks on Badu. This involved looking at investigations that have been undertaken to identify and adequately determine the major factors involved. Subsequent management and effects were evaluated, and possible suggestions have been proposed to improve future maintenance necessary to use environmental measures to prevent (where possible) monitor and respond to JE.

Investigation

There were a number of factors involved in the pest and vector problems on Badu. To identify these, we must understand JE. It is not a native virus, but an ‘import’. The specific cause of Japanese encephalitis is a mosquito bourn flavivirus that affects the meninges of the brain. The major vector is *Culex* mosquitoes, in Australia particularly *Culex annulirostris* (Hanna et al 1996). They breed extensively early in the tropics wet season (QLD Communicable Disease Unit 2001).

The natural life cycle of JE requires water birds such as egrets and herons and *Culex* mosquitoes. Pigs are very effective amplification hosts and thus almost always contribute to JE outbreaks in humans (Russell and Doggett 2006). Humans, horses and other large invertebrates are not good amplification hosts, and are really just incidentally affected, so are dead ends in the JE lifecycle (Mackenzie 1999).

Possible causes of introduction of the virus into the Badu community:

- Importation of a viraemic pig - could have been an important link but is doubtful as there are strict indigenous Quarantine Officers that enforce the Quarantine act (AQIS 2003).
- Windblown mosquitoes, although investigations into wind and weather patterns show the possibility of JE reaching the mainland would be a very rare (Ritchie & Rochester 2001).
- Bird migration - one hundred species of bird migrate between PNG and Australia each year; sixty three more irregularly cross the Torres Strait including wading birds which are an integral part of the JE cycle in Asia, It is possible that birds transmitted the virus however studies of mosquito blood meals reveal the likelihood as quite low (van den Hurk et al 2001).
- Frugivorous bats (Ritchie and Rochester 2001)
- A viraemic person travelling. Boigu, Dauan and Saibai are so close to PNG that there are visitors there basically every day. Someone with the virus may have brought it but as humans are dead end hosts, the chain is unlikely to have continued long.

Environmental factors that contributed to the preservation of the virus cycle in the Badu community and that may have been the reason why Badu, out of all the Torres Strait Islands, should have being affected by JE.

- Domestic pigs kept in close proximity to human houses. In 1996 53% of people on Badu kept pigs and 69% were 50 metres or closer to the house. Prior to 1998 there were 180-220 pigs kept domestically (Hanna 1996).

- Extensive water covered areas in the wet season from a perched water table. This facilitated mosquito breeding at close proximity to domestic pigs and people – 63% of pig pens were in or around standing water.
- Roaming horses that defecate along the swamp edges creating breeding environments for mosquitoes (Johansen et al 2001).
- 64% of the houses had defective waste systems or raw sewerage from overflowing septics (Hanna et al 1996).
- Drains and waterways throughout the community blocked from grass and garbage (Johansen et al 2001)
- Abundance of vector species – Badu has an abundance of *Culex annulirostris* and vertebrate hosts (feral and domestic pigs, and wild birds) to enable the natural cycle of JE (Daley and Dwyer 2002).
- Human population density
- Tropical location – high rainfall and warm environment allows optimal breeding environments for the mosquitoes.
- Low pressure systems and strong north to north-westerly winds from PNG to the Cape that is thought to have blown down infective mosquitoes (Ritchie and Rochester 2001).

Although JE virus in clinical expression is an acute illness, as an environmental health concern it is a chronic problem. It has been identified in serological conversions (although infection with the virus does not necessarily cause disease – there is a high ratio of asymptomatic to symptomatic conditions (Hanna et al 1996) in pigs and humans in the Torres Strait almost every year since monitoring began, following the 1995 outbreak. Annually the time of greatest risk is between February and March (QLD Communicable Disease Unit 2001). JE outbreaks are patchy and usually confined, not covering large areas (WHO 2006), as was the case on Badu. Thus when an outbreak occurs it is more a case of an acute exacerbation of a problem that was already lurking. The geographical spread of the problem ensures that JE will remain a chronic problem.

JE is not a one off and thanks to sentinel surveillance we know that it is an ongoing concern. The chief fear is that there will be geographic extension of the arbovirus from Badu and other Torres Strait Islands onto the mainland. The map (Fig 2) shows the isolations of JE in the past decade or so. It becomes obvious that the issue is a complex one. One that changes depending on uncontrollable seasonal winds, rainfall and monsoons in addition to local environmental factors.

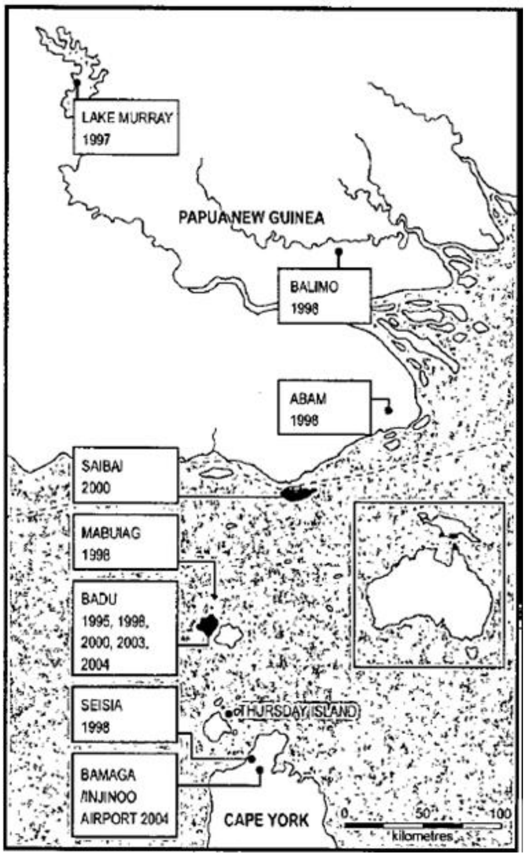


Figure 2: Location and years of JE virus isolations in north Australia and PNG. An assessment of the interval between booster doses of Japanese encephalitis vaccine in the Torres Strait. © *Australian and New Zealand Journal of Public Health* 2005 – reproduced with permission.

In the Torres Strait, *Cx annulirostris* is the principal vector. If JE continued south, it could present a major problem because *Cx annulirostris* is abundant on the mainland (Russell and Doggett 2006). One study using aerial kite traps showed that it was possible for mosquitoes to be carried, the 200 km south journey from PNG to Cape York. It is however, unlikely to disperse from tropical to temperate Australia (Kay & Farrow 2000). Female *Cx annulirostris* have been collected in western NSW in similar density to that of India or China where JE is enzootic (Kay and Farrow 2000). *Cx gelidus* is also a potential vector since its introduction from Asia (Daley and Dwyer 2002).

There are many feral pigs and wild birds in northern Australia heightening the fears that the arbovirus may become established on the mainland (Geraghty and McCarthy 2004). Extensive wetland habitats in Cape York also increase the possibility from southward movement (MacKenzie 1999). The impact of this would be much greater due to the more populous areas.

Entomological studies have shown possible isolation from the mosquito *Ochlerotatus vigilax*. Although this result may have been spurious, if its not it could mean vertical transmission of

JE. This is a possibility – it has occurred in other mosquito species. Particularly on a small island where there are limited hosts, if this occurred the impact may no longer become a wet season threat, but a year around problem if the virus uses other species during the dry (Johansen et al 2001). Further lab investigations have been made.

Optimal time for amplification in the invertebrate host before human case identification is about two months (Ritchie and Rochester 2001). Following the bite, there is an incubation period of 5 to 15 days, followed by symptom onset (CDC 2001 and Dept of Health and Ageing 2004).

How was the problem identified?

Initially it was thought that the disease of the Badu cases was Murray Valley encephalitis. Further investigation identified JE, and the associated environmental conditions leading to the disease.

Serological Studies

The problem was identified through a number of approaches. A serological analysis was taken of the population of Badu. Human blood was screened for the existence of Flavivirus IgG and IgM and antibodies to JE, Murray Valley Encephalitis and Kunjin virus. The serological survey also included blood from domestic animals, pigs being the most important. They were also screened as above (Hanna et al 1996). 100 ml of human sera from Badu residents were injected into monolayers of C6/36 cells, incubated and the viral growth monitored to determine the virus strain (Hanna et al 1996).

Entomological survey

Larval dipper samples and adult mosquito traps were performed/set in a 1km radius of the Badu community. This occurred overnight on four different occasions in the month that the outbreak occurred in 1995 (Hanna et al 1996). This was repeated in 1998 when the second incursion became obvious. They were set a week after the human case was admitted to hospital and 2 weeks after the sentinel pigs had seroconvertered. This took place over two consecutive nights using a total of 25 traps. The majority were killed on dry ice then transported for characterization and isolation in Brisbane/Cairns (Johansen et al 2001).

Household interview survey

Discussion with one adult from each house was undertaken about the features in their particular household that may have contributed to the outbreak. For instance, number and type of backyard animals like pigs and horses, and broken infrastructure for waste disposal, drainage and sewer systems (Hanna et al 1996).

Outer island community surveys

Convenience blood samples from three inner islands, twelve outer islands and seven Cape York communities (Hanna et al 1996) to determine how widespread the problem was.

Wind blown mosquito investigations

Later investigations were undertaken after surveillance showed widespread activity of the virus in 1998 – from Sabai down to the Cape. Wind speeds and directions during the monsoon season were studied to discover if it is possible that mosquitoes were blown from PNG or Irian Jaya all the way to Badu and the Australian mainland (Ritchie and Rochester 2001).

Findings

Virus isolation (Tables 1 and 2) showed that there were two viruses that were definitely JE strains. The two had 99% homology with one another. Comparisons were made with other JE isolates showing 92% homology with a strain that was present in Malaysia, Indonesia and Thailand between 1968 and 1983. The isolates from Badu were added to the GenBank, an international store of genomic sequencing data (Hanna et al 1996).

The mosquito survey showed high larval numbers in: swampy areas nearby especially ones with horse faeces, the surrounds of a waterhole filled with grass, in rubbish and horse faeces, in overgrown drains running through the community, in domestic rubbish waste and even in water collected from hoof print indents (Hanna et al 1996). In 1995, 22190 adult mosquitoes were trapped. Three types comprised 99%, one of which was *Cx annulirostris.* Eight JE viruses were located from *Cx annulirostris* only, six of these were from collections within the community. The other types were identified as only marginal vectors and played no role in the 1995 outbreak (Hanna et al 1996). In the 1998 investigations, JE found throughout the community – it was isolated from all but 3 of the 25 trap sites. The study in 1998 yielded less minimum infection rate in 1998 was lower, but the study was at a much bigger scale. This study showed that JE virus isolation was more likely to occur at sites on the outskirts of the community – closer to the habitats of potential vector birds or mammals and within reach of the pig pens (Johansen et al, 2001). 97/102 households were surveyed. 53% households kept pigs with 56% of these being ‘wet’ pig pens which were identified as breeding sites for *Cx annulirostris* and 69% within 50metres of the house. 15% kept horses within 15metres. Sixty-four percent had waste water or raw sewerage overflow from septic tanks (Hanna et al 1996).

Serum samples from the other communities showed no evidence from the inner islands or Cape York but 20 people from three outer islands showed recent JE virus infection. In pigs there was JE infection from all the outer islands but none from the inner islands or Cape York.

The wind computer simulated studies showed that wind blown mosquitoes were a possibility for JE transmission (Ritchie and Rochester 2001).

Table 1: Seroprevalence of Japanese encephalitis virus infection in people and pigs in TS (Hanna et al 1996).

Communities	People tested	People positive	Pigs tested	Pigs positive
Badu	215	35 (16%)	11	11 (100%)
Other West'n Islands	158	17 (11%)	15	11 (73%)
Nth West'n Islands	207	3 (1.5%)	31	23 (74%)
Central Islands	320	0 (0%)	15	5 (33%)
Eastern Islands	223	0 (0%)	18	13 (72%)

Table 2: Number of days that wind may have carried mosquitoes from PNG to Badu and Northern Cape York Peninsula (Ritchie and Rochester 2001)

Year	No. of days backtrack simulated	Badu Island days (%)	Cape York days (%)
1994-95	121	8 (6.6)	0 (0)
1995-96	122	21 (17.2)	7 (5.7)
1996-97	121	20 (16.5)	8 (6.6)
1997-98	121	20 (16.5)	11 (9.1)
Mean	121	17.3 (14.2)	6.5 (5.4)

Related circumstances

From December to April the prevailing monsoonal winds in the Torres Strait are north westerly. The possibility of tropical cyclones blowing the mosquitoes still further into the Cape may account for the incidence on the mainland in 1999 (Ritchie and Rochester 2001) .

The 1995 and 1998 incidences on Badu can both be linked to tropical low pressure systems to the west of Cape York. The accompanying high rainfall would have helped the mosquitoes to ground level from the high altitudes at which they were carried (Ritchie and Rochester 2001). Female *Cx annulirostris* can also fly 12km or more (Bryan et al 1992). The northern outer islands are within 10km of PNG (Hanna et al 1996).

It is assumed that JE came from PNG, where the first human cases were identified in 1997 (Dept of Health and Ageing 2004). Antibodies to JE virus were found in 23% of people in the Western Province of PNG in 1989, and 49% of porcine samples collected in the same area in 1995. Thus JE may be enzootic in south west PNG. The end of 1997 and beginning of 1998 saw a severe drought in PNG which caused stagnant waters in the swampy and low lying regions of Western PNG and large numbers of *Cx annulirostris* from which JE was isolated from (C Johansen, unpublished data in Ritchie and Rochester 2001).

Initially the virus was thought to be Murray Valley Encephalitis. Further investigation identified it as JE. Although the disease was unexpected in the sense that it had not been detected in Australia before, in hind sight, given the knowledge of the presence of the virus, and given the environmental factors on Badu, it is not at all unexpected that the disease should proliferate.

Management history and effects

Initial management strategies were put into place after the 1995 outbreak on Badu. This involved:

- Reduction of mosquito breeding potential thorough improvement of environmental conditions on the islands.
- Establishment of a communal piggery 3km from town (van den Hurk et al 2001).
- Vaccine - Implementation of attenuated vaccine in unvaccinated populations in endemic areas - 93% of people in the region were vaccinated by late 1995 (Russell and Doggett 2006). After recommendations from National Health and Medical Research in September 1998, the JE vaccine joined the Standard Australian Vaccination Schedule in November (Dept Health and Ageing 1998). The vaccine is now given simultaneously with measles-mumps-rubella (MMR) vaccine at 12 months of age (Daley and Dwyer 2002), opportunistically during the year and also in a campaign late in the year prior to the wet season (Hanna et al 2005). Apart from residents, recommendations are that all non residents who live or work there for more than a month between December and May (QLD Communicable Disease Unit 2001) should be vaccinated. The vaccine has a cost of $300 but is provided free to residents and military under the QLD Government Vaccination Program (Geraghty and McCarthy 2004). There are cheaper alternatives in China but they are not available elsewhere currently (CDC 2003).
- Quarantine restrictions were already in place (Fig 3), however after the incursion, obviously JE was identified as a significant risk. There are zones to decrease the chance of JE and other pests and vectors moving south from PNG. Restricted items can not be moved from PNG to the Torres Strait Protected Zone, from the Torres Strait Protected Zone to the Special Quarantine Zone, or from the Special Quarantine Zone to the Australian mainland.

Figure 3: Quarantine restrictions and restricted items in the Torres Strait Quarantine Guidelines (AQIS 1999).

- Public education about mosquito avoidance (repellents and nets), and vaccination from travel medicine clinics for people travelling to the area for an extended period of time.
- Herds of sentinel pigs on numerous islands in the Torres Strait, Northern Cape York Peninsula and north NT (Dept of Health & Ageing 2004). Monitoring is conducted during the wet (QLD Communicable Disease Unit 2001) and the pigs are bled every two weeks (Bond 2004)
- Entomological research to identify specific vectors. Mosquito collections were taken following sero-conversion of the sentinel pigs. Of particular interest was the blood meal identification. *Cx annulirostris* mostly fed on mammals (98.9%), pigs, dogs, horses and humans and birds (1.1%) (van den Hurk et al 2001).

Reducing mosquito breeding potential

Most of the major environmental factors that relate to mosquito proliferation are difficult to change. For example draining swamps or making the wet season less wet. Things like clearing the drains and fixing infrastructure are effective in reducing the proximity of the breeding sites to humans. The difficulty with this is that it requires ongoing commitment from both the local council and the people themselves, so successful management of these issues fluctuates.

Communal piggery

Since the construction of the communal piggery, and movement of all domestic pigs out of the community, the likelihood of Badu residents being bitten by mosquitoes who have fed on viraemic pigs has been greatly reduced. This decreases the likelihood of JE transmission but also reduces natural immunity boosting (Hanna et al 2005). In 1998 there were 66 pigs in the communal piggery and none in the community (AQIS in van den Hurk et al 2001). There remain numerous feral pigs (unquantified) however their habitats are not near the Badu community (van den Hurk et al 2001).

Since the pigs have been resettled, *Cx annulirostris* have found other mammals to feast on – horses, dogs, and humans. A study that compared the blood meals of mosquitoes in the Badu community between 1995 and 2000 show an increase in the feeding on humans, but less likelihood that those bites were from mosquitoes that had also fed on pigs. It indicates that there are few engorged mosquitoes flying the distance from the piggery into town. While the sentinel pigs have shown further incursions, the prevention of human infection can be linked to the removal of pigs from the immediate community (van den Hurk et al 2001).

Vaccination

In March 1998 a boy from Badu was hospitalized with JE (came from a religious group that refused vaccination) (Russell and Doggett 2006). He recovered, but the incidence perhaps indicates that human infection rates may have been much greater, had vaccination rates not been as high.

The existing vaccine is made from animal product (mouse brain) (Wordsworth 2005), and can have severe side effects in every 10 to 60 cases in 10 000 vaccinated (QLD Communicable Disease Unit 2001). Adverse effects can occur up to ten days after administration of the vaccine. Current trials are in place for a new vaccine with the hope that it will be released in the next two years (Norton 2005).

Quarantine restrictions

The Commonwealth Government has invested over $19 million in a three year period in the top end – the Northern Australian Quarantine Strategy (Stanton 2001). The Australian Quarantine Inspection Service (AQIS) is Australia's frontline in protecting the country from pests and disease including JE. Very committed indigenous quarantine officers mean strong policing and good public education regarding quarantine restrictions – a very effective way of preventing importation of viraemic pigs.

Public education

Also an issue that requires ongoing attention. AQIS are very good at educating people in the Torres Strait and top end and produce easily understood booklets and intermittently travel doing educational presentations about health and quarantine. While education is important, it does not necessarily mean people act on the information.

Sentinel surveillance

Since the sentinel pig surveillance was set up in 1996, they have shown evidence of JE in the Torres Strait every year. In 1998 and 2004 they also showed evidence of the virus on the Northern Cape York Peninsula (Hanna et al 2005).

The fact that the sentinel system has alerted us to incursions reveals their success. In January 2000 another incursion was identified when three of the sentinel pigs on Badu seroconverted to JE virus, in May sentinels on Moa had seroconverted.

Despite their success, pigs pose a threat to public health if they are located near to human settlement - because of their role as amplification host in the JE cycle. This means the pigs must be placed in remote locations, leading to another problem – expense. The cost of rearing and monitoring five pigs can be up to $16 000. There are also risks related to handling and bleeding live stock (Ritchie et al 2003).

Gold standard for surveillance is field mosquito collection traps, removing the 'piggie in the middle' is a goal for the Quarantine and Inspection Service Remoteness of the areas renders this impractical.

The current plan is to transfer from the pigs to self powered mosquito traps. Already some mosquito trapping is done using CO2 baited light traps. However, these must be sticked with dry ice each trapping night making it unrealistic for more remote parts of islands and the Cape. The newer traps use propane and can trap for 20 – 30 days using a 9kg tank. (Ritchie et al 2003).

They are easy to set up and maintain, can be set for testing by normal post and they are effective in surveillance of other arboviruses. They are expensive however – about $4000 and need security to combat vandalism, and the propane tanks cannot be transported on a plane, making remote deployment more time consuming (Ritchie et al. 2003).

Entomological studies.

These studies have been very important in identifying blood meals of mosquitoes and also have enabled identification of different genotypes suggesting that all JE incursions have not necessarily originated from the same place. A collection in 2000 showed no isolation of JE from *Cx annulirostris* though all the previous incursions had been linked with them as the primary vector (van den Hurk et al 2001). Instead it was linked with *Cx gelidus,* which is as proficient a host as *Cx annulirostris.* It has only recently been identified in Australia, but is now well established in north Queensland. The research arm of managing the problem is important because it ensures the correct areas for prevention are targeted.

Probable outcomes

As the emergence of JE into Australia is relatively recent, it is difficult to predict the outcome. One reality is that the problem will not go away. Now it has arrived, it is quite possible that JE will become enzootic in the Torres Strait Islands and the northern peninsula area.

Widespread vaccination ensures that there will not be an epidemic of human cases, however ongoing surveillance is necessary to monitor the distribution of the virus and if need be, to extend the current vaccination recommendation areas. Badu is likely to continue having annual JE isolation and it is a combination of public education and control of local environmental conditions that will reduce the possibility for mosquito breeding and feeding.

Since its isolation on Badu in 1995, and on the mainland in 1998 there have been a number of strategies put in place. These have already been outlined and it is evident that the disease will continue to make its presence known in the Torres Strait and possibly mainland Australia. The best public health strategy is simply to monitor its progress (if any) and react accordingly - changing immediate environmental conditions near people and vaccinating in areas where there is significant risk.

Any disease that causes fatality will have lasting effects, particularly in small communities. The deaths of some of their own may mean that the community of Badu remain aware of the serious of the nature of JE.

The introduction of the virus itself has very lasting damage as it is now fairly firmly established in the mosquito/pig populations, ensuring that it is a lasting threat and potential for more damage to humans – illness or death.

Social aspects are important because they effect what people do with the information they are given. For some the knowledge that keeping pigs close to their home will increase the likelihood of transmission of a virus that may cause disease or death is enough to move pigs away. If the society as a whole decide they don't want to travel 3 kilometres to feed their pigs, the threat 'appears' less imminent and creates a social environment where people keeping pigs in their backyards is perfectly acceptable. As an aside, the presence of JE in Muslim countries is very minor because pigs are not acceptable socially or religiously (WHO 2006).

Some positive social effects of the problem are increased shared responsibility for ongoing surveillance and early warning systems between AQIS and the indigenous people of Badu and other Torres Strait Islands. The information acquired from indigenous people in everyday surveillance in addition to the officers employed is invaluable and are important for building the capacity of the community.

The cost of a socially nonchalant attitude to the potential risks is immeasurable if another member from the Badu Island were to die. Because of the high vaccination rate, this will hopefully not occur, however remains a risk.

Resolution

Successful resolution of the problem involves:

- Culling of all pigs (domestic and feral), birds and bats
- Netting of all dwellings

- Adornment of personal protective clothing before venturing outdoors….

Obviously all of the above are impractical and unreasonable. The difficulty with JE is that it cannot be eradicated in the foreseeable future and so remains a public health threat that must be managed by effective surveillance and public education.

At the community level, knowledge is power. If the people of Badu, other Torres Strait Islands and the north of Australia are aware of the dangers they are at least able to be personally prepared. Public health information that is easily understood should be disseminated on an ongoing basis so that everyone is aware of the risks – from the young to the old.

Though mentioned in jest previously, culling of wild pigs may be of use in decreasing the most important part pf the JE cycle. The fact that they are a pest in terms of causing environmental degradation as well as carrying other disease may further validate undertaking this. It is an expensive operation and due to the high reproduction rate of pigs would have to be an ongoing program.

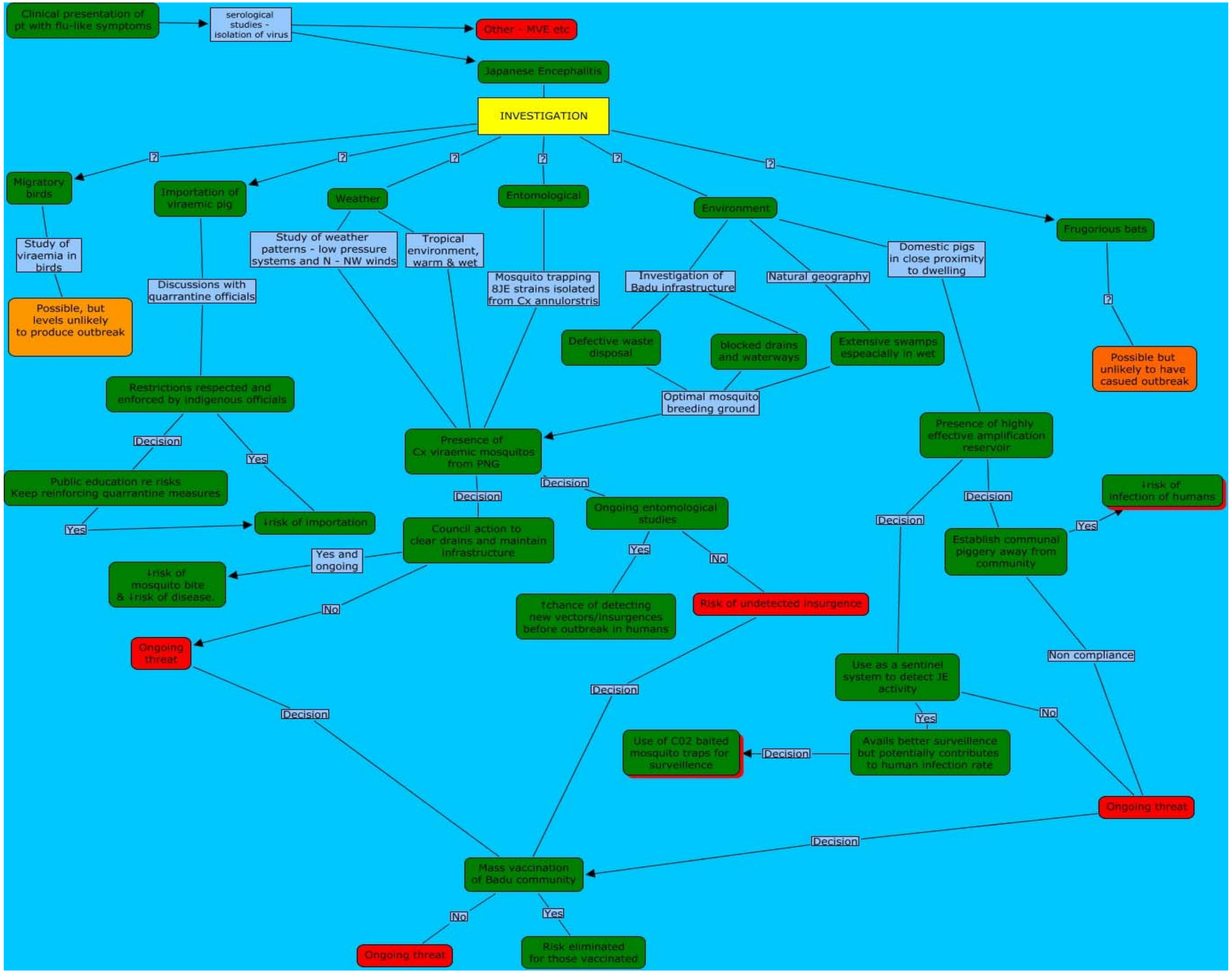
Other Torres Strait Islands could benefit from adapting the animal husbandry patterns similar to those that have proved successful on Badu (and Taiwan and Japan) in decreasing risk of transmission between pigs and humans. That is the removal of pigs from the domestic environment to set apart farms (van den Hurk et al 2001). Some governmental power in enforcing this practice may increase the effect of this.

Development of improved vaccines is an important aspect of the problem. This is of particular importance if the disease spreads further in distribution and impact. People are much less likely to vaccinate themselves or their children when there are significant risks of adverse effects. In a larger population, this could translate to more human infections. Further research is also required to test the efficacy of the current recommended booster interval, as the current regime is based on a very small sample size with questionable conclusions (Hanna et al 2005)

Conclusion

Environmental and social factors have huge effects on disease emergence – including JE. The case study has shown some interesting elements in the relationships between pests, vectors, the environment and humans. Investigations into the problem have been extensive and the subsequent outcomes have has some positive effects on progression of the disease. Changing weather patterns, animal husbandry, increasing travel, changing social practices and advances on medical practice (Daley & Dwyer 2002) will continue effecting viral epidemiology. It is vital that Australia's surveillance and response to information regarding JE modify to suit these changes, to ensure the disease continues to be contained as much as possible through the management of pests and vector.

Figure 5: Flow chart



References

AQIS (2003) Top watch quarantine: Protect our island homes. Australian government vital fact sheet, Australian Quarantine and Inspection Service Canberra.

AQIS (1999) Quarantine protects the Torres Strait. Australian government top watch. Australian Quarantine and Inspection Service

Bond J (2004) Flying pigs. Transcript from 'Catalyst', ABC, 29th April, 2004. http://www.abc.net.au/worldtoday/content/2005/s1525896.htm accessed 20/03/07.

Bryan JH, O'Donnell MS, Berry G, Carvan T (1992) Dispersal of *Culex annulirostris* in Griffith, NSW Australia: a further study. Journal American Mosquito Control Association. 8: 398-403.

Centres for Disease Control and Prevention (2001) Questions and answers about Japanese encephalitis. Division of Vector-Borne Infectious Diseases: Colorado.

Centres for Disease Control and Prevention (2003) Japanese encephalitis fact sheet. Division of Vector-Borne Infectious Diseases: Colorado.

Daley AJ and Dwyer DE (2002) Emerging viral infections in Australia. Journal of Paediatrics and Child Health 2002. 38(1):1-3.

Dept of Health and Ageing (1998) Federal government acts on Japanese encephalitis. Media release by Mr Michael Wooldridge, 10 November 1998.

Dept of Health and Ageing (2004) Communicable diseases information: arbovirus and malaria surveillance, Japanese encephalitis fact sheet. Australian Government: Canberra.

Geraghty CM and McCarthy JS (2004) Japanese encephalitis vaccine: is it being sufficiently used in travellers? MJA. 181(5): 269-270.

Hanna JN, Ritchie SA, Phillips DA, Shield J, Bailey MC, Mackenzie S, Poidinger, McCall BJ, Mills PJ (1996) An outbreak of Japanese encephalitis in the Torres Strait, Australia, 1995. Medical Journal of Australia. 165: 256-260.

Hanna JN, Smith GA, McCulloch BM, Taylor CT, Pyke AT and Brookes DL (2005) An assessment of the interval between booster doses of Japanese encephalitis vaccine in the Torres Strait. Australian and New Zealand Journal of Public Health. 29: 44-47.

Johansen CA, van den Hurk AF, Pyke AT, Zebrowski P, Phillips DA, Mackenzie JS, Ritchie SR (2001) Entomological investigations of Japanese encephalitis virus in the Torres Strait, Australia, in 1998. Journal of Medical Entomology. 38: 581-588.

Kay BH, Farrow RA (2000) Mosquito (Diptera: Culicidae) dispersal: implications for the epidemiology of Japanese and Murray Valley encephalitis in Australia. Journal of Medical Entomology. 37:797-801

Mackenzie JS (1999) Emerging viral infections: an Australian perspective. Emerging Infectious Disease. 5(1).

McCormick JG and Allworth AM (2002) Emerging viral infections in Australia. Medical Journal of Australia. 177: 45-49.

Norton R (2005) Trials of new vaccine for Japanese encephalitis. Transcript from 'The World Today': ABC Local Radio. 7th December, 12:40. http://www.abc.net.au/worldtoday/content/2005/s1525896.htm accessed 20/03/07.

Queensland Communicable Disease Unit (2001) Public health fact sheet: vaccination against Japanese encephalitis. Queensland Health: Brisbane.

Ritchie S (2005) Trials of new vaccine for Japanese encephalitis. Transcript from 'The World Today': ABC Local Radio. 7th December, 12:40. http://www.abc.net.au/worldtoday/content/2005/s1525896.htm accessed 20/03/07.

Ritchie S, Pyke AT, Smithy GA, Northill JA, Hall RA, van den Hurk AF, Johansen CA, Montgomery BL, Mackenzie JS (2003) Field evaluation of a sentinel mosquito (Diptera: Culicidae) trap system to detect Japanese encephalitis in remote Australia. Journal of Medical Entomology. 40: 249–252.

Ritchie S, Rochester W (2001) Wind blown mosquitoes and the introduction of Japanese encephalitis into Australia. Emerging Infectious Diseases. 7(5).

Russell RC, Doggett SL (2006) Japanese encephalitis virus. Department of Medical Entomology, Sydney University: Sydney. http://medent.usyd.edu.au/fact/japanese%20encephalitis.htm accessed 20/03/07.

Stanton M (2001) Australian Quarantine Services: How much is enough? An address by Australian Quarantine and Inspection Service to the Rural Press Conference of Victoria, 26th April.

Van den Hurk A.F, Nisbet DJ, Johansen CA, Foley PN, Ritchie SA, Mackenzie JS (2001) Japanese Encephalitis on Badu Island, Australia: the first isolation of Japanese encephalitis virus from the *Cx gelidus* in the Australasian region and the role of mosquito host-feeding patterns in virus transmission cycles. Trans R Soc Trop Med Hyg 95: 595-600.

Wordsworth M (2005) Trials of new vaccine for Japanese Encephalitis. Transcript from 'The World Today': ABC Local Radio. 7th December, 12:40. http://www.abc.net.au/worldtoday/content/2005/s1525896.htm accessed 20/03/07.

WHO (2006) Water Related diseases: Japanese encephalitis. Water, sanitation and health. World Health Organisation. http://www.who.int/water_sanitation_health/diseases/encephalitis/en/ accessed 20/03/07.