National Environmental Research Program

TROPICAL ECOSYSTEMS hub

Technical Report

Detecting Emerging Infectious Diseases in the Torres Strait: a review of vector, host and disease studies

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Detecting emerging infectious diseases in the Torres Strait: a review of vector, host and disease studies

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Australian Government

Department of the Environment

Supported by the Australian Government's
National Environmental Research Program
Project 11.2 Improved approaches for detection of disease and prevention of spread in Torres Strait

National Library of Australia Cataloguing-in-Publication entry:

978-1-925088-23-6

This report should be cited as:
Laurance, S.G.W., Meyer Steiger, D. and Ritchie, S. (2014) *Detecting Emerging Infectious Diseases in the Torres Strait: a review of mosquito-borne disease studies.* Report to the National Environmental Research Program. Reef and Rainforest Research Centre Limited, Cairns (17pp.).

Published by the Reef and Rainforest Research Centre on behalf of the Australian Government's National Environmental Research Program (NERP) Tropical Ecosystems (TE) Hub.

The Tropical Ecosystems Hub is part of the Australian Government's Commonwealth National Environmental Research Program. The NERP TE Hub is administered in North Queensland by the Reef and Rainforest Research Centre Limited (RRRC). The NERP Tropical Ecosystem Hub addresses issues of concern for the management, conservation and sustainable use of the World Heritage listed Great Barrier Reef (GBR) and its catchments, tropical rainforests including the Wet Tropics World Heritage Area (WTWHA), and the terrestrial and marine assets underpinning resilient communities in the Torres Strait, through the generation and transfer of world-class research and shared knowledge.

Cover photographs: D. Meyer Steiger

This report is available for download from the NERP Tropical Ecosystems Hub website:
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April 2014

Contents

List of Figures

List of Tables

Summary

The Torres Strait has long been recognised as a 'biological bridge' between Papua New Guinea and mainland Australia, where for millions of years species of plants and animals have moved between the two continents (Galloway and Loffler 1972). Currently, there is concern over the vulnerability of Torres Strait communities to emerging infectious diseases and the potential for disease movement across the islands to the mainland.

This report addresses the emerging infectious disease threat to the Torres Strait Islands and mainland Australia. We review the past and current research into mosquito-borne vectors, and their role in past disease outbreaks. The threat of new vectors and diseases is examined and we describe the vector-disease dispersal models that have been developed for the region. Finally, we discuss the implications for continued vector management and surveillance in the region.

1 Introduction

There is growing global concern over the potential for emerging infectious diseases to have greater impacts on human and wildlife health (Taylor et al. 2001, Jones et al. 2008). With international travel, emerging infectious diseases can be detected anywhere on earth, but it is frontier tropical countries which are considered hotspots for disease emergence (Jones et al. 2008). There are a number of reasons why this is the case, including changes in human land-use causing novel interactions between vectors, diseases and hosts, particularly in tropical regions where so many species co-exist. Furthermore, in frontier regions there are in general limited medical facilities and low levels of infection reporting and disease surveillance.

An understanding of disease emergence threats encompasses a range of research disciplines, including: vector biology and ecology, host-vector-pathogen interactions and pathogen prevalence and transmission. While we cannot predict with certainty which new diseases will emerge in a region, we can gain important knowledge of the presence and distribution of disease vectors (such as mosquitoes) and hosts in the environment, and keep track of disease outbreaks on our borders.

Here, we review mosquito and disease research undertaken across the Torres Strait and consider the risks of emerging infectious diseases in the region. The Torres Strait island archipelago consists of two hundred continental, volcanic and coral islands; sand cays, islets and coral reefs; situated between the northernmost point of Australia and the south-western coast of Papua New Guinea (Fig. 1). Human occupancy of the larger islands dates back 2500 to 3800 years ago (Carter 2001, David et al. 2004, McNiven et al. 2006) and at present 17 of these islands are permanently inhabited (Lawrence and Lawrence 2004) with approximately 7500 permanent residents (Hanna et al. 2006).

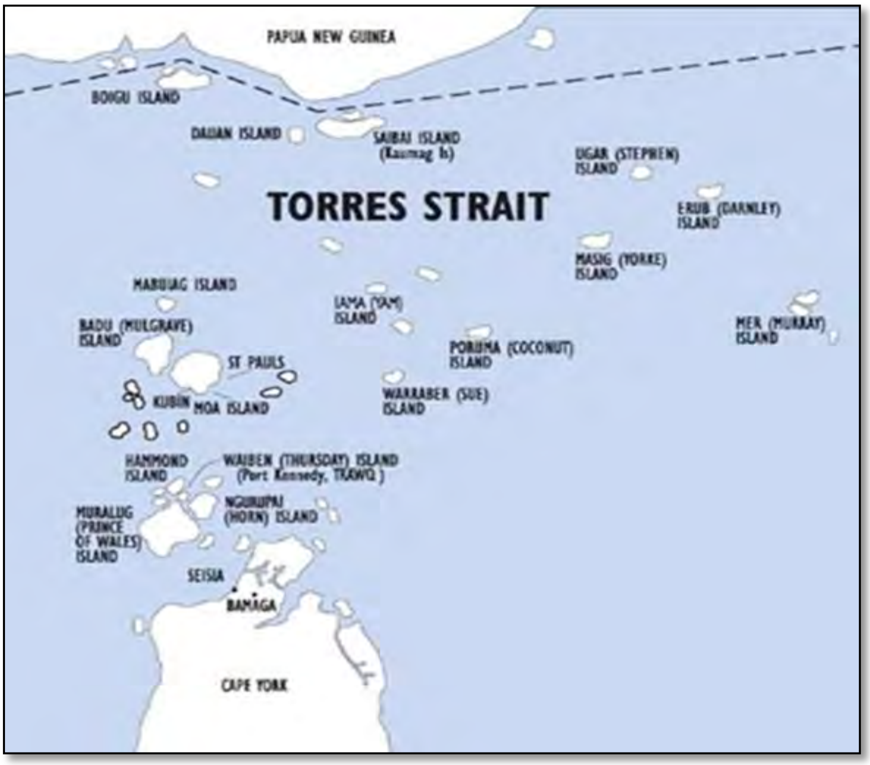

Figure 1: Map of the islands of the Torres Strait (Preston-Thomas et al. 2012).

Once an area becomes occupied by humans, it is inevitable that land-use, land-cover and landscape changes occur as natural environments are modified to support human populations (Ingold 1993, McNiven et al. 2006). The islands of the Torres Strait were no exception (Harris 1977) with early land use changes consisting of burning and clearing vegetation for cultivation (Haddon 1912, Harris 1977). Some islands, like Badu and Moa have been subjected to annual burning for thousands of years (Harris 1977, Rowe 2006, Rowe 2007). Landscape alterations were also caused by the introduction of exotic plants (e.g. yam, taro, bananas) and animals (e.g. dogs, pigs, and chickens) (Haddon 1912, Harris 1977, Abbott 1979, Swadling et al. 1996, Neldner 1998, McNiven 2006).

Such environmental changes not only damage original habitats and alter ecosystem functions but they can also change interactions between vectors, hosts and pathogens (Williams 2012). The consequences can result in the rise and emergence of infectious diseases. For example the emergence or re-emergence of mosquito-borne diseases such as malaria and yellow fever in South America and Africa, and dengue in South-East Asia and Australia (Walsh et al. 1993, Morse 1995, Patz et al. 2000, Vasconcelos et al. 2001, Reisen 2010) has been facilitated by human land-use activities.

Our previous research in the Cairns region demonstrated that while land use may increase vector densities it can also decrease wildlife-host populations and lower disease transmission cycles (Hilbert and Laurance 2011). We found that mosquito communities differed in degraded grasslands compared to adjacent rainforest habitats, with greater numbers of human-loving mosquitoes (and potential disease vectors) in the grasslands (Meyer Steiger et al. 2012). Although vector abundance and ecology has a primary role in disease dynamics, disease densities in host populations are also crucial to their transmission. In a study of avian malaria in rainforest birds, Laurance et al. (2013) found that the population density of hosts rather than vectors predicted disease prevalence in bird communities. Our research is demonstrating that disease outbreaks require both competent vectors and an appropriate density of infected hosts to maintain and cycle a disease within a population (Laurance et al. 2013).

2 Mosquito-vectored diseases detected in the Torres Strait

In the Torres Strait, mosquito species involved in the transmission of diseases, especially in relation to dengue, Japanese encephalitis, and malaria, have been studied for short intensive periods since the 1980's. Mosquitoes were predominantly trapped in or near communities. None of these studies, to our knowledge, have examined the mosquito community composition in the natural vegetation away from human communities. This is the aim of the current National Environment Research Program, Project 11.2 Disease Dynamics across the Torres Strait (Laurance 2011).

The incidence of mosquito-borne diseases in Australia is reported to the National Notifiable Diseases Surveillance System (NNDSS). The Department of Health and Aging (http://www.health.gov.au/cdna) then publishes quarterly and yearly reports in Communicable Diseases Intelligence, which is openly accessible for anyone. For example, in 2010-11, there were 9,291 cases of mosquito-borne diseases reported to the NNDSS. Most (81%) cases were attributed to Ross River and Barmah Forest viruses followed by dengue and malaria (Fig. 2; Note that chikugunya and malaria infections were not contracted within Australia, but overseas).

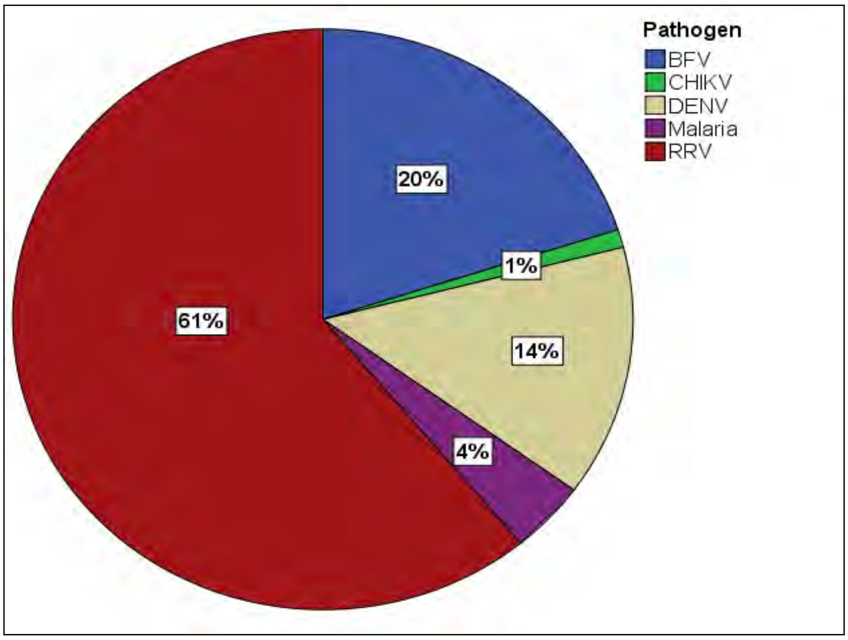

Figure 2: The incidence of mosquito-borne diseases in Australia for 2010–11; symbols represent RRV=Ross River Virus, BFV=Barmah Forest Virus, DENV=Dengue Virus, CHKV=Chikungunya Virus. Data compiled from Knope et al. 2013.

2.1 Japanese Encephalitis Virus

Japanese encephalitis virus is an important source of encephalitis in eastern and southern Asia (Fig. 3). It is the most pervasive member of the Japanese encephalitis serological complex which also includes Murray Valley encephalitis and West Nile viruses (Paterson et al 2011). Worldwide, 175,000 human infections are reported annually and 10,000 deaths, with children and elderly most at risk (Tsai 2000, van den Hurk et al. 2009). Fortunately, disease outbreaks in humans can now be avoided with the introduction of a vaccination program.

Figure 3: Distribution of Japanese encephalitis virus (van den Hurk 2009).

Japanese encephalitis virus is predominantly a disease of rural environments. The primary disease hosts are pigs and wading birds with mosquitoes being the main vector. Humans and horses can develop encephalitis but they are considered incidental or dead-end hosts, which means the virus is not amplified to the extent that it can be transmitted to another host (van den Hurk et al. 2008). In the Torres Strait, the main mosquito species that can vector the disease is *Culex annulirostris* (Ritchie et al. 1997) although other species (e.g. *Culex sitiens*, *Culex gelidus)* may also be involved in transmission (Johansen et al. 2000, Johansen et al. 2001, van den Hurk et al. 2001).

After the initial outbreak of Japanese encephalitis on Badu, disease surveillance was undertaken in the Torres Strait and Cape York in April-May 1995 (Hanna et al. 1995). Blood samples from 1242 people and 182 pigs were collected. In total 55 people and 63 pigs showed positive detection for the virus - all from the outer islands. There was no detection from the inner islands and Cape York (Table 1.) The first fatal cases of Japanese encephalitis virus in Australia occurred on Badu island in 1995 (Hanna et al. 1995, Hanna et al. 1996).

Table 1: Japanese encephalitis virus infection in people and pigs in the Torres Strait and Cape York in April-May 1995 from blood sampling (from Hanna et al. 1995).

	People		Pigs	
Communities	Tested	Positive	Tested	Positive
Badu	215	35 (16%)	11	11 (100%)
Other western islands	158	17 (11%)	15	11 (73%)
Northwestern islands	207	3 (1.5%)	31	23 (74%)
Central islands	320	0 (0)	15	5 (33%)
Eastern islands	223	0 (0)	18	13 (72%)
Total (outer islands)	1123	55 (5%)	90	63 (70%)
Inner islands	137	0 (0)	22	0 (0)
Cape York	197	0 (0)	20	0 (0)

A sentinel pig program was implemented after the outbreaks in order to monitor disease activity and prevalence across the Torres Strait. This program ran from 1997-1998, initially on Badu, Boigu, Mabuiag, Moa and Sabai and then extended to include Erub, Ugar, Warraber and Kiriri when extensive JE virus activity was identified on these islands (Hanna et al 1999). The results found that except for Warraber Island almost all pigs showed indications of JEV infections (Hanna et al 1999).

After the 1998 outbreak on Badu, pigs were removed from the community to a piggery ca. 2.5 km away (van den Hurk et al. 2008, Hall-Mendelin et al. 2012). A study of mosquitoes (principally *Culex annulirostris*) feeding behaviour on Badu in 2003, found that mosquitoes feeding on pigs could be detected up to 1.2 km from the piggery, whereas dogs were the main food source in the community and horses at the rubbish tip (Hall-Mendelin et al. 2012). Since the principal vector of Japanese encephalitis can disperse up to 12 km (Bryan et al. 1992) it has been suggested that the piggeries should be moved further away from communities (van den Hurk et al. 2008).

From 1995 to 2006, Japanese encephalitis has been present in either sentinel pigs or in captured mosquitoes nearly every year in the Torres Strait (Ritchie et al. 2007). A DNA study suggests that the virus most likely originated from the Western Province of Papua New Guinea (Johansen et al. 2000). Strong winds were the most likely explanation for the transportation of infected mosquitoes from Papua New Guinea to the Torres Strait (Hanna et al. 1996, Ritchie and Rochester 2001). Currently, the risk of human cases of JE in the Torres is nearly eliminated by vaccination.

2.2 Dengue

Over the last 40 years dengue has expanded and spread rapidly around the world (Fig. 4). Annually, an estimated 400 million infections occur worldwide, making it one of the most important mosquito-vectored diseases (Bhatt et al. 2013). In Australia, dengue had been absent for 26 years, when in 1981 new outbreaks occurred in Cairns and on the islands of Waiben, Masig, Iama and Badu in the Torres Strait (Kay et al. 1984). Further outbreaks occurred in 1996-1997 (Fig. 5) and in 2003-2004 (Hanna et al. 1998, Hanna et al. 2006). In the 2004 outbreaks, two Torres Strait Island residents died from complications of severe dengue haemorrhagic fever (McBride 2005), a complication of the disease that causes up to 20,000 deaths per year. The seasonal pattern in dengue outbreaks in Australia suggest the disease is not endemic but that annual infections occur when infected people visit and are bitten by local mosquitoes (Queensland Health 2005).

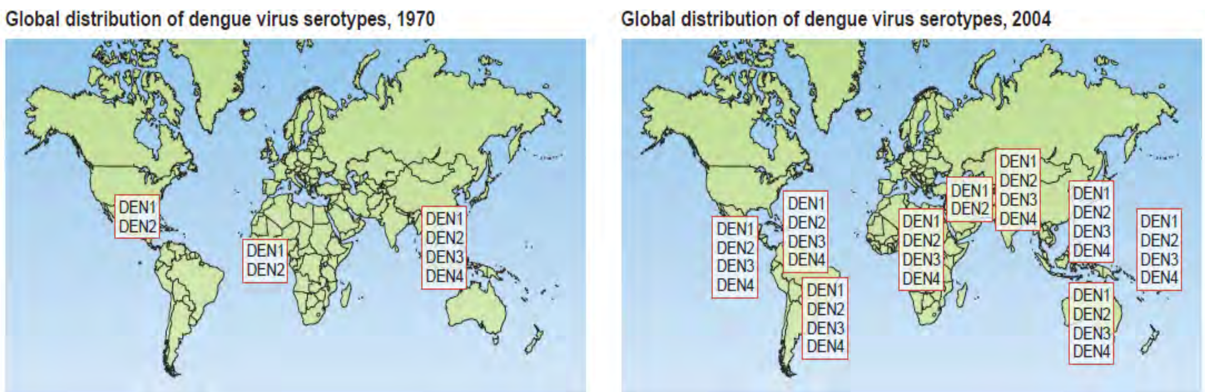

Figure 4: The spread of four dengue virus serotypes over a 24-year period (Mackenzie et al. 2004).

The main global vector for dengue transmission is the mosquito species *Aedes aegypti*, which has largely disappeared from much of the outer islands of the Torres Strait since 2005. One explanation for the apparent decline in *A. aeygypti* is that it has been displaced by another, more recent mosquito invader called the Asian tiger mosquito (*A. albopictus*) which is a competent vector of dengue (Ritchie et al. 2006, Ritchie 2009) along with *A. scutellaris,* which is also present in the Torres Strait. Humans act as dengue hosts and can transmit to other humans via mosquito vectors. It is possible that only one single infected person moving from Daru in Papua New Guinea to Mer in the Torres Strait resulted in an outbreak in 1996-97 (Fig. 5.).

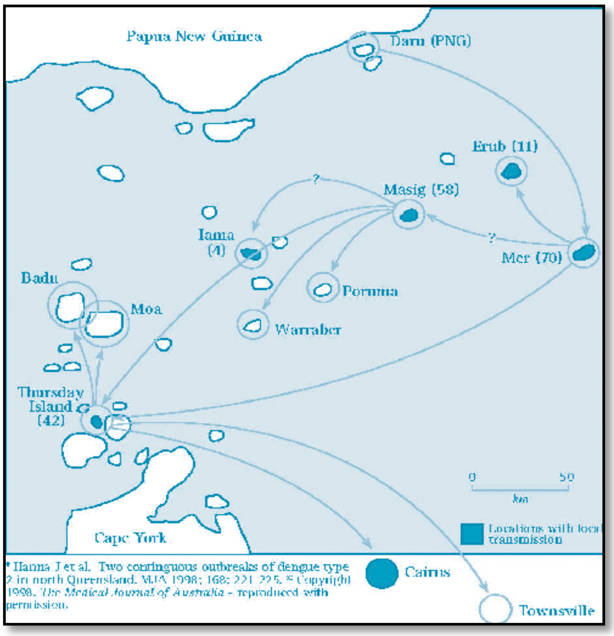

Figure 5: The transmission of dengue in the Torres Strait during the 1996-1997 outbreak (Hanna et al. 1998).

In the Torres Strait, most entomological studies on dengue vectors employ the sampling of larval habitats (Kay et al. 1984, Brown et al. 1992, Hanna et al. 1996, Ritchie et al. 2006). Predominantly, the sampling involves collecting water from discarded objects (rubbish) that hold water and searching for mosquito larvae. Sampling sites include plastic containers, buckets, older tyres, flowerpot bases, roof gutters and rainwater tanks. Rainwater tanks are important egg-laying sites for mosquitoes that can breed in containers such as *Aedes scutellaris* and *Culex quinquefasciatus* (Ritchie et al 2002).

As there have been no dengue cases for the past few years in the Torres Strait there is no ongoing surveillance program. If a dengue case is reported the Cairns-based Dengue Action Response Team (DART) will respond (pers. comm. O. Muzari) from Queensland Government Tropical Public Health Services in Cairns. Environmental Health Workers of the Torres Strait Island Regional Council (TSIRC) are responsible for mobilising communities to control mosquitoes and eliminate mosquito breeding habitat.

2.3 Malaria

Globally in 2012, there were an estimated 207 million cases of malaria with 627 000 deaths (WHO 2013). In Australia, endemic malaria was declared absent in 1981 (WHO 1983), but malaria gets imported from Papua New Guinea to the Torres Strait islands. Locally-acquired malaria also occurs sporadically (Merritt et al. 1998, Harley et al. 2001) and in 2011 outbreaks were declared on the islands of Saibai and Dauan (Preston-Thomas et al. 2012). The main mosquito vectors responsible for the transmission of malaria in the Torres Strait are the members of the *Anopheles farauti* complex (Mackerras 1947), but most other A*nopheles* spp. are also capable of transmitting malaria (Lee and Woodhill 1944, Mackerras 1947). Humans are hosts to five malaria parasites (*Plasmodium falciparum, P. vivax, P. ovale, P. malariae, P. knowlesi*). *P. falciparum* and *P. vivax* are most common globally. *P. ovale* is endemic only in tropical West Africa though is occasionally found in southeast Asia and Oceania. *P. knowlesi* occurs in rainforests in southeast Asia, particularly in Malaysian Borneo (WHO 2013).

Malaria research in the Torres Strait has mostly been clinical case or patient studies. The data have been generated from hospitalization data and the National Notifiable Disease Surveillance System (NNDSS) (Liu et al. 2006). While no studies have explored how the potential vectors are distributed across island habitats, two studies on several islands by Booth (1988) and Foley et al. (1991) captured mosquitoes with Encephalitis Virus Surveillance Traps (EVS baited with dry ice) which were set up near or inside buildings on several islands. These studies detected five *Anopheles* species (*An. farauti, An. hilli, An. bancroftii, An. meraukensis, An. annulipes* and *An. novaguinensis)*. Foley et al. (1991) also collected larvae from swamps, mainly *An. farauti*, *An. hilli* and *An. bancroftii;* and adult mosquitoes with aspirators from humans, both indoors and outdoors. With the exception of *An. novaguinensis* the same species were collected as in the EVS traps.

In 2012, a survey for *Anopheles* spp. by Queensland Health was carried out on Saibai. All night-biting collections inside and outside; and downstairs and upstairs (e.g. balcony) of buildings were performed using humans as baits. Both *An. farauti* and *An. hilli* species preferred to take bloodmeals outside and at ground level rather than inside and upstairs of buildings. Adult mosquitoes were captured with CO_2-baited CDC light traps at three sites within 10 m and 500 m from human habitation. Considerably more *An. farauti* were caught than *An. hilli* and more mosquitoes were captured close to houses; however large amounts of *Anopheles spp*. were still trapped 500m away from houses.

2.4 Ross River Fever and Barmah Forest Virus

Ross River Fever and Barmah Forest virus are the two most common mosquito-vectored illnesses in Australia (Queensland Health 2011). Fortunately for the Torres Strait islands, the main hosts for Ross River virus – kangaroos, wallabies, brushtail possums - are not present, whereas the principal mosquito vectors are common: *Culex annulirostris, Aedes vigilax* (salt marsh mosquito) and *Aedes notoscriptus*. Humans infected with Ross River Fever cannot infect mosquitoes, but humans infected with Barmah forest can act as hosts and lead to other human infections. In 2013, Queensland Health surveillance at Badu Island had a positive detection for a mosquito infected with Ross River virus (Keith Rickart pers. comm., Queensland Health), indicating that there is still a small risk of RRV transmission on the island.

3 Emerging Infectious Diseases and risks to the Torres Strait

3.1 Arrival of New Disease Vectors

The introduction of new mosquito vectors is one of the primary drivers of emerging infectious disease outbreaks. Exotic mosquito species can be introduced in four main ways: 1) wind-assisted flight or windblown (Ritchie and Rochester 2001), 2) active flight, 3) in goods such as tyres which can harbour eggs or larvae (Reiter and Sprenger 1987), and 4) transported in boats and planes (Mitchell et al. 1993).

The Asian tiger mosquito (*Aedes albopictus*) is a native species of southeast Asia and despite nearby populations in Papua New Guinea appears to have colonised the Torres Strait islands and the Fly River in Papua New Guinea from Indonesia in the early 2000's (Fig. 6; Beebe et al 2013). By 2005, *A. albopictus* occurred on 10 of the 17 inhabited islands (Ritchie et al. 2006) and had been intercepted in the mainland ports of Darwin, Cairns, Townsville, Brisbane, Sydney and Melbourne (Russell et al. 2005). After an unsuccessful attempt by Queensland Health to eradicate the mosquito from the islands in 2005, a quarantine program was initiated in 2008 where surveillance and control focussed on the inner Torres Strait islands (Waiben, Muralug and Ngurupai) to protect the mainland. In 2009, this quarantine area was breached and *A. albopictus* now occurs on Waiben and Muralug, although the Queensland Health control program has kept populations very low and prevented their spread to the mainland. An initial outbreak in New Mapoon in Cape York on the Australian mainland was detected and eliminated in 2010.

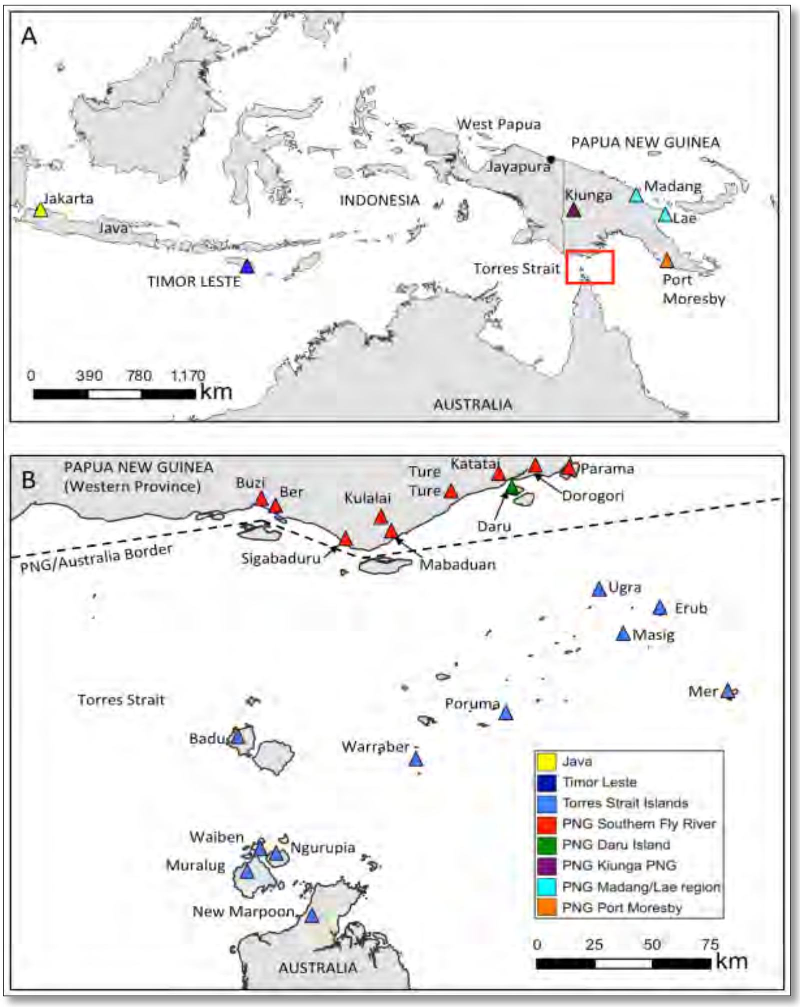

Figure 6: (A) Relatedness of the Asian tiger mosquito (*Aedes albopictus*) in Torres Strait to nearby populations in Indonesia and Papua New Guinea, and (B) distribution of *A. albopictus* in the Torres Strait (Beebe et al. 2013).

In the Torres Strait, there is an Asian tiger mosquito surveillance program that focuses on the travel hubs of Ngurupai and Waiben islands. The program is managed by the Tropical Public Health Services, Cairns, the Torres Strait Shire Council, and the Torres Strait Hospital and Health Services, and aims to prevent further spread of this species. In 2014, a survey team plans to visit five outer islands (Mer, Masig, Iama, Poruma and Warraber) to evaluate if Asian tiger mosquito (*A. albopictus*) and *A. aegypti* are present (O. Muzari pers. comm., 2014).

Concern over the dispersal of the Asian tiger mosquito in Australia is justified as it is a highly proficient disease vector for two reasons. First, it is a good vector of dengue and chikungunya viruses. Second, it is more cold tolerant than *A. aegypti*, and therefore could establish further south in urban centres such as Sydney (Russell et al. 2005). It is also an aggressive biter and public health nuisance in areas where it becomes established (Hawley 1988, Williams 2012).

Other recent arrivals from southeast Asia are *Culex gelidus*, a vector for the Japanese encephalitis virus (Gould et al. 1974), and *Culex quinquefasciatus.* Both have established populations on the Australian mainland (Ritchie et al. 2001, Russell 2010).

3.2 Arrival of New Diseases

The arrival of a new disease where there is a competent vector and host is another cause of emerging infectious disease outbreaks. Infected travellers arriving in Australia are a primary source of new introductions. For example in the Torres Strait the dengue strain (DENV-4) which caused the Pacific Island outbreak of dengue in 2007 was related to a strain that originated in Indonesia and reached the Torres Strait via Papua New Guinea (Warrilow et al. 2012).

Chikungunya – or "bend-back disease" as it is called for its painful arthritis-like symptoms – has increased significantly in frequency and geographic extent (Townson and Nathan 2008). First described in Tanzania in 1952, its lifecycle involved non-human primates and forest-dwelling mosquitoes (McIntosh and Gear 1981). Since the 1960s, outbreaks have occurred in many African, southeast Asian and even European countries (Townson and Nathan 2008), where infected travellers returning from epidemic areas have introduced the disease (Enserink 2007).

From a Torres Strait perspective, Chikungunya has not yet been reported. But in 2012, 1,590 cases were recorded in Papua New Guinea (Horwood et al. 2013). Following this initial outbreak at Vanamo, the virus has already spread to other provinces (Horwood et al. 2013). The virus has been regularly imported into Australia, but so far no outbreaks have occurred. In 2010-11 most Australian cases had contracted the virus from Indonesia and India and were in the 25 to 29 year age group (Knope et al. 2013).

The risk of Chikungunya causing an outbreak in Australia appears to be high, as it can be vectored by a wide range of mosquito species. The two mosquitoes that are associated with human epidemics, *Aedes albopictus* and *A. aegypti,* occur either in the Torres Strait (*A. albopictus*) or in north Queensland (*A. aegypti*) (Townson and Nathan 2008). With the large populations of *A. albopictus* in the outer islands of the Torres Strait, there is a high risk of a significant outbreak of Chikungunya should the virus be introduced.

3.3 Endemic Diseases

Kunjin is an encephalitic disease similar, although milder than Japanese encephalitis and West Nile virus. It was first detected in Kowanyama in far north Queensland, and is considered endemic to northern Australia and southeast Asia. It is transmitted by mosquito vectors, especially *Culex annulirostris.* Water birds like herons are the known hosts of the disease. Kunjin can infect humans and horses but these are considered dead-end hosts similar to Japanese encephalitis and unable to transmit the disease (Queensland Health 2014).

Murray Valley encephalitis is closely related to Kunjin virus but causes more severe disease pathology. It is endemic to Australia and common in northern Western Australia and the

Northern Territory. Water birds are the main disease hosts and mosquitoes such as *Culex annulirostris* are primary vectors. There are no known cases in the Torres Strait but three cases in far north Queensland in the last decade.

The diseases listed here are of concern to the communities of Torres Strait and tropical Australia, yet this is far from a complete list but just examples of what diseases are present or could become a threat to human health.

4 Predicting Vector and Disease Dispersal in the Torres Strait

Vector and disease dispersal across the Torres Strait is one of the defining parameters in understanding disease dynamics in this border region of Australia. The movement of new vectors or vectors carrying diseases from Indonesia and Papua New Guinea to the islands of the Torres Strait is of great concern in this region. Further, the location of the Torres Strait within such close proximity to this region makes it one of the most at risk locations in Australia.

4.1 Vector-dispersal models

The movement of invertebrates across the Torres Strait has long been considered a risk to island and mainland biosecurity. A long-distance dispersal model was originally developed by CSIRO to predict the distribution of *Helicoverpa* moths following a migration event (Rochester et al. 1996). The model has since been applied to noctuid moths (Gregg et al. 2001), mosquitoes (Ritchie and Rochester 2001), locusts (Deveson et al. 2005) and sugarcane plant-hoppers (Anderson et al. 2010).

The model has demonstrated that winds at altitudes of 100-400 m during the monsoon season were sufficient to potentially transport mosquitoes from Papua New Guinea to the Torres Strait and onto mainland Australia (Ritchie and Rochester 2001). The model requires identification of the distribution of the source population in Papua New Guinea and an estimation of the population density (Rochester et al. 1996). The model then predicts the probability of individuals arriving in Torres Strait.

Modelling has an important role in biosecurity and emerging infectious disease studies, however it is critical to remember that the predictive capacity of any model is only as good as the input data. Models cannot and should not replace field work, particularly in frontier regions where there is limited knowledge of the ecology of diseases and their vectors.

5 Management Strategies to reduce disease risks

Prevention of disease outbreaks is easier than dealing with outbreaks. The highest priority in reducing disease risk is to lower the interactions between humans and vectors. Reducing vector-breeding habitats close to human homes, schools and offices has been a management priority in the region, and this must continue to be the responsibility of the whole community. The location of most Torres Strait communities favours prevailing winds and along with new home design of very high set homes, there is a considerable reduction in mosquito habitat under houses. However, the availability of water-holding containers for mosquito breeding still remains high. Most of the potentially dangerous mosquito vectors such as *A. albopictus* and *A. aegypti* that favour human homes can reproduce in discarded containers. Managing rubbish, housing materials, abandoned cars and tyres must continue to be a very high priority in this region with communities remaining particularly vigilant in the wet season. Rainwater tanks can also breed these mosquitoes, and the screens on tanks must be maintained and replaced when needed.

Family gardens established away from townships in the natural vegetation, particularly close to swamps on Saibai, may increase the human-mosquito biting rates. As these areas often experience lower winds and have a high abundance of mosquitoes – we recommend that people take precautions with clothing and repellent in these areas to reduce bites.

The temporary camping of Papua New Guinea nationals in the mangrove forests of Saibai, where mosquito abundances are high, increases human-mosquito biting rates and the risk of disease outbreaks. We recommend that temporary campgrounds are open to prevailing winds and that people take precautions with clothing, and use bed-nets and repellents to reduce bites.

Educating and encouraging communities to remain vigilant is the most valuable tool in disease prevention. Regular surveillance and monitoring of vector populations and viruses can also be achieved by using simple and relatively inexpensive equipment. For instance, in 2013 Queensland Health (Communicable Diseases Unit) installed a Passive Box Trap with pressurized gas cylinders and FTA-cards (for disease detection) at the piggery in Badu. This study so far has yielded one positive result for Ross River fever (K. Rickart pers. com., Queensland Health).

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