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The Indo-Papuan conduit: a biosecurity challenge for Northern Australia

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Despite Australia's strict quarantine practices, the northern tropical region of Australia is at risk of the importation of exotic emerging diseases. The region's hot and humid climate is conducive to year-round production of mosquitoes and the pathogens they transmit. It is imperative that disease control measures extend beyond Australia's borders to improve surveillance, laboratory capacity and clinical practices in developing countries in our region.

Of particular importance to Northern Australia is the importation of vectors and diseases through the 'Indo-Papuan conduit', the land and waterways directly to the north of Australia, connecting southeastern Indonesia and New Guinea (including the West Papuan province of Indonesia and Papua New Guinea [PNG]) to the Torres Strait and Cape York Peninsula of Australia. Cultural and trade ties throughout this region result in the cross-border movement of people, livestock, wildlife and – potentially – pathogens and vectors. This traditional movement was recognised with a cross-border treaty allowing for free movement of people living in coastal villages of PNG and outer islands of the Torres Strait for traditional activities.

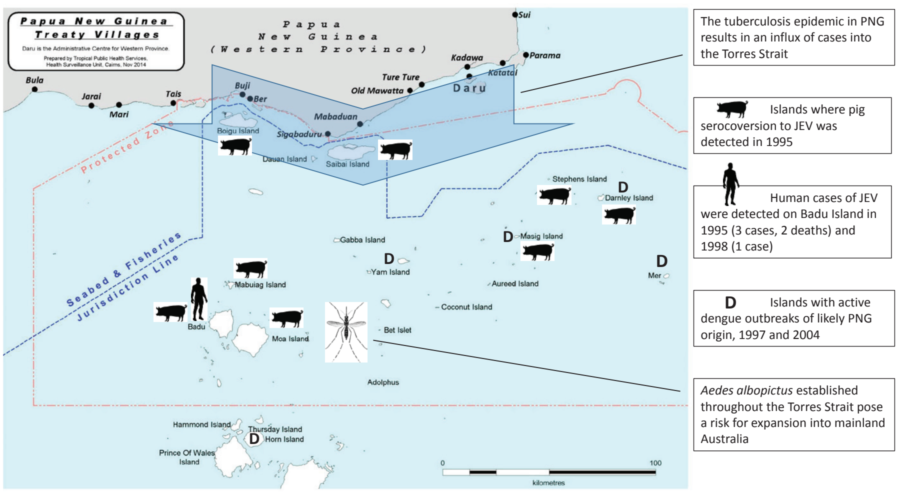
Recently, the Indo-Papuan conduit has been linked with numerous importations of exotic diseases and vectors into Australia (Figure 1). In this commentary, we discuss historical examples of disease and vector incursions, highlight future threats (Table 1) and advocate for improved engagement and capacity development with our northern neighbours.

Japanese encephalitis virus (JEV) is endemic to Southeast Asia, where it causes outbreaks of potentially fatal encephalitis. This flavivirus was first detected in Australia in April 1995 on the island of Badu in the Torres Strait.[1] In this outbreak, there were three human cases (two fatal) and JEV was detected in domestic pigs (an amplifying host) and *Culex annulirostris* mosquitoes, and serosurveys indicated it was widespread in domestic pigs on other islands. This led to a human vaccination campaign in 1996 and the gradual removal of backyard piggeries.[2] Subsequent surveys established that JEV was present in the Western Province of PNG, the likely source of the Torres Strait incursion.[3] Nearly annual detections of JEV in sentinel pigs or mosquitoes occurred on Badu until those programs were disbanded. In addition, several incursions into Cape York Peninsula occurred, although there is no evidence that the virus became established in the Australian mainland.[4] These repeated detections of JEV indicate that the Indo-Papuan conduit is a source of active JEV movement into the region.

There have been repeated dengue outbreaks in the Torres Strait since an outbreak of dengue virus 1 (DENV-1) in 1981 on Thursday Island.[5] Six subsequent outbreaks resulted in 547 confirmed cases and two deaths (Joe Davis, Queensland Health, unpublished data). Dengue outbreaks in the Torres Strait are thought to commonly originate from PNG, as they typically start on a single outer island then rapidly disseminate to other islands and even to mainland North Queensland. An outbreak of DENV-2 started on Mer Island in November 1996 and rapidly spread to other islands before causing outbreaks in Cairns and Townsville, with a total of 201 confirmed cases.[6] Before 2005, all outbreaks were thought to be transmitted by *Aedes aegypti*. However, in 2005, *Aedes albopictus* was detected throughout the Torres Strait,[7] and was the suspected vector in an outbreak of DENV-1 on Erub in 2015, the first occurrence of dengue transmission by this mosquito in Australia.[8]

Because of the establishment of *Aedes albopictus* in the Torres Strait, the area is now at risk of a new mutated strain of chikungunya, adapted to *Ae. albopictus* as its primary vector.[9] In June 2012, an outbreak of chikungunya started in a PNG town on the border with Indonesia[10] and rapidly spread throughout much of the country. Assessments concluded that Pacific Island communities and Northern Australia were at high risk of chikungunya virus (CHIKV) incursion,[11,12] and the public health response was rapid; health personnel in the Torres Strait were trained to detect CHIKV symptoms and to test and notify suspected cases. Vector control staff developed rapid response plans should CHIKV transmission be suspected. Fortunately, no CHIKV transmission occurred in the Torres Strait or wider Oceania regions. However, the risk of further CHIKV outbreaks remains as there is evidence the virus is still circulating in PNG (Papua New Guinea Institute of Medical Research, unpublished data) and Indonesia.[13]

Figure 1: The Torres Strait islands, showing past and current disease risks through the Indo-Papuan conduit.



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Outbreaks of Zika virus (ZIKV) in Micronesia and French Polynesia were the first hints that this vector-borne pathogen had the potential to become a global health emergency.[14] However, it wasn't until the explosive outbreak in Brazil, linked to microcephaly in newborn children, that the true impacts of the virus were realised.[15] Because ZIKV is efficiently transmitted by *Ae. aegypti* and *Ae. albopictus* mosquitoes, which are both abundant in the Asia Pacific region,[16] ZIKV is likely to circulate well beyond the countries in the region in which transmission has been identified. Inadequate disease surveillance in many countries in the Asia Pacific region coupled with the usually mild presentation of Zika disease allows for cryptic circulation.

Exotic species of mosquitoes have also been introduced into the Torres Strait via the Indo-Papuan conduit. The Japanese encephalitis vector *Culex gelidus* was first confirmed in the Torres Strait in 2000. Since then, multiple detections of JEV have been made from this mosquito on Badu and Moa Islands,[17] and the mosquito is established in much of Northern Australia. The most notorious exotic mosquito to be introduced into Australia via the Indo-Papuan conduit is the Asian tiger mosquito *Ae. albopictus*.[18] This highly invasive mosquito was first detected on Masig Island in the Torres Strait in March 2005. Subsequent delimiting surveys found large populations of this aggressive mosquito throughout much of the Torres Strait.[7] A Commonwealth funded *Ae. albopictus* control program has nearly eliminated it from Thursday and Horn Islands and prevented its spread onto the mainland of Australia.[8] This mosquito is a serious concern for the transmission of DENV and CHIKV in the Torres Strait, and could become a dangerous pest mosquito in much of urban eastern Australia, resulting in significant economic loss.[19] *Ae. albopictus* has displaced *Ae. aegypti* in some regions, notably much of Florida and the outer islands of the Torres Strait. Thus it could displace *Wolbachia*-infected *Ae. aegypti* established in North Queensland, destroying this successful dengue prevention strategy.[20] Strategies of using *Wolbachia* virus-blocking strains in *Ae. albopictus* should be investigated for use in the Torres Strait.

While malaria is endemic in PNG and Indonesia, and large numbers of introduced cases occur in Australia annually, we do not perceive the re-establishment of malaria as a serious threat to Australia. The primary vector in Northern Australia, *Anopheles farauti*, is also common in adjacent coastal PNG, but is restricted to coastal wetlands north of Townsville, and has a limited flight range. Occasional small outbreaks of malaria do occur in areas of North Queensland where *An. farauti* is common, such as Saibai Island in the Torres Strait and lowland rainforests in Northern Queensland.[21] Due to the limited range of the vector, and the presence of a strong public health system, it is highly unlikely that malaria will become established in Northern Australia.

Tuberculosis (TB) represents one of the greatest human health threats of all infectious diseases, killing more people per year than any other pathogen, including human immunodeficiency virus (HIV) and malaria combined. Increasing drug resistance is the greatest barrier to global TB control because multi-drug resistant TB (MDR-TB) requires costly, lengthy treatment and more often results in treatment failure.[22]

Over the past 30 years, TB epidemiology has changed in North Queensland. In the 1990s, most tuberculosis came from endemic transmission among Indigenous inhabitants, predominantly from the Northern Peninsula Area rather than the Torres Strait.[23] Recently, a new epidemiology has emerged with most TB cases notified from this region coming from PNG nationals and many of the *Mycobacterium tuberculosis* (*Mtb*) isolates being multidrug-resistant.[24] Strains arising in patients from PNG diagnosed through Torres Strait health services exhibit high genetic clustering, suggesting an intense focus of transmission.[25] Furthermore, there is epidemiological evidence of primary transmission (direct person-to-person spread) of MDR-TB in this group.[25]

Although the absolute number of cases of tuberculosis in the Torres Strait Islander inhabitants is relatively small, with 20 cases over the two-year period of 2014–2015,[26] the incidence is approximately 200 per 100,000 for those years. This rate is nearly fifty times higher than in Indigenous Aboriginal communities elsewhere in Australia[27] and more than 200 times higher than the non-Indigenous Australian-born population.[28] This likely results from proximity to PNG. Across the international border on Daru Island, Western Province, PNG, the incidence of MDR-TB alone is estimated to be 1,000 per 100,000,[29] making it higher than any nation in the world. Here, primary transmission of extensively drug-resistant tuberculosis has been observed.[30] The official estimate of tuberculosis incidence in PNG in 2015 was 432 per 100,000.[31] This is likely an under-estimate, and notification rates of 1,000 per 100,000 were observed when measured accurately and systematically in the Gulf Province.[32]

Under the National Health Partnership Agreement on Health Services, Queensland Health provides emergency treatment to PNG nationals who access health facilities in the Torres Strait and elsewhere in Queensland.[33] The rapid and effective management of PNG nationals at these facilities is an important

Table 1: Exotic pathogen risks for Australia through the Indo-Papuan conduit.

Pathogen	Animal reservoir	Vector	Current distribution	Evidence for threat to Australia[a]
Japanese encephalitis virus	Ardeid wading birds and pigs	*Culex* mosquitoes	Asia	Van den Hurk et al., 2003; Van den Hurk et al., 2008; Hall-Mendelin et al., 2012;
Dengue virus	Humans	*Aedes* mosquitoes	Asia, Africa and south/ central America	Naish et al., 2014; Viennet et al., 2014; Akter et al., 2017
Zika virus	Humans	*Aedes* mosquitoes	Asia, Africa, south/central America and Oceania	Baggoley et al., 2014; Viennet et al., 2016; Duchemin et al., 2017
Chikungunya virus	Humans	*Aedes* mosquitoes	Asia, Africa, south/central America and Oceania	Horwood et al., 2013; Viennet et al., 2013; Roth et al., 2014; Suhrbier and Devine, 2016
Rift Valley fever virus	Livestock	Various mosquito species	Africa, Middle East	Turell and Kay, 1998
Yellow fever virus	Humans	*Aedes* mosquitoes	Africa, south/central America	Van den Hurk et al., 2011
Rabies	Canines	N/A	Global (Asia, Africa, Americas, Eastern Europe)	Sparkes et al., 2015; Brookes and Ward, 2017; Brookes et al., 2017
Highly pathogenic avian influenza virus	Charadriiformes and Anseriformes water birds	N/A	Asia, Africa, Middle East	Tracey et al., 2004; East et al., 2008a
Nipah virus	*Pteropus* fruit bats and pigs	N/A	Asia	Roche et al., 2015
Drug resistant *Mycobactcerium tuberculosis*	Humans	N/A	Global	Gilpin et al., 2008; Queensland Health, 2017; Donnan et al., 2017;

Note:
a: References are listed in Supplementary file

step to minimise the spread of infectious diseases, in particular, tuberculosis. However, care for chronic health conditions, recall of patients and follow-up are not permitted, necessitating referral of cross-border PNG nationals presenting to clinics in the Torres Strait to Daru. To enable safe transfer of patients with tuberculosis and other health conditions and to exchange clinical and surveillance data, it is imperative to maintain good cross-border communications between PNG and people within the Torres Strait Protected Zone. Early diagnosis and contact tracing of cases arising within the Torres Strait will be necessary to prevent drug resistant TB spreading further through North Queensland.

Both the Northern Territory and Queensland have strong surveillance and control programs for exotic mosquitoes, and the Department of Agriculture and Water Resources monitors for exotic mosquitoes at ports. The Northern Australia Quarantine Strategy monitors for exotic livestock pathogens, including JEV, in sentinel animals and mosquito traps.[34,35] Queensland Health administer the *Aedes albopictus* Control Programme in the Torres Strait,[8] and also actively respond to outbreaks of dengue in the region. The *Aedes*-borne diseases of Zika, chikungunya and particularly dengue remain the greatest ongoing arboviral risks to the area. However, as the global sweeps of these viruses illustrate, exotic viruses can suddenly appear and cause major outbreaks. Therefore, disease and mosquito surveillance in the Torres Strait and the Indo-Papuan conduit need to be strengthened. Currently, mosquito surveillance is limited to the inner islands of Thursday and Horn. Periodic entomological surveys should be conducted to determine the status of *Aedes* vectors, with studies to understand their inter-island distribution so control programs can target high risk areas. Public health workers should be informed of risk diseases such as chikungunya and dengue and be vigilant for their introduction. Rapid identification and response is critical to preventing large outbreaks of exotic disease and the establishment of exotic vectors. We encourage the development of sustainable vector control programs in high-risk areas of PNG and Indonesia that will improve health outcomes to residents and decrease the risk of disease incursions into Australia. In addition, further engagement and capacity development with our northern neighbours is critical to reduce the risk of exotic disease outbreaks and further expansion of MDR-TB.

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Supporting Information

Additional supporting information may be found in the online version of this article:

Supplementary File 1: Supplementary References from Table 1.

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