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Analysis

An Economic Analysis of the Threats Posed by the Establishment of *Aedes albopictus* in Brisbane, Queensland

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ABSTRACT

Aedes albopictus is an invasive mosquito, aggressive biter and potential disease vector. Its establishment in Europe and the Americas resulted in local disease transmission and impacted quality of outdoor recreational activities. Economic implications of its likely invasion into Australia had not been considered.

A benefit-cost analysis of an elimination response scenario to an *Ae. albopictus* incursion in Brisbane was developed with a benefits transfer estimate of the local population's willingness-to-pay for an *Ae. albopictus*-free environment. Other costed considerations included i) necessary precautionary vector control responses to importations of mosquito-borne diseases (e.g. dengue, Zika) and ii) projected rises in complaints to local government regarding increased mosquito nuisance.

Costs of implementing a successful elimination program were estimated between 1 and 4 AU$ per capita, and the annual benefit-cost ratio regarding the value of an unaffected outdoor environment was between 50 and 78. In the event of establishment, annual costs of local government and public health responses were between 0.5 and 1.3 AU$ per capita. The recurrent expense of permanent colonization will be magnified by loss of value associated with an *Ae. albopictus*-free environment.

We conclude it is more cost-beneficial to conduct a thorough elimination program for *Ae. albopictus* than to allow establishment.

1. Introduction

Aedes albopictus is the most invasive mosquito in the world (Medlock et al., 2012). It is an aggressive biter, active all-day long (Caglioti et al., 2013) and feeds on humans and a variety of other vertebrate hosts. It is relatively long lived and lays its desiccation resistant eggs in natural and artificial containers (Charrel et al., 2007; Pardigon, 2009). Originally of Asian origin, it is now widely distributed across Europe, Africa, the Americas and the Pacific (Tsetsarkin et al., 2007). It has recently colonized the islands of the Torres Strait (Ritchie et al., 2006) where a limited control program costs over AU$1 M per annum (Muzari, 2015).

Ae. albopictus is a vector of more than 20 arboviruses, is recognised as a secondary vector of dengue (Bonizzoni et al., 2014; Gratz, 2004; Lambrechts et al., 2010) and is the major vector of many recent chikungunya virus (CHIKV) outbreaks including the La Reunion epidemic (200,000 cases and 203 deaths: Renault et al., 2007). In that instance, a single point mutation within the CHIKV genome led to a dramatic increase in transmissibility by this mosquito. *Aedes albopictus*, at least in a laboratory context, is also capable of transmitting four major Australian endemic arboviruses; Murray Valley encephalitis virus (MVEV), West Nile virus Kunjin strain (KUNV), Ross River virus (RRV), and Barmah Forest virus (BFV) (Nicholson et al., 2014c).

Ae. albopictus now has a significant urban presence around the globe (Caglioti et al., 2013; Medlock et al., 2012; Powers and Logue, 2007; Rezza et al., 2007; Tsetsarkin et al., 2007; Weaver and Barrett, 2004) and, in some settings, feeds almost exclusively on humans (Ponlawat and Harrington, 2005). In those instances, *Ae. albopictus* can transmit viruses with a human reservoir (i.e. dengue, chikungunya) very efficiently (Weaver and Barrett, 2004).

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Ae. albopictus is likely to assume an increasingly prominent role in the transmission of human arboviruses in the future. Australia is made vulnerable to that threat by a busy transport and travel network that links it to regions where both *Ae albopictus* and the diseases it transmits are endemic. Exotic mosquito incursions at Australia's ports are on the increase (van den Hurk et al., 2016) as are the number of imported cases of viruses such as dengue (Huang et al., 2016). In 2016, *Ae. albopictus* was responsible for a dengue outbreak on the island of Darnley (Erub) in the Australian Torres Strait. This is the first *Ae albopictus*-mediated dengue outbreak in Australian history.

Models indicate that *Ae. albopictus* could spread along the entire eastern seaboard of Australia (Benedict et al., 2007; Hales et al., 2002; Naish et al., 2014; Rochlin et al., 2013; Russell et al., 2009), and we propose that Queensland is especially vulnerable to its establishment because of the plethora of suburban areas and parklands that currently harbor high densities of two native container breeding mosquitoes: *Ae. aegypti* and *Ae. notoscriptus*. These mosquitoes have similar ecologies to *Ae. albopictus* (Ritchie et al., 2001), and a number of papers discuss the overlap of their habitat (Nicholson et al., 2014a) and the potential displacement of native species by the more aggressive *Ae. albopictus* (van den Hurk et al., 2016). A recent household survey in Brisbane found that 26.2% of all premises surveyed harbored *Ae. notoscriptus* (Trewin et al., 2013). That suggests that an *Ae. albopictus* invasion might result in universal urban coverage (Fig. 1). Experiences in Europe and the USA suggest that *Ae. albopictus* will become an extreme nuisance and increase the demand for mosquito control services. It is likely to incur large economic and societal costs (Benedict et al., 2007; Caminade et al., 2012; Rochlin et al., 2013).

The establishment of *Ae. albopictus* in new areas with human populations unaccustomed to aggressive day biting mosquitoes can impact the use of outdoor recreational space (Halasa et al., 2012; Halasa et al., 2014; Manica et al., 2016; Worobey et al., 2013).

Early detection and the timeliness of the emergency response are critical for containing or eliminating an incursion or limiting the scale and rate of establishment. Economic analyses of early detection or long term control programs would give the councils and state government some estimate of the potential economic cost of an *Ae. albopictus* invasion and the opportunity to assess the readiness of their control programs. In Queensland, the surveillance and control of exotic mosquito incursions is a responsibility partly shared by the Department of Agriculture and Water Resources (port areas only) and the public health units that are attached to local, state-funded health services. The bulk of the management of established nuisance or disease-vector species is, however, largely the responsibility of local councils. The exception to this is the control program for *Ae. aegypti* in those areas of tropical North Queensland that experience regular dengue outbreaks and that are at increased risk from other viruses such as chikungunya (CHIKV) and Zika. That program is almost exclusively conducted by public health units, attached to local hospital and health services (Queensland Health, 2015).

The most thorough economic analysis of *Ae. albopictus* is from New Jersey, USA (Crans et al., 1996). Halasa et al. (2012) estimated that New Jersey residents valued an enhanced mosquito control program at almost 4 times its actual cost and Shepard et al. (2014) estimated that the area-wide integrated pest management of mosquitoes over a 13-week New Jersey summer facilitated an extra 43 h of yard and porch time by the local populace. Each adult resident in that community valued those extra hours at US$355.82 per annum. Here, we have carried out a benefit-cost analysis (BCA) with costs estimated from a Queensland consultation document: the "Exotic mosquito incursion emergency response framework" (Appendix 1). This document outlines the magnitude of resources that may be required to mount an elimination campaign against a limited *Ae. albopictus* invasion in Brisbane. In combination with a benefits transfer (BT) estimate derived from the

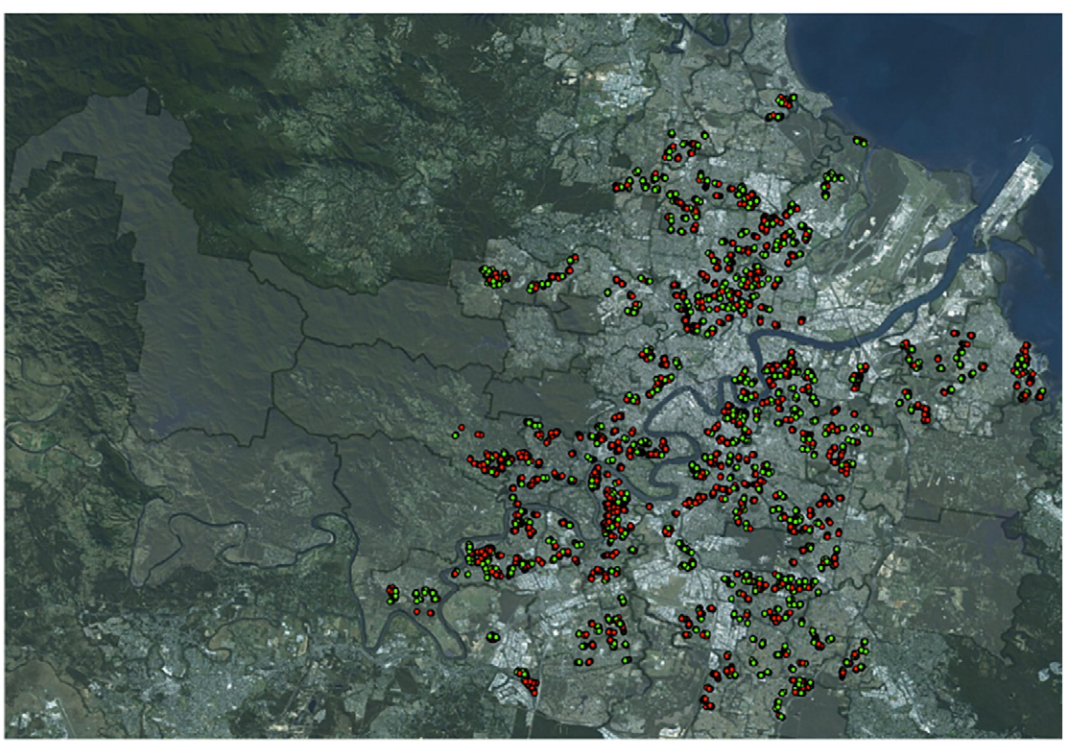

Fig. 1. Brisbane premises where *Aedes notoscriptus* was present (green dots) or absent (red dots) in domestic containers during a 2010–2012 yard survey (data in Heersink et al., 2015). It is expected that *Ae. albopictus* could utilize similar breeding habitats (green dots) to facilitate its establishment. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)