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DISCOVERY OF A WIDESPREAD INFESTATION OF *AEDES ALBOPICTUS* IN THE TORRES STRAIT, AUSTRALIA

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ABSTRACT. *Aedes albopictus* is a container-breeding *Stegomyia* mosquito that has dispersed widely from its origins in Southeast Asia. Because *Ae. albopictus* is a known dengue vector and a potential vector of a variety of arboviruses and it can tolerate cooler climates than *Aedes aegypti*, Australian quarantine and health authorities have strategies to detect and eliminate it from international ports. Following the detection of 42 adult *Ae. albopictus* in BG-Sentinel traps set on Yorke island in the Torres Strait of Australia in April 2005, extensive surveys were conducted to determine the distribution of *Ae. albopictus* in the Torres Strait and adjoining Cape York Peninsula. A total of 17 islands and the northern peninsula area of Cape York Peninsula were surveyed by collection of larvae and pupae from flooded containers and human bait collections of adult mosquitoes with aspirators and sweep nets. *Aedes albopictus* was detected on 10 islands and comprised 100% of the day-biting container-breeding mosquitoes on Yorke and Stephens Islands. No *Ae. albopictus* were detected in the mainland sites on Cape York. Retrospective genetic analysis of larvae collected in April 2004 and April 2005 on Yorke Island indicated that *Ae. albopictus* was present in low densities in 2004 and that there were 3 genetically distinct mitochondrial haplotypes on Yorke Island in April 2005. Additionally, on Yorke Island there is evidence that *Ae. albopictus* is displacing *Aedes scutellaris.*

KEY WORDS *Aedes albopictus*, dengue, exotic mosquito, Australia

INTRODUCTION

The container-breeding mosquito *Aedes albopictus* (Skuse) has spread rapidly in the past 30 years from its original source in southeast Asia. It is an invasive mosquito whose desiccation-resistant eggs have facilitated its transportation to most continents via used tires, machinery, and other potential containers (Reiter and Sprenger 1987, Lounibos 2002, Gratz 2004, Juliano and Lounibos 2005). *Aedes albopictus* is now well established in parts of the Pacific, North America, southern Europe, South America, and parts of Africa (Gubler 2003, Gratz 2004, Juliano and Lounibos 2005); for a review of its biology see Hawley (1988) and Estrada-Franco and Craig (1995). *Aedes albopictus* is a known vector of dengue viruses (DENV) and a competent laboratory vector of a variety of arboviruses including Ross River virus (RRV), Japanese encephalitis virus (JEV), Eastern encephalomyelitis virus, and yellow fever virus (Mitchell 1995, Gratz 2004). Nonetheless, with the exception of dengue, it has not been linked to any significant outbreaks of human arboviral disease in areas it has recently colonized (Moore and Mitchell 1997, Gratz 2004). *Aedes albopictus* is a natural vector of dog heartworm, *Dirofiliaria immitis* Leidy (Cancrini et al. 2003, Gratz 2004).

Australia has a history of interceptions of *Ae. albopictus.* Larvae were first detected in imported tires in Brisbane and in ovitraps at Darwin in 1988 and 1989, respectively (Kay et al. 1990). In accordance with Article 19 of the World Health Organization's International Health Regulations 1969, the Australian Quarantine and Inspection Service (AQIS) has an active surveillance and control program targeting container-breeding mosquitoes at all international ports in Australia. These measures include routine larval surveys, setting of ovitraps and sentinel tires, and adult trapping with dry ice–baited encephalitis vector surveillance (EVS) traps. From 1997 to 2005, there were at least 28 interceptions of *Ae. albopictus* at 6 Australian ports (Russell, unpublished data). Upon interception of an exotic

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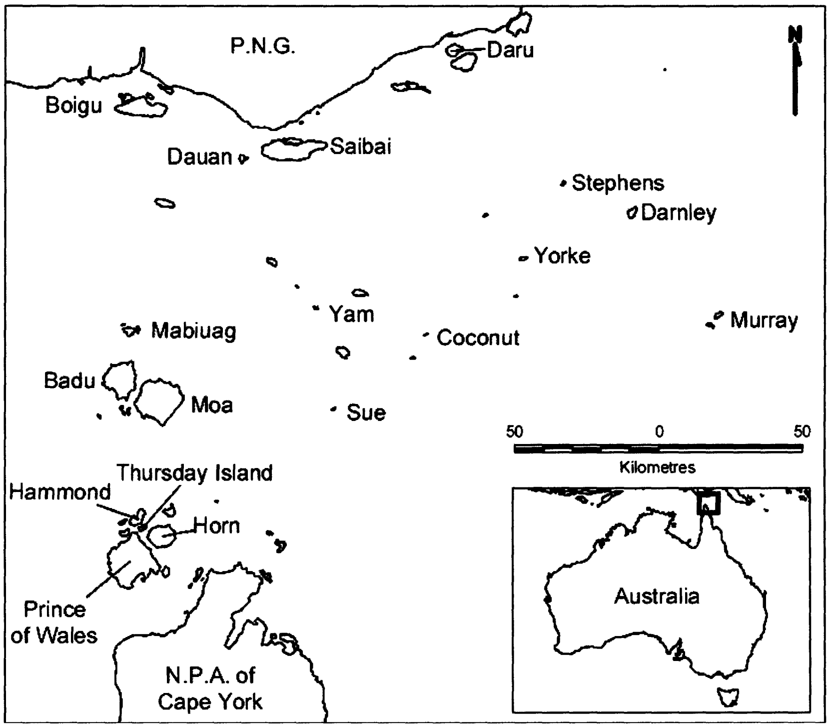

Fig. 1. Map of the Torres Strait and the northern peninsula area (NPA) of the Cape York Peninsula surveyed for *Ae. albopictus*.

mosquito, emergency mosquito control is conducted by state health and local government agencies within 1 km of the port, consisting of ultra-low volume (ULV) fogging with bioresmethrin, treatment of vegetation with residual synthetic pyrethroids, and surveillance and treatment of containers with s-methoprene or a residual pyrethroid spray. Mosquito surveillance is also enhanced with additional EVS traps, ovitraps, and sticky ovitraps (Ritchie et al. 2003, 2004) deployed for up to 1 month after interception. To date, all responses to detections of *Ae. albopictus* on mainland Australia have been successful, with no evidence of establishment after treatment.

The Torres Strait (Fig. 1), separating the north of Queensland, Australia, from the island of New Guinea, is a high-risk area for the introduction of exotic pests and disease into Australia. This relatively narrow strait, ~150 km wide, contains 17 inhabited islands lying between the Cape York Peninsula of Queensland and the coastline of the Western Province of Papua New Guinea (PNG). The area has been subject to repeated introductions of exotic mosquito-borne diseases, including JEV (Hanna et al. 1999), malaria (Harley et al. 2001), and DENV (Hanna et al. 1998, McBride 2005, Ritchie 2005). Furthermore, dengue outbreaks in the Torres Strait often spread to mainland Australia, with Torres Strait outbreaks in 1997 (Hanna et al. 1998) and 2004 (Ritchie 2005) subsequently seeding outbreaks in Cairns. Kay et al. (1990) reported *Ae. albopictus* from the PNG southern coastal village of Busi in 1988, while Cooper et al. (1994) reported *Ae. albopictus* on Daru Island off the southern PNG coastline in 1992. Despite indications that *Ae. albopictus* was threatening to invade the Torres Strait, it was never detected in mosquito surveys conducted during or after recent dengue outbreaks in the Torres Strait (Hanna et al. 1998, Ritchie et al. 2002, Montgomery et al. 2005) or by routine mosquito surveillance by AQIS at ports on Thursday and Horn islands.

In early 2004, a man contracted dengue hemorrhagic fever (DHF) on Yorke Island, located in the eastern Torres Strait (McBride 2005). Mosquito surveys conducted in 2001 demonstrated that *Aedes scutellaris* (Walker) was the only container-breeding *Stegomyia* mosquito on Yorke Island (Ritchie et al. 2002). To examine whether *Ae. scutellaris*, a known DENV vector in PNG (Mackerras 1946), could be involved in DENV transmission in the Torres Strait, collections were made from Yorke Island in April 2004 to initiate a colony for vector competence studies. A year later, from 11 to 14 April 2005, 44 adult *Stegomyia* mosquitoes were

Table 1. Human bait collections undertaken in the Torres Strait and NPA of Cape York in 2005.

Location (indigenous name)	Community	Island type; size (km^2)	Human pop.[1]	Collection date 2005	No. *Ae. albopictus* collected	Percentage of all mosquitoes that were *Ae. albopictus*	Percentage of day-biting container-breeding mosquitoes that were *Ae. albopictus*
Yorke (Masig)		coral cay; 1.5	336	03 May	51	92.7%	100.0%
Stephens (Ugar)		volcanic; 0.4	57	05 May	22	95.7%	100.0%
Moa (Moa)	St. Paul's	continental; 152.4	239	24 May	19	86.4%	95.0%
Darnley (Erub)		volcanic; 6.9	320	07 May	18	48.6%	50.0%
Mabuiag (Mabuiag)		continental; 6.3	240	26 May	12	60.0%	80.0%
Sue (Warraber)		coral cay; 0.6	239	25 May	8	10.8%	11.3%
Coconut (Poruma)		coral cay; 0.4	175	24 May	6	33.3%	33.3%
Yam (Iama)		continental; 1.5	363	27 May	2	6.1%	8.0%
Dauan (Dauan)		continental; 4	120	13 May	1	9.1%	9.1%
Murray (Mer)		volcanic; 4.3	462	09 May	1	7.7%	7.7%
Badu (Badu)		continental; 101.9	786	25 May	0	0.0%	0.0%
Boigu (Boigu)		alluvial; 66.5	295	15 May	0	0.0%	0.0%
Hammond (Kiriri)		continental; 14.5	208	17 May	0	0.0%	0.0%
Horn (Ngurapai)		continental; 54.2	667	18 May	0	0.0%	0.0%
Moa (Moa)	Kubin	continental; 152.4	226	24 May	0	0.0%	0.0%
Prince of Wales (Muralug)		continental; 202.7	90	17 May	0	0.0%	0.0%
Saibai (Saibai)		alluvial; 101.9	368	12 May	0	0.0%	0.0%
Thursday Island (Waiben)		continental; 3.5	3,053	19 May	0	0.0%	0.0%
NPA Cape York	5 communities	mainland, NA	2,175	18 May	0	0.0%	0.0%

[1] Based upon 2004 census data.

collected in 2 BG-Sentinel traps (http://www.bg-sentinel.com/index.html) set for 24 h each at 6 different locations over 3 days. Of these mosquitoes, 42 (95%) were tentatively identified as *Ae. albopictus*, with the remainder *Ae. scutellaris* (Ritchie, unpublished data). In view of this finding, an emergency delimiting survey for *Ae. albopictus* was initiated in the 17 inhabited islands of the Torres Strait, along with 5 communities in the northern peninsula area (NPA) of Cape York Peninsula during May 2005. We report here on the finding of this survey and subsequent genetic comparisons of collected specimens.

MATERIALS AND METHODS

The Torres Strait

The Torres Strait (Table 1) contains ~100 islands situated between the northern tip of Cape York, Queensland, and the southern border of PNG. Seventeen of the islands are populated, with 15 having their own island councils. The largest, Thursday Island, is the seat of local government for the Torres region and has a population of ~3,500. The total population of the Torres Strait is ~9,000, with most of Melanesian descent. The islands vary in geography, with 4 general types: 1) continental granitic dominated by rain forest covered hills, 2) small, low elevated coral cays with sparse vegetation, 3) flat alluvial mud islands dominated by swamps and mangroves, and 4) volcanic islands with rain forest or grassy hills. The Torres Strait has distinctive wet and dry seasons. Thursday Island has a mean annual rainfall of 1,746 mm, but only 8% of this falls during the May–November dry season.

Queensland Health, and the Tropical Population Health Unit (TPHU) in particular, has a long tradition of working on the health problems unique to the Torres Strait, especially vector-borne diseases. Being close to PNG, the Torres is exposed to mosquito-borne pathogens such as JEV, malaria, and DENV that are endemic in PNG. Most of the Torres Strait islands have high populations of vector mosquitoes, especially *Aedes aegypti* (L.). Large outbreaks of dengue, with nearly 200 cases each year, have affected the Torres Strait in 1996–97 (Hanna et al. 1998) and in 2003–04 (McBride 2005, Ritchie 2005). Indeed, there were 4 cases of DHF resulting in 2 deaths during the 2004 outbreak (McBride 2005).

Entomological surveys

All inhabited islands in the Torres Strait and the NPA of Cape York (Table 1) were inspected for container-breeding mosquitoes in May 2005. In communities and disturbed areas (e.g., dumps, industrial areas), the grounds and vegetated habitat for a distance of 50 m were inspected for artificial and natural containers that could hold water (e.g., tires, boats, buckets, coconuts, rainwater tanks, etc.); larvae and pupae were collected using a pipette. Because *Ae. albopictus* and *Ae. scutellaris* larvae are difficult to distinguish morphologically (Lamche and Whelan 2003), all larvae and pupae were reared to adulthood for identification.

Adult mosquitoes were collected at human bait by inspectors that stood or sat in well-shaded areas for 5 to 15 min. A sample of the attracted mosquitoes was collected with a small handheld power aspirator (Hausherr's Machine Works, Tom's River, NJ) and a 30-cm diameter sweepnet that had been treated with deltamethrin-based aerosol spray, similar to the technique used by Ho et al. (1971) in Singapore. Adult mosquitoes were identified to species using a stereo microscope and the keys of Huang (1972).

Genetic analysis

For genetic analysis, *Ae. albopictus* larvae collected in April 2005 during routine surveys by Queensland Health (QH) staff on Yorke Island were identified to species using a polymerase chain reaction (PCR) method currently under development (Beebe, unpublished data). Those identified as *Ae. albopictus* were used in the genetic analysis. For a genetic comparison, *Ae. albopictus* were also obtained from neighboring regions including Sohano, Buka Island (North Solomon Province, PNG), Balibo in Timor-Leste (formerly East Timor), Kiunga in the Western Province of PNG, and Daru Island off the coast of PNG in the Torres Strait. *Aedes scutellaris* collected from Busi in the Western Province of PNG was also included in the genetic analysis.

Genomic DNA was extracted from mosquitoes (partial or whole adults and larvae), and a 5′ segment of the mitochondrial DNA cytochrome oxidase I gene (mtDNA *COI*) was amplified and sequenced following the methods of Beebe et al. (2005). DNA sequences were aligned with *Ae. albopictus* mtDNA from Genbank (AY072044 spanning the bases 1778–2250). Genetic analysis was performed using the Templeton Crandall Sing (TCS) algorithm (Clement et al. 2000), which estimates a parsimonious network. *Aedes albopictus* isolates were sequenced for a segment of the mtDNA *COI* to confirm their species status against *Ae. scutellaris* on Yorke Island.

Larvae tentatively identified as *Ae. scutellaris* that were collected from Yorke Island in April 2004 by QH staff while investigating a small dengue outbreak were retrospectively analyzed using the above assay to determine whether any *Ae. albopictus* were present at that time.

RESULTS

Entomological surveys

Container surveys were not effective in detecting *Ae. albopictus* in the Torres Strait. Because it had not rained significantly in the Torres Strait since early April 2005, almost all ground containers were dry and only 3 larval samples were obtained. *Aedes albopictus* larvae were collected only from a rainwater tank on Coconut Island and from a plastic tray on Mabuiag Island. However, 47 larval samples were collected from the NPA of Cape York. Other species collected as larvae or pupae were *Ae. aegypti*, *Ae. scutellaris, Anopheles* sp. (unidentified), *Culex quinquefasciatus* Say, *Culex bitaeniorhynchus* Giles, *Culex halifaxii* Theobald, *Cx.* E. N. Marks sp. no. 32, *Culex pullus* Theobald, *Ochlerotatus notoscriptus* (Skuse), *Ochlerotatus tremulus* (Theobald), *Ochlerotatus vigilax* (Skuse), *Toxorhynchites* sp., and *Tripteroides magnesianus* (Edwards).

Human bait collections proved the most efficient way to detect the presence of *Ae. albopictus*. Most islands had houses with adjacent forested areas where adult mosquito collections were made. *Aedes albopictus* was collected on 10 of the 17 inhabited islands in the Torres Strait (Table 1). No *Ae. albopictus* were detected on the NPA of Cape York, nor on the inner islands (Thursday Island, Prince of Wales Island, Horn Island, and Hammond Island) of the Torres Strait closest to the Australian mainland. Sweepnet collections consisted of both males and females, with aspirator collections almost exclusively female mosquitoes collected while attempting to bite. However, all the human bait collections were pooled and the precise sex ratio of mosquitoes collected could not be determined for each method. Other mosquitoes collected at human bait included *Ae. aegypti, Ae. scutellaris, Coquillettidia crassipes* (Van der Wulp), *Culex annulirostris* Skuse, *Cx. halifaxii*, *Culex sitiens* Wiedemann, *Ochlerotatus culiciformis* (Theobald), *Ochlerotatus kochi* (Dönitz), *Oc. notoscriptus*, *Oc. tremulus, Oc. vigilax*, *Tr. magnesianus*, *Uranotaenia* sp. (not identified), and *Verrallina funerea* (Theobald).

Finally, the mosquito collections (Table 1) do not represent the absolute or the relative density of *Ae. albopictus* on each island, as variability in operator attractiveness and collecting efficacy, weather conditions, time of day, or other factors would have influenced the collection of *Ae. albopictus*. However, they do confirm the presence of *Ae. albopictus* and provide an estimate of its abundance relative to other day-biting container-breeding mosquitoes (*Ae. aegypti, Ae. scutellaris*, and *Oc. notoscriptus*) at each island.

Table 2. Haplotypes and mtDNA *COI* sequence diversity of *Ae. albopictus* 4th stage larvae used in the genetic analysis.

		COI sequence variation (nt[1])					
Haplotype	Collection location (year)	27	45	144	189	252	396
H1	Taiwan,[1] Yorke Island (05)	G	T	T	C	C	G
H2	Daru (92), Kiunga (92), Buka Island (99)		C	C	T		
H3	Timor-Leste (01)				T	T	A
H4	Yorke Island (05), Timor-Leste (01)				T	T	
H5	Yorke Island (05)	A			T	T	

[1] H1 is the same at *Ae. albopictus* genbank sequence AY072044 from Taipei in Taiwan (begins at 1778 and ends at 2250); see genbank for collection date.

Genetic analysis

Sixty-nine larvae collected from 16 collection sites were identified to species by the PCR. From the 4 *Ae. albopictus* specimens sequenced for the *COI*, 3 different haplotypes were identified from 3 separate collection sites on Yorke Island where *Ae. albopictus* was found. Specimens from neighboring regions (2 isolates per site) were also sequenced for the mtDNA *COI*, and the genetic diversity of these individuals was compared (Table 2). All nucleotide variation appeared at the 3rd codon position, and a minimum parsimony network was generated (Fig. 2). Material from Western Province of PNG (Daru and Kiunga) and Buka Island was the same haplotype (H2). There were 3 different haplotypes on Yorke Island (H1, H4, and H5), 2 from Timor-Leste and 1 from each of the collection sites in Kiunga and Daru islands in PNG, and Buka Island in the northern Solomon Islands.

Retrospective genetic analysis was conducted on 78 4th stage *Stegomyia* larvae collected from 16 different containers on Yorke Island in April 2004. Positive identifications using PCR were obtained from 70 (90%) larvae, consisting of 65 (93%) *Ae. scutellaris* and 5 (7%) *Ae. albopictus*. *Aedes scutellaris* were found in all 16 containers, while only 3 containers (18.8%) yielded *Ae. albopictus*.

DISCUSSION

Aedes albopictus is widespread in the Torres Strait, with specimens collected on 10 of the 17 inhabited island communities. In one respect, the detection of *Ae. albopictus* in the Torres Strait comes as little surprise considering their detection on Daru Island off the coast of southern PNG in 1992 (Cooper et al. 1994). The southern villages of PNG, including Daru Island, are a likely source of *Ae. albopictus*; small boats often travel from these to many of the Torres Strait islands, and the boats themselves may contain water and serve as a source of *Ae. albopictus*. This could account for the multiple haplotypes observed in the *Ae. albopictus* from Yorke Island, although the H2 haplotype found in Daru and Kiunga was not, perhaps because this is a new haplotype not present when Daru and Kiunga were sampled in 1992.

Fortunately, *Ae. albopictus* does not appear to be on the mainland itself (NPA region) or Thursday Island or Horn Island in the southwestern Torres Strait, perhaps because of their relatively greater distance from PNG than the other Torres Strait islands. Thursday Island is the most populated Torres Strait island and is the seat of regional government and commerce. Horn Island is the primary regional travel and freight hub between the other Torres Strait islands and the Australian mainland. Thus, both pose the highest risk of facilitating the dispersal of *Ae. albopictus* to mainland Australia. Several ovitrap, larval, and adult surveys were conducted on these islands in March–April 2005 in response to a dengue outbreak, and while other container-breeding mosquitoes were common, no *Ae. albopictus* were collected. However, because dry

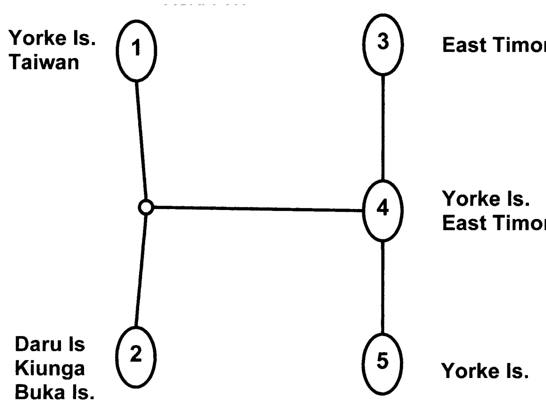

Fig. 2. Mitochondrial *COI* haplotype network of *Ae. albopictus* generated using the TCS algorithm (Clement et al. 2000). Circles represent the different *COI* sequence haplotypes, and specimen collection sites are described beside haplotypes. The H1 haplotype from Taiwan was from a whole genome sequence from genbank (AY072044, nucleotides 1778 to 2250). Connecting nodes represent single mutational steps between haplotypes and may be unidentified extant haplotypes. The haplotype frequency and diversity is detailed in Table 2.

weather reduced populations of container-breeding mosquitoes on many islands, *Ae. albopictus* may have been present as eggs on islands that were negative during our surveys, and further surveys should be conducted during the upcoming wet season.

The level of *Ae. albopictus* infestation varied between islands. On Yorke and Stephens Island, it represented 100% of the day-biting container-breeding mosquitoes; the species was predominant at St. Paul's on Moa Island and at Mabuiag Island, but only single specimens were detected on Murray and Dauan islands. In some heavily infested islands, it is possible that *Ae. albopictus* has been present for some time but has remained undetected. Indeed, Stephens Island, which had not been surveyed for container-breeding mosquitoes since 1997, had some 5-min human landing counts of >50, with all the 22 mosquitoes collected by sweepnet and aspirator identified as *Ae. albopictus*. Local island AQIS inspectors do not routinely trap for mosquitoes, and Queensland Health staff often do not collect larvae from containers during emergency dengue control interventions in order to improve speed of treatments. Finally, *Ae. albopictus* larvae may have been misidentified as *Ae. scutellaris*, since 4th stage larvae of these species are difficult to distinguish (Lamche and Whelan 2003).

Nonetheless, the spread of *Ae. albopictus* in much of the Torres Strait appears to be relatively recent. Retrospective genetic analysis of 4th stage larvae collected on Yorke Island in April 2004 indicates that *Ae. albopictus* was present in low densities a year before they were initially detected in the Torres Strait. Sticky ovitrap (Ritchie et al. 2004) collections conducted on Murray, Yorke, and Darnley islands in November–December 2004 only detected *Ae. scutellaris* (Ritchie, unpublished data). Sticky ovitraps are a reliable method to collect a variety of *Stegomyia* mosquitoes including *Ae. aegypti* in Australia (Ritchie et al. 2003), *Aedes polynesiensis* in French Polynesia (Russell and Ritchie 2004), *Ae. scutellaris* in the Torres Strait (Ritchie and Williams, unpublished data), and *Ae. albopictus* in Vietnam (Ritchie, unpublished data).

Yorke Island provided a greater insight into the dynamics of *Ae. albopictus* in the Torres Strait. More sites were sampled on Yorke Island than on other islands, and retrospective survey material was available for genetic analysis. In April 2004, *Ae. albopictus* comprised only 7% of larvae collected from containers. However, by April 2005, *Ae. albopictus* had become dominant, with BG-Sentinel trap collections consisting of 95% *Ae. albopictus*, and 69% of adults reared from concurrent ovitrap collections were *Ae. albopictus* (van den Hurk and Johnson, unpublished data). Ultimately, human bait collections in May 2005 contained only *Ae. albopictus*. These collections revealed that *Ae. albopictus* was restricted to domestic and peridomestic areas, with none captured in sylvan areas further than 200 m from areas of human activity. Indeed, male *Ae. albopictus* were restricted to areas within 50 m of human activity. The mtDNA *COI* sequences of Yorke Island larvae collected in April 2005 revealed 3 different *COI* haplotypes from 3 different collection sites. Specimens from Daru, Kiunga, and Buka islands were found to be the same haplotype, although only 1 collection site was sampled from each region, while samples from Timor-Leste specimens displayed 2 haplotypes from 2 collection sites. These findings indicate an elevated genetic diversity on Yorke Island relative to material from other areas in the region, suggesting that either a significant incursion of genetically diverse individuals or multiple incursions of different haplotypes may have occurred. A more detailed genetic analysis of *Ae. albopictus* collected throughout the region needs to be conducted. The presence of *Ae. albopictus* on Yorke Island for 2 consecutive years also indicates that it can survive the lengthy dry season that occurs in the Torres Strait.

Our results suggest that *Ae. albopictus* may be displacing other day-biting container-breeding mosquitoes on Yorke Island and some other Torres Strait islands. On Yorke and Stephens islands, *Ae. albopictus* was the only day-biting container-breeding mosquito collected, while it represented 95% of the day-biting container-breeding mosquitoes at St. Paul's on Moa Island (Table 1). In a subsequent human bait survey on Yorke and Stephens islands in January 2006, 100% and 98% of mosquitoes sampled were *Ae. albopictus* (Davis, Queensland Health, unpublished data). Interestingly, *Ae. scutellaris* displaced *Ae. aegypti* following dengue control efforts on Yorke Island in 1997 (Ritchie et al. 2002) in response to an outbreak of DENV-2 in 1996–97 (Hanna et al. 1999). Conversely, despite collecting large numbers of *Ae. aegypti* ($n = 63$) on Sue Island, only 8 *Ae. albopictus* were collected, suggesting either a recent introduction or cohabitation. A similar argument could be made for Murray and Dauan islands, where only single *Ae. albopictus* specimens were collected and *Ae. scutellaris* predominated. If it is a recent introduction on these islands, it is possible that *Ae. albopictus* will become the dominant *Stegomyia* sp. over the following years.

The presence of *Ae. albopictus* will likely change the dynamics of DENV transmission in the Torres Strait where *Ae. aegypti* has been the primary epidemic vector. There is the potential that *Ae. aegypti* populations may be reduced or even locally eradicated on some islands because of interspecific competition from *Ae. albopictus*. This phenomenon has been observed in some areas recently invaded by *Ae. albopictus*, such as the southern USA, although the reverse has also occurred (Gratz 2004). Conversely, both *Ae. aegypti* and *Ae. albopictus* coexist in many areas where the latter species has recently been introduced (Juliano and Lounibos 2005). If *Ae. aegypti* are marginalized, or even driven to local extinction, the risk of dengue epidemics could decline significantly in the Torres Strait. Gubler (2003) pointed out that *Ae. aegypti* is a more important epidemic vector of DENV than *Ae. albopictus* and suggested that the introduction of *Ae. albopictus* could have a public health benefit by decreasing the risk of urban epidemics of dengue if it displaced *Ae. aegypti*.

Aedes albopictus is likely to invade coastal areas in much of mainland Australia should it become established on the Australian mainland. Using CLIMEX®, a model that forecasts potential distributions of invasive insects (Sutherst and Maywald 1999), Russell et al. (2005) postulated that most east coast areas of Australia as far south as Tasmania could support colonization by *Ae. albopictus*. The role that *Ae. albopictus* could play in disease transmission in these regions is uncertain, but the presence of *Ae. albopictus* in cities such as Brisbane, Sydney, and Melbourne where *Ae. aegypti* is absent would certainly introduce a risk of DENV transmission to those major urban centers, which receive viremic international travelers. However, the outbreaks are not likely to be large or explosive, as is seen when *Ae. aegypti* is the primary vector (Gubler 2003). Nonetheless, tropical and subtropical areas where only *Ae. albopictus* is present have had significant outbreaks, with 1,418 dengue cases reported from Macau, China, in 2001 (Almeida et al. 2005), and 122 cases confirmed during an outbreak in Hawaii in 2002 (Effler et al. 2005).

What should be done about *Ae. albopictus* in the Torres Strait? To do nothing would probably result in the rapid colonization of the remaining Torres Strait islands, and possibly the Australian mainland. The risk of dengue epidemics could decrease if *Ae. albopictus* displaced *Ae. aegypti*, but the species could increase transmission risks if it augmented low populations of *Ae. aegypti*, and it could vector DENV in areas where *Ae. aegypti* was absent or had been eliminated by control efforts. *Aedes albopictus* could become a significant pest in both the Torres Strait and much of coastal Australia. Finally, it is likely to become a significant local vector of dog heartworm, and it may become involved in the transmission of endemic Australian arboviruses such as RRV and Murray Valley encephalitis virus.

Owing to the collective threats that *Ae. albopictus* poses to Australia, the National Arbovirus and Malaria Advisory Committee of the Communicable Disease Network of Australia, reporting through the National Public Health Partnership, has endorsed an intervention program to control and potentially eradicate *Ae. albopictus* in the Torres Strait. As a stopgap measure, QH staff initiated emergency mosquito control on heavily infested islands (Yorke, Stephens, and Darnley) in May 2005, treating rainwater tanks and other large containers with s-methoprene briquettes and small containers with bifenthrin (Biflex Aqua®). Proposed comprehensive control efforts will target communities and adjacent bushland and include source reduction, community participation, larval control, and adulticiding. While this program may not eradicate *Ae. albopictus*, it will have the benefit of reducing or even eradicating populations of *Ae. aegypti*. Reducing or eliminating populations of these 2 species would reduce the risk of dengue transmission in the Torres Strait and subsequently the mainland of Australia.

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