

Updating the geographical distribution and frequency of *Aedes albopictus* in Brazil with remarks regarding its range in the Americas

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The geographical distribution of Aedes albopictus in Brazil was updated according to the data recorded across the country over the last eight years. Countrywide house indexes (HI) for Ae. albopictus in urban and suburban areas were described for the first time using a sample of Brazilian municipalities. This mosquito is currently present in at least 59% of the Brazilian municipalities and in 24 of the 27 federal units (i.e., 26 states and the Federal District). In 34 Brazilian municipalities, the HI values for Ae. albopictus were higher than those recorded for Ae. aegypti, reaching figures as high as HI = 7.72 in the Southeast Region. Remarks regarding the current range of this mosquito species in the Americas are also presented. Nineteen American countries are currently infested and few mainland American countries have not confirmed the occurrence of Ae. albopictus. The large distribution and high frequency of Ae. albopictus in the Americas may become a critical factor in the spread of arboviruses like chikungunya in the new world.

Key words: *Aedes albopictus* - distribution - house index - infestation - surveillance

Aedes albopictus (Skuse), also known as the Asian tiger mosquito, was first described 120 years ago based on specimens collected in Calcutta, India (Zeller 1998). Its original distribution included Southeast Asia, the islands of the Pacific and Indian Oceans, northern China, Japan and Madagascar. It has since spread from this original range to dozens of countries across all continents (Lounibos 2002). Thus, *Ae. albopictus* is considered one of the most important invasive species worldwide (Benedict et al. 2007, Medlock et al. 2012). It is likely that the intense trading of used tires containing eggs has favoured the wide dispersion of this species over recent decades, particularly beginning in the 1980s; the intercontinental traffic of other goods and varied routes have also been suggested as passive dispersal mechanisms (Reiter 1998, Lounibos 2002, Benedict et al. 2007, Paupy et al. 2009). Its colonisation of temperate regions such as North America and Europe as well as tropical and subtropical regions such as South America and Africa was facilitated by the species' strong biological and behavioural plasticity, including its use of a substantial variety of larval habitats (e.g., artificial and natural containers), highly competitive ability during the larval stage, relative resistance to low temperatures, and other unfavourable environmental conditions during both immature and adults stages, and ability to colonise both human-made and natural environments (e.g., near human dwell-

ings, non-residential areas and forest fringes) (Reiter & Sprenger 1987, Hawley 1988, Estrada-Franco & Craig Jr 1995, Lounibos et al. 2003, Lourenço-de-Oliveira et al. 2003, Juliano & Lounibos 2005, Paupy et al. 2009, Fernández et al. 2012, Lima-Camara et al. 2013). Immature forms of *Ae. albopictus* are found in natural deposits such as bromeliads, tree holes and bamboo and its larvae can also co-occur and compete with those of *Aedes aegypti* in human-made containers (Consoli & Lourenço-de-Oliveira 1994, Natal et al. 1997, Forattini 2002).

The first report of *Ae. albopictus* colonisation in the Americas was made in August 1985 in Houston, Texas, United States of America (USA) (Sprenger & Wuithiranyagool 1986). *Ae. albopictus* was detected for the first time in Brazil in 1986 in the states of Rio de Janeiro (RJ) and Minas Gerais (MG), located in the Southeast Region of the country (Consoli & Lourenço-de-Oliveira 1994). Actually, in May 1986, one of us (RLO) received a batch of mosquitoes bred from larvae collected in a container in the urban area of Viçosa, MG, by Prof Paulo Fiuza Ferreira. He reared the mosquitoes to know if they were *Ae. aegypti*, which was responsible for a severe dengue outbreak in Rio de Janeiro, about 300 Km from his city. Although the specimens were poorly preserved, it was perceived that they did not belong to any known Neotropical species of *Aedes*. Almost one month later, a student of Federal Rural University of Rio de Janeiro collected mosquito larvae in an abandoned tire in the university campus, at Seropédica, RJ, taking them to his teacher, Prof Eugênio Izelkson. They reared the larvae supposing they were *Ae. aegypti*, but when the first adults emerged, they were seen not to belong to this species. On 22 June, Prof Izelkson was watching a TV program on the invasion of *Ae. albopictus* in the USA, when a close-up of this mosquito was shown; he immediately assumed that his mosquitoes probably belonged to that species. On

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the following day, he advised the health authorities, the Brazilian Superintendence of Public Health Campaigns (SUCAM), and sent some specimens to be identified by one of us (RLO) and the late Prof Leonidas M Deane. On 24 and 25 June, after examining females, males, male genitalia and larvae from Seropédica, and comparing them with the specimens caught in Viçosa, we (RLO and LMD) identified all specimens as *Ae. albopictus*, a diagnosis subsequently confirmed by Prof Oswaldo P Forattini, who also made the same diagnosis using specimens from the same batch. The surveys conducted by SUCAM in the Southeast Region detected this species in the states of São Paulo (SP) that same year and in Espírito Santo (ES) the following year.

The first invasion in Brazil was hypothesised to have occurred through the ports located in ES and the species most likely gained access to other states *via* the railway network. It is likely that more than one invasion and colonisation event has occurred at different sites and times since the 1980s by *Ae. albopictus* founder populations with distinct origins (Consoli & Lourenço-de-Oliveira 1994, Lounibos 2002, Lounibos et al. 2003, Lourenço-de-Oliveira et al. 2003, Usmani-Brown et al. 2009, Vidal et al. 2012).

In Brazil, the population density of *Ae. aegypti* is periodically accessed to direct and evaluate control measures (MS 2009, Coelho 2012). The surveillance of *Ae. aegypti* infestation levels in Brazil has been performed in each state and data have regularly been stored since 1997, when the National Health Foundation created a database for entomological data called the Yellow Fever and Dengue Information System (SISFAD) (dos Santos 2003). Therefore, the geographic distribution and house index (HI) of *Ae. aegypti* in Brazil is frequently updated (Coelho 2012). However, this information is fragmented, out-dated or even absent for *Ae. albopictus* (dos Santos 2003). In fact, *Ae. albopictus* has never been considered natural vector of arboviruses in Brazil or in any other American country. Thus, its surveillance has not been prioritised. Despite not being the target species of the DENV control program, immature stages of *Ae. albopictus* have been detected and recorded during routine entomological surveys of *Ae. aegypti* in Brazil. However, these records have not been analysed or made available for over 10 years (dos Santos 2003). Nevertheless, experiments have demonstrated that *Ae. albopictus* populations from Brazil and other American countries are highly competent at transmitting dengue (DENV), Yellow fever (YFV) and Chikungunya (CHIKV) (Mitchell et al. 1987, Miller et al. 1989, Lourenço-de-Oliveira et al. 2003, Vega-Rua et al. 2014). The recent circulation of CHIKV in the Caribbean (Nasci 2014) and the high vector competence of *Ae. albopictus* populations from Brazil and nine other American countries to transmit two CHIKV genotypes (Vega-Rua et al. 2014) underscores the need for updating the knowledge of this mosquito species' distribution and frequency to better target timely preventive and control measures.

Therefore, the current paper updates the information on the geographic distribution of *Ae. albopictus* in Brazil according to the data recorded across the country over the last eight years. Furthermore, this study is the

first to describe the countrywide HI of this mosquito in urban and suburban areas using a sample of Brazilian municipalities chosen by the National Program for Dengue Control (PNCD).

MATERIALS AND METHODS

The current analysis was based on the data recorded by each Brazilian municipality according to annual larval surveys conducted from 2007-2014. The primary data were collected using two methodologies applied for the entomological surveillance of the PNCD: (i) the house-to-house larval survey (LI), which determines the most traditional *Stegomyia* index (i.e., the HI, whose data are routinely stored in the SISFAD), and (ii) the Rapid Assessment of Infestation by *Aedes aegypti* (LIRAA) (Pilger et al. 2011, Coelho 2012).

In the LI procedure, health agents search larval habitats over two consecutive months in 100%, 33%, 20% or 10% of municipal premises (depending on the number of buildings in the municipality) as recommended by the WHO (2009) and MS (2005, 2009). The LI was done in 5,562 municipalities. The HI corresponds to the percentage of houses with at least one positive larval habitat.

The methodology used for the LIRAA was also based on the detection of immature mosquito forms. However, the LIRAA consists of dividing municipalities into strata of 8,100-12,000 premises (residential or commercial buildings), depending on the municipality's population density (MS 2005). The sampling is performed using premise clusters containing two sampling units: block and premise. The initial sample size is calculated based on the stratum size, with a maximum sample size of 450 houses. The number of randomly sorted blocks to be surveyed was calculated based on the mean block size, as described by Pilger et al. (2011). Using this methodology, around 5% of the total premises were inspected in one week visited in each municipality (MS 2005).

Since 2003, the PNCD has defined certain municipalities as a priority for performing a nationwide LIRAA (MS 2006). The nationwide LIRAA has conducted on a bimonthly basis each year in October or November, which is at the beginning of the rainy and DENV transmission seasons in most Brazilian territories. The municipalities were classified as infested when the occurrence of *Ae. albopictus* was confirmed *via* either LI or LIRAA inspection during at least one of the annual surveys conducted between 2007-2014 (MS 2009).

The historical analysis of the HI values was based on the nationwide LIRAA data collected from 2007-2011 because the primary data gathered from 2012-2014 had not yet been fully verified or recorded for all Brazilian municipalities. The number municipalities prioritised for the nationwide LIRAA has increased annually according to the criteria established by the CG-PNCD. From 2007-2009, 169 municipalities were annually surveyed (3% of Brazilian municipalities); in 2010 and 2011, 427 (7.5%) and 665 (12%) municipalities were included, respectively (MS 2006). The ratios between the HI values found for *Ae. aegypti* and *Ae. albopictus* were calculated and the municipalities where the HI values for *Ae. albopictus* were greater than those for *Ae. aegypti* were identified.

RESULTS

The geographical distribution of Ae. albopictus in Brazil - In 2014, *Ae. albopictus* was detected in 59% of the 5,565 surveyed Brazilian municipalities ($n = 3,285$). A 51.6% increase in the number of infested municipalities was observed compared to 2011 (Fig. 1). The LI and LIRAA, performed from 2007-2012, recorded the occurrence of *Ae. albopictus* in 23 of the 27 Brazilian federal units (i.e., 26 states and the Federal District). *Ae. albopictus* showed a wider geographical distribution in the Southeast, South and Central-West, where 1,489 (89.3%), 748 (63%) and 245 (52.6%) municipalities were infested, respectively. The percentages of infested municipalities were much lower in the North (139 municipalities, 31%) and Northeast (663; 37%) (Fig. 1).

The historical evolution of the HI by Ae. albopictus across Brazilian municipalities from 2007-2011 - Fig. 2 shows the HI values in the Brazilian municipalities surveyed by the nationwide LIRAA between 2007-2011. Twenty-one municipalities in the North, Northeast, South and Southeast exhibited HI values ≥ 0.9 for *Ae. albopictus* in at least one of annual surveys. The highest HI values for *Ae. albopictus* were recorded in the municipalities of Teresópolis (RJ) in the Southeast in 2008, Florianópolis, Santa Catarina (SC) in the South in 2009, Mario Campos (MG) in the Southeast in 2010 and 2011, Muriaé (MG) and Cariacica (ES) in the Southeast in 2011. Remarkably, the great majority of municipalities recording the highest annual HI values for *Ae. albopictus* in Brazil were in the Southeast (Table I). HI reached values as high as 7.72 in the Southeast, as in Mario Campos (MG) (Table I). In the Southeast Region, some municipalities reported HI values

for *Ae. albopictus* several fold higher than those detected for *Ae. aegypti* (Table II), such as in Teresópolis and Mario Campos (ratios = 5.28 and 16.83, respectively).

The HI values for *Ae. albopictus* were higher than those reported for *Ae. aegypti* in 34 Brazilian municipalities. These areas included (i) the South Region [Porto Alegre, Rio Grande do Sul in 2008, Florianópolis (SC) in 2008, 2009 and 2010, Apucarana and Cambé, Paraná (PR) in 2011], (ii) the North Region [Presidente Figueiredo, Iranduba, Novo Airão, Rio Preto da Eva and Tabatinga (Amazonas), in 2011], (iii) the Northeast Region [Moreno, Pernambuco in 2010, Parnamirim, Rio Grande do Norte in 2011] and (iv) the Southeast Region [Santa Luzia (MG) in 2007 and 2010, Ibirité and Sabará (MG), Angra dos Reis, Rezende and Teresópolis (RJ) in 2008, Guapimirim and Itatiaia (RJ), Mário Campos (MG) in 2010 and 2011, Pirai and Porciúncula (RJ), Além Paraíba and Confins (MG) in 2010, Marataízes and Cariacica (ES), Itanhaém and Peruíbe (SP), Aperibé, Engenheiro Paulo de Frontin, São Francisco de Itabapoana (RJ), Caratinga, Manhuaçu and Muriaé (MG) in 2011]. The HI values for *Ae. albopictus* were lower than those recorded for *Ae. aegypti* for all municipalities from the Central-West, regardless of year.

DISCUSSION

This paper provides the first description of the geographic distribution of *Ae. albopictus* in Brazil at the municipal level and assesses the HI values recorded for this species vs. those reported for *Ae. aegypti* in municipalities sampled across the country.

A noticeable and increased spread of *Ae. albopictus* was detected in Brazil since the last evaluation (dos San-

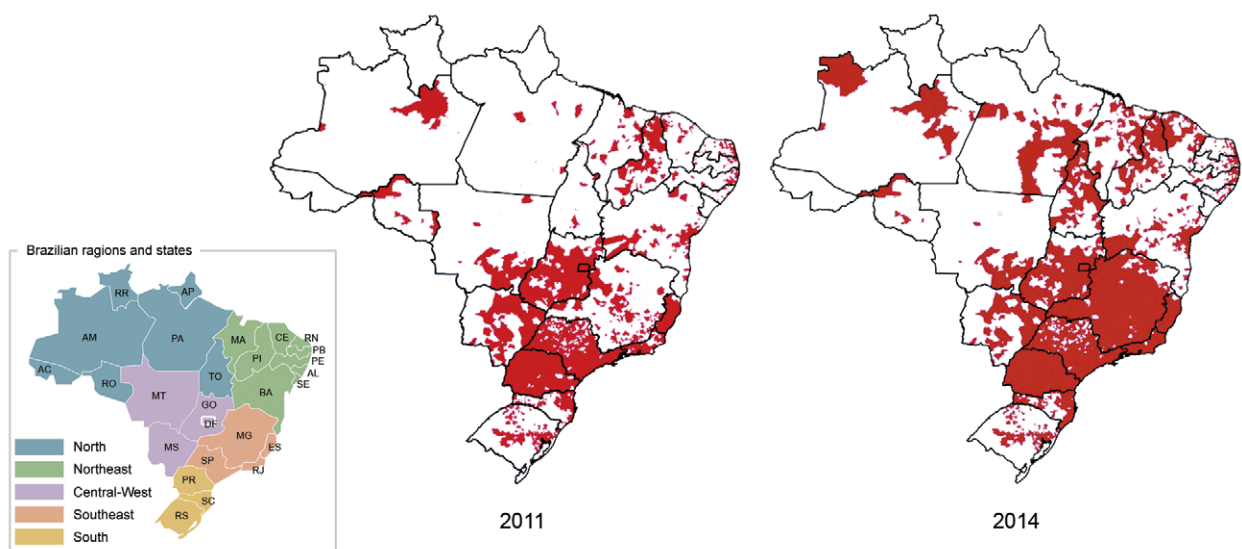


Fig. 1: Brazilian municipalities where *Aedes albopictus* was detected in 2011 and 2014. AC: Acre; AL: Alagoas; AM: Amazonas; AP: Amapá; BA: Bahia; CE: Ceará; DF: Federal District; ES: Espírito Santo; GO: Goiás; MA: Maranhão; MG: Minas Gerais; MS: Mato Grosso do Sul; MT: Mato Grosso; PA: Pará; PB: Paraíba; PE: Pernambuco; PI: Piauí; PR: Paraná; RJ: Rio de Janeiro; RN: Rio Grande do Norte; RO: Rondônia; RR: Roraima; RS: Rio Grande do Sul; SC: Santa Catarina; SE: Sergipe; SP: São Paulo; TO: Tocantins.

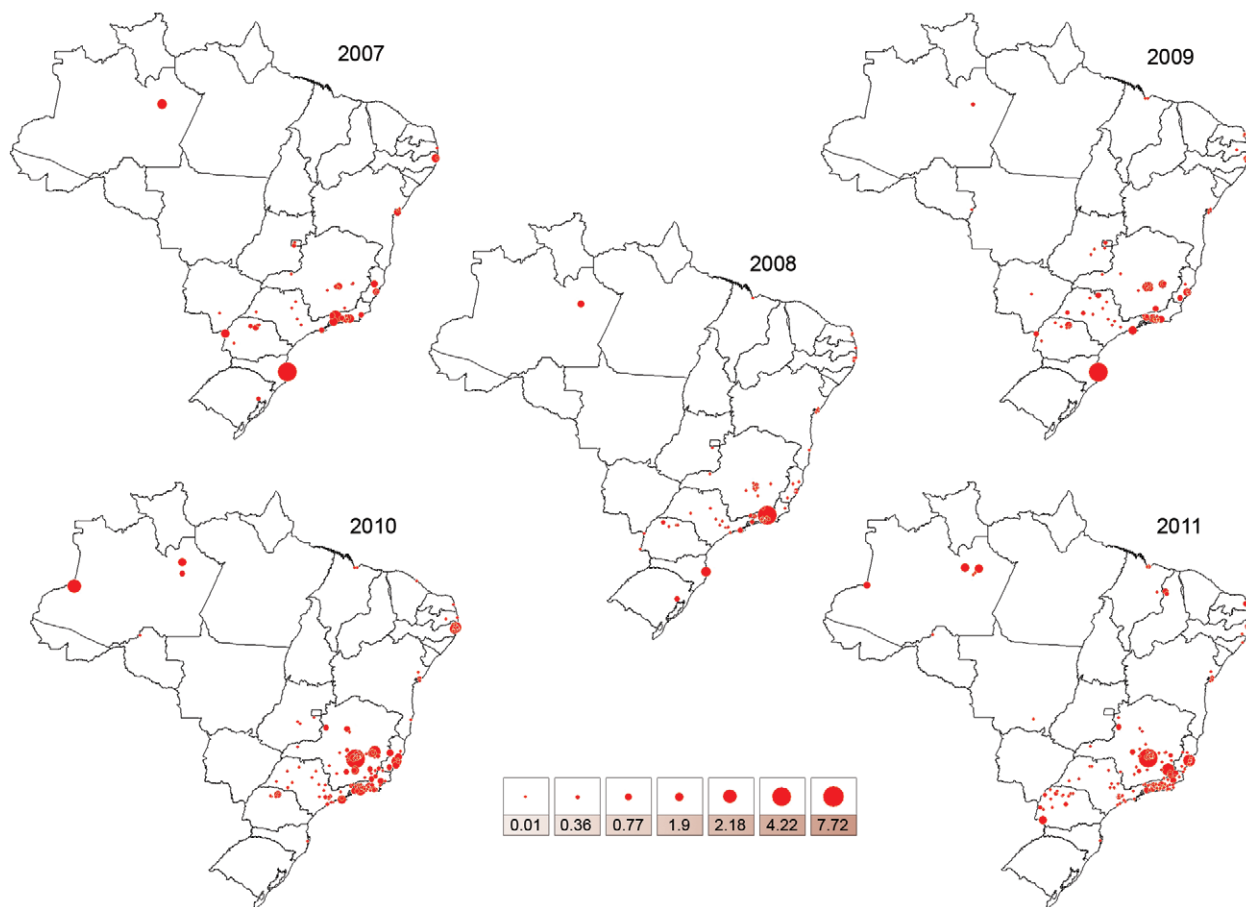


Fig. 2: variation of house index for *Aedes albopictus* in Brazilian surveyed municipalities from 2007-2011.

tos 2003). According to dos Santos (2003), seven Brazilian states did not report the presence of this mosquito species until 2002: Acre (AC), Amapá (AP), Roraima (RR), Tocantins, Piauí, Ceará and Sergipe (SE). However, according to the data gathered in the SISFAD and LIRAA assessments from 2007-2014, this mosquito species was detected in all but the following four states: AC, AP, RR and SE. Although not detected by the LI and LIRAA surveys performed in RR between 2007-2014, Aguiar et al. (2008) found immature forms of *Ae. albopictus* in this state in 2006 and 2007. In conclusion, only three of the 27 Brazilian federal units did not report the presence of this mosquito species.

Unfortunately, neither the HI values for this species nor previous detailed data (dos Santos 2003) regarding the number of municipalities infested by *Ae. albopictus* exist in Brazil at the national level. Therefore, we cannot assess whether these indicators have recently increased. Importantly, *Ae. albopictus* is present in more than half of all Brazilian municipalities (59%) and it has the largest geographic distribution and the highest reported HI values in municipalities and states located in the Southeast. Likewise, *Ae. albopictus* was first found in Brazil in the Southeast (Consoli & Lourenço-de-Oliveira 1994).

It is likely that the geographical distribution of *Ae. albopictus* remains underestimated in Brazil. It is pos-

sible that this mosquito species might be present in certain municipalities classified herein as negative. Three major methodological issues and limitations in LI and LIRAA may reduce the detection rate for this mosquito. The first limitation is the low sample size of the LI and LIRAA surveys ($n \leq 10$ larvae/positive larval habitat). As a result, in larval sites where *Ae. albopictus* is much less frequent than *Ae. aegypti*, the probability of detecting the former species becomes very low. The second is related to the sample site locations targeted by LI and LIRAA, which only focus on the target species, *Ae. aegypti*, and do not consider the essentially extradomiciliary behaviours of *Ae. albopictus* that might include the colonisation of Brazilian forest fringes (Albuquerque et al. 2000, Lourenço-de-Oliveira et al. 2004). In fact, the data analysed herein correspond to the records of larval collections made in urban areas, mostly in containers located inside or within the close vicinity of houses. However, *Ae. albopictus* is usually uncommon in these environments in Brazil, which strongly reduces the chance of finding its larvae during the LI and LIRAA surveys. Braks et al. (2003) demonstrated that the frequency of *Ae. albopictus* in Southeast of Brazil is directly and positively correlated with vegetation coverage and shows a negative relationship with increasing urbanisation. Finally, the third metrological issue is

TABLE I
Brazilian municipalities where the house index values were higher than 0.9 from 2007-2011,
according to the nationwide Rapid Assessment of Infestation by *Aedes aegypti*

Region	State	Municipality	2007	2008	2009	2010	2011
N	AM	Novo Airão	NR	NR	NR	NR	1.9
N	AM	Rio Preto do Eva	NR	NR	NR	NR	1.71
N	AM	Tabatinga	NR	NR	NR	2.18	1.38
NE	PE	Camaragibe	0.4	0.23	0.5	1.68	1.4
NE	PE	Moreno	NR	NR	NR	1.25	0.2
SE	RJ	Aperibé	NR	NR	NR	0	1.15
SE	RJ	Conceição de Macabu	NR	NR	NR	0.53	1.02
SE	RJ	Guarapimirim	NR	NR	NR	0.7	1.88
SE	RJ	Itaguaí	NR	NR	NR	1.38	0.82
SE	RJ	Teresópolis	NR	5.05	NR	NR	NR
SE	MG	Dores do Indaiá	NR	NR	NR	0.22	1.03
SE	MG	Ipaba	NR	NR	NR	1.77	NR
SE	MG	Mario Campos	NR	NR	NR	4.22	7.72
SE	MG	Muriaé	NR	NR	NR	0.18	3.25
SE	MG	Ribeirão da Neves	0.13	0.38	1.06	0.22	0.40
SE	MG	Santa Cruz das Minas	NR	NR	NR	0.91	NR
SE	MG	Timóteo	0.08	0.08	0.94	0.95	0.32
SE	ES	Cariacica	0.28	0.24	0.80	1.21	3.45
SE	SP	São Sebastião	0.23	0.50	1.00	0.95	0.05
S	SC	Florianópolis	2.04	1.45	4.16	0.19	0.02
S	PR	Capanama	NR	NR	NR	NR	1.78

the number of municipalities annually surveyed were 169 in 2007-2009, 427 in 2010 and 665 in 2011. NR: not realised; Brazilian Regions: North (N), Northwest (NE), South (S), Southeast (SE); states: Amazonas (AM), Espírito Santo (ES), Minas Gerais (MG), Paraná (PR), Pernambuco (PE), Rio de Janeiro (RJ), Santa Catarina (SC), São Paulo (SP).

related to potential larval misidentification, especially in states or counties where *Ae. albopictus* does not traditionally or frequently occur. In addition, the entomological surveillance seeking to control DENV in Brazil (i.e., LI and LIRAA) is limited to municipal urban and suburban areas; no data exist for rural areas. Thus, it is likely that *Ae. albopictus* is present in more than 59% of all Brazilian municipalities and the lack of *Ae. albopictus* records in certain counties is simply because this species is not yet a priority target species.

Because its extradomiciliary behaviour, detecting immature forms of *Ae. albopictus* using the current LI and LIRAA methodologies is much less likely compared to *Ae. aegypti* (Consoli & Lourenço-de-Oliveira 1994, Forattini 2002, Honório et al. 2009). Consequently, as might be expected, the HI values for *Ae. aegypti* are traditionally higher than those detected for *Ae. albopictus* across Brazil. Nonetheless, the HI values for *Ae. albopictus* were higher than those reported for *Ae. aegypti* in at least 34 Brazilian municipalities, 67.7% of which are located in the Southeast.

Ae. albopictus has been present in urban and suburban areas of all Brazilian regions for decades and its territory overlaps that of *Ae. aegypti*. Furthermore, LI and LIRAA often found immature forms of *Ae. albopictus* in association with those of *Ae. aegypti*. In fact, *Ae. albopictus*

might be abundant in urban and suburban areas where artificial containers are commonly accumulated at open fields in the backyards, as described in Nova Iguaçu (RJ) in the Southeast (Braks et al. 2003). The population density of *Ae. albopictus* at Ubiratã (PR) in the South was higher than that of *Ae. aegypti*, even in urban centres (Prophiro et al. 2011). Therefore, although *Ae. albopictus* is not common inside human dwellings in Brazil, its density can be high in backyards and in the transition zone between human-made and natural environments (Lourenço-de-Oliveira et al. 2004, Honório et al. 2009). These behaviours and distributions increase the chances of human infection due to the arboviruses (e.g., YFV, DENV and CHIKV) that the Brazilian *Ae. albopictus* populations have been shown to be competent to transmit (Lourenço-de-Oliveira et al. 2003, Vega-Rua et al. 2014). Furthermore, the ability of *Ae. albopictus* females to move between the forest and human-made environments (Lourenço-de-Oliveira et al. 2004, Maciel-de-Freitas et al. 2006) might favour the dissemination of forest-restricted arboviruses such as YFV (Lourenço-de-Oliveira et al. 2003).

The range of *Ae. albopictus* in the Americas has significantly increased since its first detection early in the 1980's (Benedict et al. 2007). Currently, the colonisation of *Ae. albopictus* has been confirmed in 19 countries (Fig. 3): Brazil, Paraguay, Colombia, Venezuela, Trini-

TABLE II
Ratio between house infestation index values for *Aedes aegypti* and *Aedes albopictus* in Brazilian municipalities according to the nationwide Rapid Assessment of Infestation by *Aedes aegypti* performed from 2007-2011

Region	State	Municipality	2007			2008			2009			2010			2011		
			<i>Ae. aegypti</i>	<i>Ae. albopictus</i>	Ratio	<i>Ae. aegypti</i>	<i>Ae. albopictus</i>	Ratio	<i>Ae. aegypti</i>	<i>Ae. albopictus</i>	Ratio	<i>Ae. aegypti</i>	<i>Ae. albopictus</i>	Ratio	<i>Ae. aegypti</i>	<i>Ae. albopictus</i>	Ratio
S	RS	Porto Alegre	NR	NR	NR	0	0.66	0.66	NR	NR	NR	NR	NR	NR	NR	NR	NR
S	SC	Florianópolis	NR	NR	NR	0	1.45	1.45	NR	4.16	4.16	NR	0.19	NR	NR	NR	NR
S	PR	Apucarana	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0	NR	0.27	0.27
S	PR	Cambé	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0	NR	0.13	0.13
N	AM	Irlanduba	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0	NR	0.10	0.10
N	AM	Novo Airão	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1.70	NR	1.90	1.12
N	AM	Presidente Figueiredo	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.20	NR	0.80	4.00
N	AM	Rio Preto da Eva	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0	NR	1.51	1.51
N	AM	Tabatinga	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.30	NR	1.38	4.60
NE	PE	Moreno	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1.25	NR	NR	NR	NR
NE	RN	Parnamirim	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.47	NR	0.79	NR	0.79
SE	MG	Além Paraíba	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.51	NR	0.60	NR	1.20
SE	MG	Caratinga	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.50	NR	NR	NR
SE	MG	Confins	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
SE	MG	Ibirité	NR	NR	NR	0.30	0.34	1.13	NR	NR	NR	NR	NR	NR	NR	NR	NR
SE	MG	Manhuaçu	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
SE	MG	Mario Campos	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
SE	MG	Muriae	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.10	NR	1.09	10.90
SE	MG	Sabará	NR	NR	NR	0.10	0.20	2.00	NR	NR	NR	NR	NR	NR	NR	7.72	2.86
SE	MG	Santa Luzia	0.20	0.33	1.65	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	3.25	2.95
SE	ES	Cariacica	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
SE	ES	Maratizes	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
SE	RJ	Angra dos Reis	NR	NR	NR	0.20	0.30	1.50	NR	NR	NR	NR	NR	NR	NR	NR	NR
SE	RJ	Aperibé	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
SE	RJ	Eng Paulo de Frontin	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
SE	RJ	Guapimirim	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
SE	RJ	Itatiaia	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
SE	RJ	Pirai	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
SE	RJ	Porciúncula	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
SE	RJ	Rezende	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
SE	RJ	São Francisco	NR	NR	NR	0.10	4.00	40.00	NR	NR	NR	NR	NR	NR	NR	NR	NR
SE	RJ	de Itabapoana	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.34	1.13
SE	RJ	Teresopolis	NR	NR	NR	0.30	5.05	16.83	NR	NR	NR	NR	NR	NR	NR	NR	NR
SE	SP	Itanhaém	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.11	0.11
SE	SP	Peruíbe	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.20	2.00

NR: not realised; Brazilian Regions: North (N), Northwest (NE), South (S), Southeast (SE); states: Amazonas (AM), Espírito Santo (ES), Minas Gerais (MG), Paraná (PR), Pernambuco (PE), Rio de Janeiro (RJ), Rio Grande do Norte (RN), Rio Grande do Sul (RS), Santa Catarina (SC), São Paulo (SP).



Fig. 3: American countries infested with *Aedes albopictus*.

dad and northeastern Argentina, in South America, and in all mainland countries in Central America, i.e., Panama, Costa Rica, Honduras, Nicaragua, Guatemala, El Salvador and Belize. In addition, it has also been confirmed in the Dominican Republic, Cuba, Haiti, Barbados, Cayman Islands, and in the USA and Mexico, in North America (Benedict et al. 2007, Navarro et al. 2009, Calderón-Arquedas et al. 2010, Fernández et al. 2012, Wagman et al. 2013, MSES 2014). In Uruguay, a few *Ae. albopictus* were once detected near the Brazilian border, however subse-

quent efforts have failed to confirm the colonisation of the country by this species (*apud* Lourenço-de-Oliveira et al. 2013). Similarly, the occurrence of this mosquito in Bolivia, in South America, as previously suggested as infested by Benedict et al. (2007), has never been confirmed. The occurrence of *Ae. albopictus* in Puerto Rico has also been suggested (Cook et al. 2006).

To date, *Ae. aegypti* mosquitoes are the only confirmed natural vectors of DENV and CHIKV in the Americas (Consoli & Lourenço-de-Oliveira 1994, de

Castro et al 2012, Nasci 2014). However, regional dynamics as well as special climate and environmental conditions might favour the proliferation and spread of *Ae. albopictus*, even leading to the displacement of *Ae. aegypti* in certain places (Gilotra et al. 1967, Lounibos et al. 2002). Under such conditions, *Ae. albopictus* may assume an important epidemiological role (Powell & Tabachnick 2013). Incidentally, in Gabon (Pagès et al. 2009) and Cameroon (Simard et al. 2005), *Ae. albopictus* has become the most frequent mosquito species, overcoming *Ae. aegypti* in density and assuming the role of the primary vector of CHIKV. Moreover, *Ae. albopictus* became the primary (or only) natural vector in locations where *Ae. aegypti* is scarce or absent, which occurred during the epidemics of CHIKV in European countries such as Italy in 2007 (Carrieri et al. 2011) and France in 2010 (Gould et al. 2010), Indian Ocean islands such as Mauritius in 2006 (CDC 2008), Mayotte in 2005 and 2006 (Sissoko et al. 2008) and La Reunion in 2005 and 2006 (Renault et al. 2007, Thiboutot et al. 2010).

Because of the ability of *Ae. albopictus* females to move between wild and human-made environments while searching for oviposition sites and blood sources, this mosquito has been considered a potential vector of arboviruses for humans still restricted to the sylvan environment (Moore & Mitchell 1997, Lourenço-de-Oliveira et al. 2003, Maciel-de-Freitas et al. 2006). In fact, experiments have revealed that *Ae. albopictus* competently transmits several arboviruses such as Eastern equine encephalitis, Mayaro, Western equine encephalitis, Venezuelan equine encephalitis, CHIKV, Ross River and Sindbis, DENV, Japanese encephalitis, YFV and West Nile fever (Mitchell & Miller 1990, Smith & Franci 1991, Mitchell et al. 1992, Forattini 2002, Holick et al. 2002, Lourenço-de-Oliveira et al. 2003, Fernández et al. 2003, Gratz 2004, Vazeille et al. 2007, Pessoa et al. 2013). *Ae. albopictus* is a natural vector of DENV in certain areas of Asia and has caused small epidemics in Europe. Furthermore, it is natural vector of CHIKV in Central Africa and Mediterranean Europe (Hawley 1988, WHO 2006, Delatte et al. 2008, Paupy et al. 2009, Tomasello & Schlagenhauf 2013).

Therefore, the wide geographic distribution of *Ae. albopictus* in the urban and suburban areas of Brazil and other American countries is a potential threat for arbovirus control in the new world. In Brazil, the range of *Ae. albopictus* includes mostly the busiest international ports and airports as well as the largest road and railway networks located in the Southeast. Furthermore, the highest HI values for this mosquito was recorded in the Southeast. Therefore, the large distribution and high frequency of *Ae. albopictus* might become a critical factor in the spread of arboviruses in Brazil. The current epidemics of CHIKV in some Caribbean islands that began in October 2013, as well as the growing number of imported CHIKV cases to mainland American countries like Brazil already infested with *Ae. albopictus* mosquitoes competent to transmit two CHIKV genotypes (Vega-Rua et al. 2014) are real threats to the spread of this arbovirus in the Americas. This situation illustrates the imperative need to strengthen research concerning the vectorial capacity of local *Ae. albopictus* populations to transmit CHIKV (Lambrechts & Failloux

2012), in addition to designing entomological surveillance and control measures focusing on *Ae. albopictus* in Brazil and other infested American countries.

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