Esther Anderson

Dengue fever is endemic in Timor-Leste, and chikungunya has been sporadically reported. Both diseases are transmitted by *Aedes* mosquitoes, and *Aedes aegypti* and *Aedes albopictus*, the major vectors of both diseases are present in Timor-Leste. *Aedes albopictus* is widespread and highly invasive (Benedict et al 2007; Bonizzoni et al 2013; Miller and Loaiza 2015). Contributing to its success as an invasive species is its ability to utilize a variety of container habitats, both natural and artificial, for oviposition. Coconut (*Cocos nucifera*) Arecaceae shells (endocarp, with or without husks (mesocarp plus exocarp)) that have been gnawed by rodents or broken for domestic use, discarded and subsequently filled with rainwater are common habitats for larval *Ae albopictus* in various countries where coconut trees are abundant (Thavara et al 2004; Eapen et al 2010; Guillaumot et al 2012; Gopalakrishnan et al 2013; Noda et al 2013; Vijayakumar et al 2014) either as the sole Culicidae species or coexisting with two or more different Culicidae species (Lounibos et al 1983; Mercer et al 2005; Banerjee et al 2013). *Ae aegypti* larvae are less frequently found in coconut shells (Edillo et al 2012).

Coconut trees are abundant in the sub-District of Same, District of Manufahi, where this study was conducted. Broken or cut shells/husks are spread throughout the study area, usually close to houses or to groves of coconut trees, mainly as a result of harvesting for domestic use, although fallen shells that appear to have been gnawed by animals are also present. Coconuts are generally harvested either as green coconuts at approximately 9 months old, at the stage where the solidifying endosperm is still soft and translucent (Jackson et al 2004), for coconut 'water' and/or white coir (mesocarp) or as mature (brown) coconuts, to harvest solid endosperm and/or brown coir. Under normal circumstances (i.e. in the absence of strong winds or disease) green coconuts do not fall from the tree, but it is desirable to harvest them at this stage, in areas where they are randomly planted or self-sown because after the exocarp has turned brown, coconuts will fall spontaneously, endangering people and livestock. Coconuts at different stages of ripeness are present on the one tree, and coconuts are harvested or fall all year, so there is a continuous supply of new coconut shells that potentially could become larval habitats.

Gravid female Aedes rely on a range of sensory cues when locating and assessing suitable oviposition sites and subsequently being stimulated to oviposit. These cues relate to physical properties of the habitat, such as reflectance, colour, depth of water, surface area of the container and proportion of oviposition site above the water-line (e.g. Clements 2006; Wong et al 2011; Dieng et al 2011) and also to other factors, which the female mosquito may detect by visual or chemical cues that indicate the presence of conspecific or heterospecific eggs, larvae (Allan and Kline 1998; Zahiri and Rau 1998; Ong and Jaal 2015), predators (Torres-Estrada et al 2001; Albeny-Simões et al 2014) or potential larval food (Reiter et al 1991; Arbaoul and Chua 2015). For coconut shell habitats, sensory cues are likely to depend partly on the stage of maturity at harvest and the progress of the decomposition process. Decomposition affects visual, olfactory and tactile properties, and also waterholding capacity. Liquid in rainwater-filled coconut shells varies in colour from very dark brown to clear, odours vary from extremely pungent to slight, and texture from viscous to non-viscous. The inside of the shell changes from very pale brown to dark brown, and the exocarp may darken to almost black as decomposition progresses. Mattingly (1969) observed a succession of Culicidae species over time, relating this to the decomposition of endosperm, so when investigating coconut shells as larval habitats for Ae albopictus, the effect of the decomposition process on oviposition choices of potential competitors or predators was also considered.

Method

Larval surveys

Larval surveys for container-breeding mosquitoes were conducted in wet and dry seasons (September 2010, January, July and November 2011, January and July 2012, January 2013 and November 2014)

sampling all available container habitats, over an area of approximately 1 km² bordering the Welala River in Same sub-district, Manufahi District. The area included forest, land cleared for grazing and agriculture and houses.

Effect of larval Armigeres spp on oviposition

Three trials were conducted using placed pairs of spring-water filled coconut shells to determine if the presence of larval *Armigeres* in coconut shells deterred oviposition by *Ae albopictus*.

Trial 1 (late wet season): Coconuts (72) were split in half along the long axis with a machete, resulting in 144 half shells (72 pairs). The layer of endosperm remaining in the shell was scraped out with a knife. Halved coconut shells (consisting of exocarp, mesocarp (husk) and endocarp) were placed in pairs, over three land use types (domestic, i.e. close to houses, in cleared areas and in forest) throughout the study area. The shells in each pair were placed approximately 10 -20 cm apart (at least 100 metres from another pair) and filled with spring water. A strip of red velour paper was placed in one shell of each pair (Shell A) as an oviposition site and the other shell (Shell B) was covered with wire mesh to prevent oviposition, Shell A was monitored until stage 3 or 4 larvae were detected, and if the larvae were identified as *Armigeres (Ar malayi* or *Ar milnensis)* then the wire mesh was removed from the covered shell, the old red velour strip was removed from Shell A and new strips placed in both shells. Mosquito eggs subsequently deposited on oviposition strips in each shell were counted, and eggs hatched and stage 4 larvae identified.

If shells initially were overturned or chewed by pigs, goats or cattle, they were replaced where possible, in a more secure or hidden setting. The contents of shells placed at the base of trees tended to be washed out by heavy rain; if this occurred the shells were placed in a more protected site.

Trial 2 (mid dry season). Method as in Trial 1, but only 35 coconuts were used (70 half shells) and the entire internal surface of the half shells above the waterline was covered with red velour paper.

Trial 3 (end of extended dry season). Method as in Trial 2.

Identification of mosquito eggs

Aedes sp. oviposit primarily on the sides of containers, with a varying proportion of eggs laid directly on the water surface. Armigeres sp. in the subgenus Armigeres also oviposits on the sides of containers (Amerasinghe and Alagoda 1984; Mattingly 1971b). Ar milnensis and Ar malayi are classified as subgenus Armigeres. Although Aedes eggs can be distinguished visually, with a hand lens, from, for example, Culex and Anopheles eggs, which are laid on the water surface, Aedes eggs cannot easily be distinguished from Armigeres eggs (Mattingly 1971a) and it was not possible to determine visually with a hand lens or digital microscope whether eggs on the strips were Aedes eggs or Armigeres eggs, therefore the eggs on the strips were hatched in vials of avocado (Persea americana (Mill) leaf infusion or grass infusion (species unknown). Some were identified when larvae had grown to Stage 4, and others were allowed to pupate and eclose, and identified as adults.

Statistical analysis

Statistical analysis for Trials 1 and 2 was performed using SPSS statistical software. Pairwise comparison was performed by the Wilcoxon Signed Ranks test.

Results

Larval surveys

Ae albopictus larvae were found frequently in rainwater filled broken coconut shells in the wet season, less frequently in the dry season. *Ae albopictus* larvae were found in shells at different stages of decomposition, often as the sole or predominant Culicidae species (Table 1). Armigeres spp larvae were also common in water-filled broken coconut shells, with *Culex* and *Tripteroides* species being observed less frequently.

Species	Late	Mid dry	Early wet	End of extended dry
	wet season	season	season	season
Ae albopictus only	4*	2	3*	0
Ae albopictus + Culex sp.	3	0	4*	0
Ae albopictus + Tripteroides	1	0	1	0
sp.				
Ae albopictus + Uranotaenia	1	0	0	0
sp.				
Ar. malayi only	8発	3	7光	0
Ar. milnensis only	3	1₩	3	0
Ar. malayi + Ar milnensis	6	0	3光	0
Ar. malayi + Ae albopictus	7	1	4	0
Ar. milnensis + Ae	3	0	1	0
albopictus				
Ar. malayi + Culex sp	2	0	0	0
Ar. milnensis $+$ Culex sp	1	0	0	0
Ar. malayi + Ae albopictus +	1	0	0	0
Culex sp.				
Ar. milnensis + Ae	0	0	0	0
albopictus + Culex sp.				
Ar. malayi + unidentified	3	1	2	0
larval Culicidae				

 Table 1- Number of coconut shells containing Ae albopictus or Armigeres spp. alone or cohabiting with other larval Culicidae

*Includes shells in which the exocarp and endocarp had earlier rotted away, leaving only the mesocarp, and the water in the shell was clear.

 \mathfrak{H} Includes whole shells with a small aperture, as well as half shells.

Effect of Armigeres larvae on oviposition

Significantly more eggs were laid in Shell Bs (with no larvae) than in Shell As (with larvae) ($p \le 0.05$) in Trial 1 and Trial 2 over all land use types (domestic, agricultural and cleared), whether an oviposition strip was used that left areas of the shell exposed (Trial 1) or whether the surface of the shell above the water line was covered (Trial 2). No eggs were laid in any of the shells in Trial 3.

Discussion

Larval surveys have shown that rainwater-filled discarded coconut shells are common oviposition sites for *Ae albopictus* in this area of Timor-Leste in the wet season, less so in the dry season, and in an extended dry season they cease to function as larval habitats. Egg dormancy induced by drying occurs in both *Aedes* and *Armigeres* and it is likely that coconut shells will harbour dormant eggs over the dry season.

Effect of larval Armigeres on Ae albopictus

These field trial results suggest that the presence of larval *Armigeres* in coconut shells deters oviposition by container-breeding mosquitoes (*Armigeres* and *Aedes* sp) in that significantly fewer eggs were laid in shells without larval *Armigeres* than in shells with larval *Armigeres*.

Larval *Armigeres* may be not only competitors for resources but also predators on early stage culicid larvae (Tanaka 1979), which may be a factor in the deterrent effect.

Ar milnensis and *Ar malayi* had not previously been recorded in Timor-Leste (Anderson and Davis 2014) and it is possible that they are recently arrived species. Features of larval *Armigeres* that may give them a competitive advantage in coconut shells rich in decomposing organic matter include

a short hatching period, large, fast-growing larvae that survive crowding, an ability to thrive in a semiliquid, viscous medium (Lounibos 1983) and large mandibular teeth that both increase efficiency in grazing and also in predation on early stage larval Culicidae (Tanaka 1979; Lounibos 1983;). In general, container-dwelling larvae may suffer from desiccation of their habitats in the dry season, and being flushed out of their habitats in the wet season (Koenraadt and Harrington 2008). Culicid larvae and pupae differ in their ability to resist the flushing effects of rain (Koenraadt and Harrington 2008; Dieng et al 2011). Larval *Ar malayi* and *Ar milnensis* attach themselves tenaciously to the insides of coconut shells, to the extent that when the shells are overturned, many larvae remain inside. Similarly, when water is splashed out of a coconut shell, as may happen in heavy rain, larval *Armigeres* tend to remain attached to the shell. This may give them a competitive advantage over larval *Ae albopictus*.

It was observed in larval surveys in wet and dry seasons that while larval *Ae albopictus* was sometimes present in shells high in organic matter that were quite turbid and also in shells in clear water with little organic matter, larval *Armigeres* predominated in shells high in decomposing endosperm. Further experiments would be necessary to ascertain whether it is the presence of *Armigeres* spp. or some feature of the habitat itself that is responsible for the lower incidence of *Ae albopictus* in these shells.

Decreasing vector populations by source reduction

Many of the Culicidae species that oviposit in coconut shells are vectors of disease, including filariasis, malaria and Japanese encephalitis, as well as dengue and chikungunya (Table 2).

Species	Disease	Reference	
Ae aegypti H	Vector of many arboviruses e.g.	Banerjee et al 2013; Khan et al 2014	
	dengue, chikungunya and yellow		
	fever virus		
Ae albopictus	Vector of many arboviruses e.g.	Banerjee et al 2013, Grard et al 2014	
	dengue, chikungunya and zika		
	virus		
Ae oceanicus	Wuchereria bancrofti filariasis	Lambdin et al 2008	
Ae polynesiensis	Wuchereria bancrofti filariasis	Mercer et al 2005; Burkot et al	
		2007; Lambdin et al 2008	
Ae quasiscutellaris	Wuchereria bancrofti filariasis	Lee et al 1987	
Ae scutellaris	Potential vector of dengue virus,	Trpis 1981	
	Brugia malayi and Brugia pahangi		
	filariasis		
Anopheles balabacensis	Malaria	Taylor and Maffi 1978; Sinka et al	
		2011	
An farauti	Malaria and filariasis	Taylor and Maffi 1978	
Ar subalbatus	Brugia pahangi filariasis, also	Khan et al 2014, Muslim et al 2013,	
	Dirofilaria immitis	Lee et al 2007	
Culex Fuscocephala	Japanese encephalitis	Van den Hurk et al 2009; Khan et al	
^		2014	
C gelidus	Japanese encephalitis	Taylor and Maffi 1978	
C quinquefasciatus	Wuchereria bancrofti filariasis	Khan et al 2014	

Table 2 - Disease vectors that oviposit in coconut shells

Filariasis (caused by both *Brugia timori* and *Wuchereria bancrofti*), Japanese encephalitis and malaria are present in Timor-Leste as well as dengue and chikungunya (David and Edeson 1965; Melrose and Rahmah 2006; Berger et al 2014; Cooper et al 2010). In addition to being breeding sites for nuisance biters, the fact that coconut shells are larval habitats for potential disease vectors is an added incentive to take steps to remove or destroy them.

Eliminating larval habitats is a widely used strategy for reducing mosquito vector populations (Kittayapong 2006; Fonseca et al 2013; Unlu et al 2013; Healy et al 2014). At present there is little or

no attempt to prevent cut, broken or gnawed coconut shells from becoming larval habitats in the study area in Same sub-district. Husks and shells will eventually decompose to the point where they will no longer hold water, but in the interim they may well have been larval habitats for many generations of disease vectors. Coconut shells/ husks can be burnt or buried to prevent them becoming larval habitats, or used for coir fibre or handcrafts. At present, cooking over a wood fire is common rural Same, but shells appear to be underused as fuel. Although the coir industry is economically important in for example Indonesia, India and the Philippines (producing rope, fishing nets, sacks, brushes, mats, geotextiles for erosion control etc.) there is to date no coir industry in Same. Coconut husks, when buried, reportedly improve soil structure (Coconut Research Institute, 1989) so this is an option to consider.

Destroying coconut shells is preferable to empting and overturning, because of the possibility they will be turned again, and again fill with rainwater, allowing not only the oviposition of fresh eggs, but the hatching of pre-existing dormant eggs.

Raising awareness of the need to break, burn or bury or otherwise dispose of coconut shells as part of a concerted source reduction program may assist in reducing not only the prevalence of known disease vectors in the community, but also the prevalence of nuisance biters, such as *Ar malayi* and *Ar milnensis* whose vector status is at present largely unknown.

Bibliography

- Allan, Sandra and Daniel Kline 1998, 'Larval rearing water and pre-existing eggs influence oviposition by *Aedes aegypti* and *Aedes albopictus* (Diptera: Culicidae)', *Journal of Medical Entomology* 35: 943-947.
- Amerasinghe, Felix and TSB Alagoda 1984, 'Mosquito oviposition in bamboo traps, with special reference to Aedes albopictus, Aedes novalbopictus and Armigeres subalbatus,' International Journal of Tropical Insect Science 5: 493-500.
- Anderson, Esther and Jennifer Davis 2014, 'First records of Armigeres malayi and Armigeres milnensis in Timor-Leste,' Journal of the American Mosquito Control Association 30(1): 51-53.
- Banerjee, Soumajit, Aditya Gautam and Goutam Saha 2013, 'Household disposables as breeding habitats of dengue vectors: linking wastes and public health,' *Waste Management*, 33(1): 233–9.
- Benedict, Mark, Rebecca Levine, William Hawley and Philip Lounibos 2007, 'Spread of the tiger: global risk of invasion by the mosquito *Aedes albopictus', Vector Borne Zoonotic Disease* 7: 76–85.
- Berger, Stephen 2014, 'Infectious Diseases of East Timor' Gideon Informatics <u>http://www.gideononline.com/ebooks/country/infectious-diseases-of-east-timor/</u> Viewed 21 Jan 2014.
- Bonizzoni, Mariangela, Giuliano Gasperi, Xioaguang Chen and Anthony James 2013, 'The invasive mosquito species *Aedes albopictus*: current knowledge and future perspectives', *Trends in Parasitology* 29(9):460-468.
- Burkot, Thomas, Thomas Handzel, Mark Schmaedick, Joseph Tufa, Jacqueline Roberts and Patricia Graves 2007, 'Productivity of natural and artificial containers for *Aedes polynesiensis* and *Aedes aegypti* in four American Samoan villages', *Medical and Veterinary Entomology*, 21(1):22 9.
- Clements, Alan 2006, *The biology of mosquitoes*, Vol. 2. Sensory reception and behaviour. Cabi Publishing; 2006, Oxon, UK.
- Coconut Research Institute. Lunuwila, 1989, 'Use of husks and coir dust in coconut lands', http://cri.nsf.ac.lk/handle/1/908 Accessed 6 Sept 2014.
- Cooper, Robert, Michael D Edstein, Stephen P Frances and Nigel W Beebe 2010, 'Malaria vectors of Timor-Leste', *Malaria Journal* 9: 40.
- David, Hugo and JFB Edeson 1965, 'Filariasis in Portuguese Timor, with observations on a new microfilaria found in man', *Annals of Tropical Medicine and Parasitology* 59: 193-204.
- Dieng, Hamady, Saifur Rahman, Ahmad Abu Hassan, Che Salmah Rawi, Tomomitsu Satho, Fumio Miake F, Michael Boots and Sazaly Abu Bakr 2011, 'The effects of simulated rainfall on immature population dynamics of *Aedes albopictus* and female oviposition', *International Journal of Biometeorology* 56(1): 113-120.
- Eapen, Alex, K. John Ravindran, and Aditya Dash 2010, 'Breeding potential of *Aedes albopictus* (Skuse, 1895) in chikungunya affected areas of Kerala, India 2009,' *Indian Journal of Medical Research*, 129: 442 445.
- Edillo, Frances, Noel Roble and Nenito Otero 2012, 'The key breeding sites by pupal survey for dengue mosquito vectors, *Aedes aegypti* (Linnaeus) and *Aedes albopictus* (Skuse), in Guba, Cebu City, Philippines', *Southeast Asian Journal of Tropical Medicine and Public Health* 43(6): 1365-1374.

- Fonseca, Dina, Isik Unlu, Taryn Crepeau, Ary Farajollahi, Sean Healy, Kristen Bartlett-Healy, Daniel Strickman, Randy Gaugler, George Hamilton, Daniel Kline, and Gary Clark 2013, 'Area-wide management of *Aedes albopictus*. Part 2: gauging the efficacy of traditional integrated pest control measures against urban container mosquitoes', *Pest Management Science* 69(12): 1351-1361.
- Gopalakrishnan, Reji, Momi Das, Indra Baruah, Vijay Veer and Prafulla Dutta 2013, 'Physicochemical characteristics of habitats in relation to the density of container-breeding mosquitoes in Asom, India,' *Journal of Vector Borne Disease* 50: 215-219.
- Grard, Gilda et al. 2014, 'Zika virus in Gabon (Central Africa) 2007: a new threat from *Aedes albopictus?*' *Public Library of Science Neglected Tropical Diseases* 8(2): e2681.
- Guillaumot, Laurent, Reynold Ofanoa, Lucien Swillen, Narendra Singh, Hervé C Bossin and Francis Schaffner 2012, 'Distribution of *Aedes albopictus* (Diptera, Culicidae) in southwestern Pacific countries, with a first report from the Kingdom of Tonga,' *Parasites and Vectors* 5: 247.
- Healy, Kristen, George Hamilton, Taryn Crepeau, Sean Healy, Isik Unlu, Ary Farajollahi, and Dina Fonseca 2014; Integrating the public in mosquito management: active education by community peers can lead to significant reduction in peridomestic container mosquito habitats', *Public Library of Science One* 9(9): e108504.
- Jackson, Jose, Andre Gordon, Gavin Wizzard, Kayanne McCook, Rosa Rolle 2004, 'Changes in chemical composition of coconut (*Cocos nucifera* L.) water during maturation of the fruit', *Journal of the Science of Food and Agriculture* 84: 1049–1052.
- Khan, Humayun Reza, Muzahidul Islam, Tangin Akter, Rezaul Karim, Sheik Farid 2014, 'Diversity of mosquitoes and their seasonal fluctuation in two wards in Dhaka City', *Dhaka University Journal of Biological Science* 23(1): 17-≈6.
- Kittayapong, Pattamaporn, Uruyakorn Chansang, Chitti Chansang and Amaret Bhumiratana 2006, 'Community participation and appropriate technologies for dengue vector control at transmission foci in Thailand', *Journal of the American Mosquito Control Association* 22(3): 538-546.
- Koenraadt, Constantianus and Laura Harrington 2008, 'Flushing effect of rain on container inhabiting mosquitoes Aedes aegypti and Culex pipiens', Journal of Medical Entomology 45(1): 28-30.
- Lambdin Barrot, Mark Schmaedick and Thomas Burkot 2008, 'Utilization of domestic and natural containers by *Aedes oceanicus* in American Samoa', *Journal of Medical Entomology* 45(4): 758-762.
- Lee, David, Megan Hicks, Mabel Griffiths, Margaret Debenham, Joan Bryan Richard Russell, Merilyn Geary and Elizabeth Marks 1987, *Culicidae of the Australasian Region*, Volume 4. Australian Government Publishing, Canberra.
- Lee, Sang-Eun, Heung-Chul Kim, Sung-Tae Chong, Terry Klein and Won-Ja Lee 2007, 'Molecular survey of *Dirofilaria immitis* and *Dirofilaria repens* by direct PCR for wild caught mosquitoes in the Republic of Korea', *Veterinary Parasitology* 148(2): 149-155.
- Lounibos, Leon Philip 1983, Behavioral convergences among fruit-husk mosquitoes. *The Florida Entomologist* 66: 32-41.
- Lounibos, Leon Philip, George O'Meara, Naoya Nishimura and Richard Escher 2003 'Interactions with native mosquito larvae regulate the production of *Aedes albopictus* from bromeliads in Florida' *Ecological Entomology* 28: 551–558.
- Mattingly, Peter 1969, The Biology of Mosquito-Borne Disease, Allen and Unwin. London.
- --- 1971a, 'Contributions to the mosquito fauna of Southeast Asia. XII. Illustrated keys to the genera of mosquitoes (Diptera, Culicidae)', *Contributions of the American Entomological Institute* 7: 1-84.
- --- 1971b, 'Mosquito eggs XVIII,' Mosquito Systematics News 3:122-126.
- Melrose, Wayne and Noordin Rahmah 2006, 'Use of Brugia Rapid dipstick and ICT test to map distribution of lymphatic filariasis in the Democratic Republic of Timor-Leste', *Southeast Asian Journal of Tropical Medicine and Public Health* 37(1): 22-5.
- Mercer, David, George Wettach and Julie Smith 2005 'Effects of larval density and predation by *Toxorhynchites amboinensis* on *Aedes polynesiensis* (Diptera: Culicidae) developing in coconuts', *Journal of the American Mosquito Control Association* 21(4): 425-431.
- Miller. Matthew and Jose Loaiza 2015, 'Geographic expansion of the invasive mosquito Aedes albopictus across Panama implications for control of dengue and Chikungunya viruses', Public Library of Science. Neglected Tropical Diseases 9(1): e0003383.
- Muslim, Azdayanti, Mun-Yik Fong, Rohela Mahmud, Yee-Ling Lau and Sinnadurai Sivanandam 2013, *Armigeres subalbatus* incriminated as a vector of zoonotic *Brugia pahangi* filariasis in suburban Kuala Lumpur, Peninsular Malaysia', *Parasites and Vectors* 6: 219.
- Noda, Shinichi, Sota Yamamoto, Takako Toma and Livinson Taulung 2013, 'Distribution of mosquito larvae on Kosrae Island, Kosrae State, the Federated States of Micronesia', *Tropical Medicine and Health* 41(4): 157-61.

- Ong, Song-Quan and Zairi Jaal 2015, 'Investigation of mosquito oviposition pheromone as lethal lure for the control of *Aedes aegypti* (L.) (Diptera: Culicidae),' *Parasites and Vectors*, 8(1): 28.
- Reiter, Paul, Manuel Amador and Nelson Colon 1991, 'Enhancement of the CDC ovitrap with hay infusions for daily monitoring of *Aedes aegypti* populations', *Journal of the American Mosquito Control Association*, 7, 52–55.
- Sinka, Marianne et al. 2011, 'The dominant *Anopheles* vectors of human malaria in the Asia-Pacific region: occurrence data, distribution maps and bionomic précis', *Parasites and Vectors* 25: 4:89.
- Tanaka, Kazuo, Kiyoyuki Mizusawa and Edward Saugstad 1979, 'A revision of the adult and larval mosquitoes of Japan (including the Ryukyu Archipelago and the Ogasawara Islands) and Korea (Diptera: Culicidae)', *Contributions of the American Entomological Institute* 16: 1-987.
- Taylor, Brian and Mario Maffi 1978, 'A review of the mosquito fauna of the Solomon Islands (Diptera: Culicidae)', *Pacific Insects* 19: 165-248.
- Thavara, Usavadee, Apiwat Tawatsin and Jakkrawarn Chompoosri 2004, 'Evaluation of attractants and egglaying substrate preference for oviposition by *Aedes albopictus* (Diptera: Culicidae)', *Journal of Vector Ecology* 29(1): 66-72.
- Torres-Estrada, José, Mario Rodríguez, Leopoldo Cruz-López and Juan Arredondo-Jimenez 2001, 'Selective oviposition by *Aedes aegypti* (Diptera: Culicidae) in response to *Mesocyclops longisetus* (Copepoda: Cyclopoidea) under laboratory and field conditions' *Journal of Medical Entomology* 38(2): 188-192.
- Trpis, Milan 1981, 'Susceptibility of the autogenous group of the *Aedes scutellaris* complex of mosquitoes to infection with *Brugia malayi* and *Brugia pahangi*', *Tropenmedizin Und Parasitologie* 32(3): 184-188.
- Unlu, Isik, Art Farajollahi, Daniel Strickman and Dina Fonseca 2013, 'Crouching tiger, hidden trouble: urban sources of *Aedes albopictus* (Diptera: Culicidae) refractory to source-reduction', *Public Library of Science One* 8(10): e77999.
- van den Hurk, Andrew, Scott Ritchie and John Mackenzie 2009, 'Ecology and geographical expansion of Japanese encephalitis virus', *Annual Review of Entomology* 54: 17-35.
- Vijayakumar, Krishna, Sudheesh Kumar, Zinia Nujum, Farook Umarul and Anu Kuriakose 2014, 'A study on container breeding mosquitoes with special reference to *Aedes (Stegomyia) aegypti* and *Aedes albopictus* in Thiruvananthapuram district, India', *Journal of Vector Borne Disease* 51(1): 27-32.
- Wasserberg, Gideon, Nicholas Bailes, Christopher Davis and Kim Yeoman 2014, 'Hump-shaped densitydependent regulation of mosquito oviposition site-selection by conspecific immature stages: theory, field test with *Aedes albopictus*, and a meta-analysis', *Public Library of Science One* 28; 9(3): e92658.
- Williams, Craig, Katherine Leach, Natasha Wilson and Veronica Swart 2008, 'The Allee effect in site choice behaviour of egg-laying dengue vector mosquitoes', *Tropical Biomedicine* 25(2): 140 4.
- Wong, Jacklyn, Steven T. Stoddard, Helvio Astete, Amy C. Morrison and Thomas W. Scott 2011, 'Oviposition site selection by the dengue vector *Aedes aegypti* and its implications for dengue control', *Public Library of Science Neglected Tropical Diseases* 5, e1015.
- Zahiri, Nayer and Manfred Rau 1998, 'Oviposition attraction and repellency of *Aedes aegypti* (Diptera: Culicidae) to waters from conspecific larvae subjected to crowding, confinement, starvation, or infection', *Journal of Medical Entomology* 35: 782–787.