REVIEW

AEDES DENGUE VECTOR OVITRAP SURVEILLANCE SYSTEM: A FRAMEWORK FOR MOSQUITO DENSITY PREDICTION

Lilian A De Las Llagas[1], Brij Kishore Tyagi[2] and Lisa Grace S Bersales[3]

[1]Department of Parasitology, College of Public Health, University of the Philippines Manila; [2]Centre for Research in Medical Entomology (ICMR), Tamil Nadu, India; [3]School of Statistics, University of the Philippines Diliman, Quezon City, Philippines

Abstract. Dengue is a major global public health problem then and now. Vector surveillance is a key component of any vector-borne disease (VBD) prevention and control program. There is no single available survey tool to monitor the mosquito population. Different methods answer different aims. Larval survey indices are commonly and widely used in monitoring the mosquito infestation levels. The negative attributes attached to these indices made these indicators unreliable to predict dengue transmission and spread. The proposed framework provides a clearer understanding on the merits of using the ovitrap system and its measurement, the ovitrap index (OI). The empirically derived variables in the framework depict the interrelationships of the mosquito population growth and development which would potentially allow for a prediction of mosquito density.

Keywords: dengue, mosquito, ovitrap, vector surveillance, Philippines

INTRODUCTION

Dengue is endemic in more than 100 countries in the world, with Southeast Asia and the Western Pacific Regions most affected (DOH-NCR, 2013-2014). In the Philippines alone, the National Capital Region (NCR), for the past five years has reported the highest number of cases and deaths. In 2010, the Department of Health (DOH)-NCR Surveillance Unit reported 26,867 cases and 180 deaths, 40% and 46%, respectively belonging to the 5-14 years age group (DOH-NCR, 2013-2014).

Public areas such as elementary and high schools contribute to mosquito vector production. Statistics show that out of the tens of thousands of dengue cases reported per year, 75% of these affected children are less than 15 years of age, while majority of deaths occur in children under 9 years. These are the age groups that are in elementary and high schools for most part of the day which coincides with the biting patterns of the female *Aedes aegypti* which transmits dengue viruses (Ocampo *et al*, unpublished).

Controlling the *Aedes aegypti* mosquito

Correspondence: Prof Lilian A De Las Llagas, Department of Parasitology, College of Public Health, University of the Philippines Manila, 625 Pedro Gil St, Ermita 1000, Manila, Philippines.
E-mail: lilyemerine@yahoo.com

Table 1
Stegomyia indices for low and high risk transmission.

Larval indices	High risk of transmission	Low risk of transmission
BI	>50	<5
HI	>10%	<1%

is of public health importance because at present, it is the only means to stop dengue virus transmission. Implementing successful mosquito control programs requires understanding what factors regulate population abundance, as well as anticipating how mosquitoes respond to control measures. Reducing transmission is reducing dengue related morbidity and mortality.

Dengue is a major public health problem in the Philippines and elsewhere. The disease incidence is affected by an interplay of spatial, ecological and socio-economic and biological factors (Bohra and Andrianasolo, 2001; Lian *et al*, 2006; Su, 2008; Hii *et al*, 2009; Garcia and De Las Llagas, 2011).

The infection is caused by four serotypes of dengue virus (DENV), that is, DENV 1-4. *Aedes aegypti* and *Ae. albopictus* transmit dengue and chikungunya. The mosquitoes are anthropophilic, day biting, and the female lay eggs in containers that are damp or moist in and around human habitation. Transmission of the disease occurs when there is an effective contact between an infected mosquito and unprotected susceptible human vector density estimation, analysis and surveillance are considered indispensable in comprehending virus load in nature as well as prospective disease outbreaks.

There is no single method effective enough in regulating the *Aedes* population below the entomological thresholds for transmission and infestation level. These thresholds can be as low as two (2) adult females emerging daily in a locality of 100 people (Lee *et al*, 2008); 2% House Index (HI) in areas where there is low level of immunity from Singapore data; 5 for Breteau Index (BI) from WHO (2009) technical reports; 10% Ovitrap Index (Lee, 1992) (Table 1). India estimated Stegomyia indices (BI and HI) for both low and high risk transmission of dengue (National Vector Borne Diseases Control Program, 1998), as follows:

In a five-year study in Chennai urban setting (compared to four other Asian countries urban agglomeration; *vide infra* as Table 2), both in private and public spaces, the PHI was significantly higher in clusters with a high population density (74.6; 95% CI: 46.3-102.9) than in those with a low one (11.0; 95% CI: 7.8-14.1); in clusters with schools (42.7; 95% CI: 25.21-60.3) than in those without schools (14.4; 95% CI: 7.7-21.2); in clusters with religious sites (38.4; 95% CI: 23.8-52.9) than in those without them (11.8; 95% CI: 3.2-20.4); in clusters with houses separated from each other by an average distance of >4 m (35.4; 95% CI: 19.7-51.1) than in those separated by ≤4 m (11.6; 95% CI: 5.4-17.8). Across all study sites, people's knowledge about the dengue vectors was negatively correlated with the PHI (overall correlation coefficient: -0.6). Other variables associated with a higher PHI but not significantly were middle or lower socioeconomic

Table 2
Vector breeding places and measures of vector production in buildings[a] in a study of risk factors for dengue vector breeding in six Asian sites, 2006-2009.

Parameter	Site					
	India (n^b = 20)	Indonesia (n = 12)	Myanmar (n = 20)	Philippines (n = 12)	Sri Lanka (n = 20)	Thailand (n = 12)
Container Index[c]	5.4	10.7	7.1	12.9	11.1	7.6
House index[d]	19.4	33.1	36.3	16.6	9.1	30.2
Breteau Index[e]	28.1	55.3	65.9	24.1	11.3	48.8
Total number of water containers	10,511	5,420	18,510	2,319	2,063	7,804
Percent of all containers located indoors	83.4	51.5	37.5	42.8	7.1	62.2
Percent of all containers filled with tap water	95.0	77.6	81.6	86.4	53.6	67.0
Most frequent container types (% of all containers)	Plastic pot (45.4)	Bucket (26)	Flower vase (48.7)	Drum/barrel (38.7)	Tin/bottle (27.1)	Ceramic jar (50)
	Metal container (21.5)	Cement tank (25.7)	Cement tank (14.3)	Ceramic jar (32.5)	Bowl (16.2)	Cement tank (13.7)
	Drum/barrel (10.5)	Tin/bottle (6.4)	Drum (12.4)	Coconut (16.17)	Plant axil (11.7)	Bucket (9.9)
Total no. of pupae in all containers	1,652	2,324	2,155	1,478	543	453
Most productive container types (% of all pupae)	Cement tank (39.9)	Cement tank (42.8)	Spiritual flower bowl (51.7)	Drum/barrel (49.2)	Bowl (41.6)	Bucket/bowl (38.9)
	Drum/barrel (14.0)	Drum/barrel (13.8)	Cement tank (19.5)	Coconut (18.8)	Tin/bottle (38.6)	Tyres (14.6)
	Grinding stone (13.4)	Flower vase (12.5)	Flower vase (7.2)	Ceramic jar (9.8)	Cement tank (5.7)	Tins/bottles (10.8)

[a]Data collected through entomological survey, wet season only. [b]n is the number of clusters studied. [c]Percent of water containers positive for immature forms of *Aedes*. [d]Per cent of inspected houses with at least one container positive for immature forms of *Aedes*. [e]Number of containers positive for immature forms of *Aedes* per 100 inspected houses. Source: Arunachalam *et al* (2010).

stratum; poor housing conditions; house with garden; residential area (as opposed to commercial area); presence of cemetery or garbage dump in the neighborhood; availability of abundant piped water (the only exception being Myanmar); and the absence of vector control interventions (Arunachalam *et al*, 2010).

Higher container-catch value of the vector, *Aedes aegypti*, were also recorded in a number of South American studies (Williams *et al,* 2007; Honório *et al*, 2009).

A locally derived index being proposed by Salazar (1978-1979, unpublished report), of one (1) parous mosquito in adjacent two (2) households, and 2 parous mosquitoes in a cluster of ten (10) households during wet and dry months, respectively, will make the sites (community) at risk of dengue transmission. Currently, there is no threshold index for elementary and high schools.

The mosquito life cycle, as in the other arthropods, is generally sensitive to climatic influences especially relative humidity (% RH), temperature and rainfall (Scanlon, 1966; Tonn *et al*, 1969; Southwood *et al*, 1972; Pant and Yasuno, 1979; De Las Llagas and Bersales, 2014).

De Las Llagas (1995), in her review of dengue vectors in the Philippines, enumerated three factors influencing vector distribution. These are seasonal pattern, geography and living conditions, and habits of people. The three climatological factors according to her review influencing mosquito activities in particular, the reproductive cycle, are relative humidity (RH), temperature and rainfall. In the Salazar *et al* (1978-1979, unpublished report), she found that an increase in serologically dengue confirmed cases coincided with elevated mosquito indices. The findings document that the cool-wet and dry months (August to January) favor mosquito density increase. Homme and Arambulo (1965) empirically supports such seasonal pattern explaining that an epidemic of dengue/DHF takes place during the rainy season and closely parallels the vector density. Hii *et al* (2009) described how weather influenced the increase in magnitude of dengue in Singapore from 2000-2007.

Given the threat of climate change and the major challenges facing the dengue prevention and control program of the Philippines, and the association of climate and mosquito, and dengue incidence, there is sufficient alarm, if the shift in climate escalates dengue vector abundance, transmission, and disease outbreaks.

De Las Llagas and Bersales (2014) pioneered in the Philippines in the development of statistical model to predict mosquito density in communities, and found climate variables and household practices as significant determinants of mosquito density.

The framework (Fig 1) depicts the relationship of variables involved in the mosquito population growth and its population measure the ovitrap index.

THE OVITRAP

The Ovitrap (Fig 2) is the kit used to survey container-inhabiting *Aedes* mosquitoes and it is measured as the Ovitrap Index (OI).

Fay and Perry (1965) were first to use ovitraps for *Aedes aegypti* surveillance and Fay and Eliason (1966) demonstrated the ovitrap was in some aspects superior to larval surveys. Ovitraps were also shown to be useful sampling devices in determining *Ae. aegypti* distribution (Hoffman and Killingworth, 1967), seasonal population

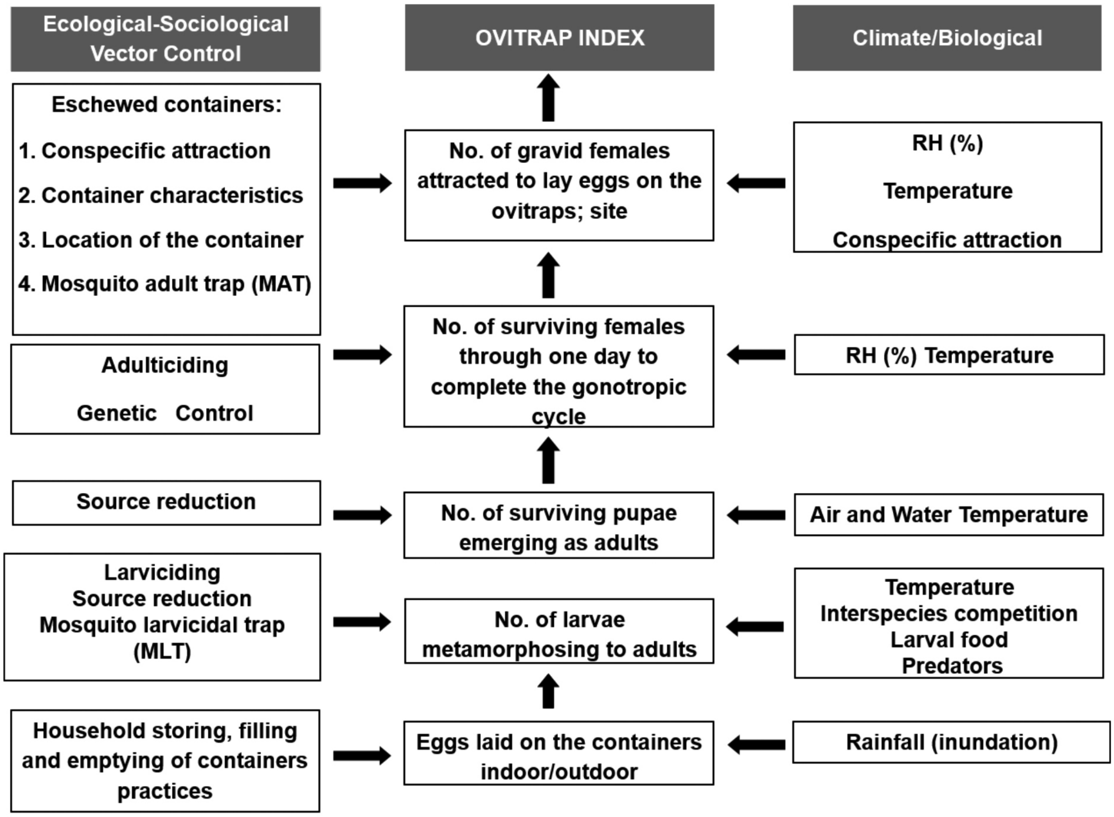

Fig 1–The Ovitrap Surveillance System Framework (De Las Llagas, 2002, 2007, 2009, 2013; De Las Llagas and Bersales, 2014).

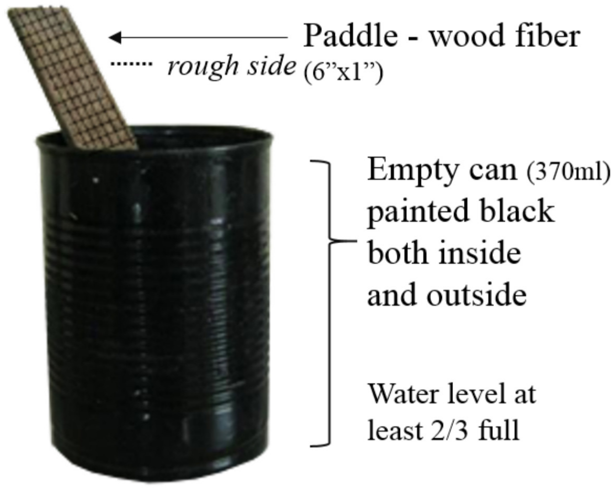

Fig 2–The Philippine Ovitrap Kit (De Las Llagas).

and fluctuation (Jacob and Bevier, 1969), and evaluating the efficacy of aerial ULV malathion application (Kilpatrick *et al*, 1970).

Yap (1975), affirmed that ovitrap used in his studies has been found to be an effective sampling device for *Aedes* vectors on Penang Island, Malaysia. He described the system as quick and accurate and is not dependent on the diligence of workers, not intrusive and laborious.

De Las Llagas (2009) obtained higher OI compared to larval indices in all her vector surveillance studies. The DOH-

NCR espousing an evidence-based vector control program is using ovitrap as its surveillance tool.

The scientific interpretation behind higher mosquito density values obtained by the system compared to the conventional larval surveys, is couched on the behavior of a gravid female mosquito searching for its preferential oviposition site. Egg distribution among containers is highly influenced by the ability of the mosquito to respond to stimulating factors from the containers (Wong *et al*, 2011). Specifically: Conspecific attraction; Container characteristics; Location of container; Key containers as preferred for breeding.

Ovitrap kit best fits the requirements of an attractive container for the mosquito to strongly respond to. The system, interplayed with eco-bio-socioeconomic factors, will be able to offer 'alert signals' to comprehend impending disease outbreaks, thus also in preparation to encounter or thwart that.

REFERENCES

Arunachalam N, Susilowati T, Espino F, *et al*. Eco-bio-social determinants of dengue vector breeding: a multicountry study in urban and periurban Asia. *Bull World Health Organ* 2010; 88: 173-84.

Bohra A, Andrianasolo H. Application of GIS in modeling of dengue risk based on sociocultural data: case of Jalore Rajasthan Inia. *Dengue Bull* 2001; 25: 92-102.

De Las Llagas LA. Biology and control of *Aedes* mosquito vector of dengue/dengue haemorrhagic fever in the Philippines. *UP Manila J* 1995; 1: 11-8.

De Las Llagas LA, Medina AC. Establishment of sensitive vector indicator for dengue surveillance. DOH-Research Compendium 1993-2001. Manila: HRD-HPDPB; 2002. 106-8.

De Las Llagas LA, Mistica MS, Bertuso AG. Dengue mosquito ovitrapping and preventive fogging trials in the Philippines. Philipp Entomol 2007; 21: 136-45.

De Las Llagas LA. DOH-NCR dengue prevention and control program: manual of procedures. Manila: Center for Health Development–Metro Manila; 2009: 137 pp.

De Las Llagas LA. Philippine handbook on integrated vector control concepts and (DOH) practices. Manila: Department of Health; 2013. 143 pp.

De Las Llagas LA, Bersales LGS. Application of modeling in forecasting dengue mosquito density in Los Baños, Laguna, Philippines [poster]. Cebu City: The 45th Anniversary and Annual Scientific Conference of the Pest Management Council of the Philippines, 2014.

Department of Health-Regional Office of the National Capital Region (DOH-NCR). Fever as an early warning tool for dengue: DOH-NCR report 2013-2014. Manila: DOH-NCR, 2013-2014.

Fay RW, Eliason DA. A preferred oviposition site as a surveillance method for *Aedes aegypti*. *Mosq News* 1966; 26: 531-5.

Fay RW, Perry AS. Laboratory studies of ovipositional preferences of *Aedes aegypti*. *Mosq News* 1965; 25: 276-81.

Garcia FB, De Las Llagas LA. An examination of the spatial factors of dengue cases in Quezon City, Philippines: a Geographical Information System (GIS)-based approach, 2005-2008. *Acta Med Philipp* 2011; 43: 53-62.

Hii YL, Rocklov J, Ng N, Tang CS, Pang FY, Sauerborn R. Climate variability and increase in intensity and magnitude of dengue incidence in Singapore. *Global Health Action* 2009 Nov 11; 2.

Hoffman BL, Killingsworth BF. The egg-laying habits of *Aedes aegypti* (Linnaeus) in Central Texas. *Mosq News* 1967; 27: 466-9.

Homme PJ, Arambulo PV. Epidemiology of mosquito-borne haemorrhagic fevers in Southeast Asia. *Philipp J Pediatr* 1965; 14: 119-23.

Honório NA, Codeco CT, Alves FC, Magalhaes, MA, Lourenco-De-Oliveira R. Temporal distribution of *Aedes aegypti* in different districts of Rio De Janeiro, Brazil, measured by two types of traps. *Entomol Soc Am* 2009; 46: 101-14.

Jacob WL, Bevier GA. Application of ovitraps in the U.S. *Aedes aegypti* eradication program. *Mosq News* 1969; 29: 55-62.

Kilpatrick JW, Town RJ, Jatanasen S. Evaluation of ULV insecticide dispensing system for use in single-engine aircraft and their effectiveness against *Aedes aegypti* population in Southeast Asia. *Bull World Health Organ* 1970; 42 : 1-14.

Lee H. *Aedes* Ovitrap and larval survey in several suburban communities in Selangor, Malaysia. *Mosq Borne Dis Bull* 1992; 9: 9-15.

Lee H, Vasan S, Nazni W, Shanaz M. Scientific report on the innovative application of *Aedes aegypti* RIDL-sterile insect technique to combat dengue and chikungunya in Malaysia. Kuala Lumpur: Institute of Medical Research, 2008.

Lian CW, Chan MS, Wang YC. Spatial environmental and entomological risk factors analysis on a rural dengue outbreak in Landee District in Sarawak, Malaysia. *Trop Biomed* 2006; 23: 85-96.

National Vector Borne Diseases Control Program (NVBDCP). Investigation and control of outbreaks – DF and DHF. Delhi: NVBDCP, 1998.

Pant CP, Yasuno, M. Field studies on the gonotrophic cycle of *Aedes aegypti* in Bangkok, Thailand. *J Med Entomol* 1973; 10: 219-23.

Scanlon JE. Bangkok hemorrhagic fever investigations 1962-1963 mosquito collections. *Bull World Health Organ* 1966; 35: 82-3.

Southwood TRE, Murdie G, Yasuno M, Tonn RJ, Reader PM. Studies on life budget of *Aedes aegypti* in Wat Samphaya, Bangkok, Thailand. *Bull World Health Organ* 1972; 46: 211-26.

Su GL. Correlation of climatic factors and dengue incidence in Metro Manila, Philippines. *Ambio* 2008; 37: 292-4.

Tonn RJ, Sheppard PM, WW MacDonald, Bang YH. Replicate surveys of larval habitats of *Aedes aegypti* in relation to DHF in Bangkok, Thailand. *Bull World Health Organ* 1969; 40: 819-29.

Williams CR, Long SA, Webb CE, *et al*. *Aedes aegypti* population sampling using BG-sentinel traps in North Queensland Australia: statistical considerations for trap deployment and sampling strategy. *Entomol Soc Am* 2007; 44: 345-50.

World Health Organization (WHO). Dengue: guidelines for diagnosis, treatment, prevention and control. Geneva: WHO, 2009.

Wong J, Stoddard ST, Astete H, Morrison AC, Scott T. Oviposition site selection by the dengue vector *Aedes aegypti* and its implications for dengue control. *PLOS Negl Trop Dis* 2011; 5: 1-11.

Yap HH. Distribution of *Aedes aegypti* (Linnaeus) and *Aedes albopictus* (Skuse) in small towns and villages of Penang Island, Malaysia–an ovitrap survey. *Southeast Asian J Trop Med Public Health* 1975; 6: 519-24.