ECOLOGICAL STUDIES OF *AEDES* MOSQUITOES IN BANDA ACEH, INDONESIA 5 YEARS AFTER TSUNAMI

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LIST ABREVIATION AND SYMBOL

TSU	Tsunami affected area
NTSU	Non tsunami affected area
Ae. Aegypti	*Aedes aegypti*
Ae. albopictus	*Aedes albopictus*
ANOVA	Analysis of variance
BI	Breteau index
CI	Container index
cm	centimeter
DF	dengue fever
DHF	dengue haemorrhagic fever
HI	house index
KM	kilometer
L	liter
N	number of samples
p	P-value
r	correlation
R	regression
RH	relative humidity
S.E	standard error
Temp	temperature
ºC	Celsius degree
%	percentage
±	plus minus
>	Greater than
<	Less than
χ2	chi-square
df	degree of freedom
Z	Z-test statistic value
®	Registered trademark
DP	dry period
WP	wet period
WHO	World Health Organization
N	North
E	East
Sp	Species

LIST OF SEMINARS AND PRESENTATION

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KAJIAN EKOLOGI NYAMUK *AEDES* DI BANDA ACEH, INDONESIA 5 TAHUN SELEPAS TSUNAMI

ABSTRAK

Aceh merupakan wilayah yang paling dekat dengan pusat gempa dan kawasan paling teruk terjejas oleh gempa bumi Lautan Hindi yang melanda Sumatera Utara, Nicobar dan Pulau Andaman pada tahun 2004. Kajian telah dijalankan untuk mengkaji ekologi populasi nyamuk vektor di kawasan yang dilanda tsunami dan yang tidak dilanda tsunami di Banda Aceh, Indonesia. Kelimpahan populasi nyamuk *Aedes* sebagai vektor denggi di kawasan telah dikaji dengan menggunakan ovitrap dari bulan Januari hingga Disember 2010. Disamping itu tinjauan habitat larva selama setahun menunjukkan bahawa bilangan peringkat tidak matang di kawasan yang dilanda tsunami adalah lebih tinggi daripada kawasan bebas tsunami. Jumlah telur yang dikumpulkan adalah lebih tinggi dalam musim yang kering berbanding dengan musim hujan, dan didapati yang lebih tinggi di dalam daripada di luar rumah. Dalam kaji selidik bekas, 2,436 bekas daripada 800 rumah di kawasan tsunami dan bebas tsunami dan sebanyak empat belas jenis bekas direkodkan menjadi habitat larva di dalam atau di luar rumah di ke dua – dua kawasan. Bekas ini termasuk tangki konkrit, tangki seramik, tangki plastik, dispenser air, baldi, laci titisan air peti sejuk, drum, tin timah, pasu tanah, pasu bunga gelas, pasu bunga plastik, kolam konkrit dan tayar. Bekas yang paling dominan ialah telaga dan tangki; peratusan bekas yang positif dengan *Aedes* adalah lebih tinggi di kawasan tsunami berbanding bukan tsunami. Bekas plastik adalah bekas yang paling biasa ditemui sepanjang kajian ini. Bekas yang bersaiz besar adalah yang paling banyak terdapat di kedua –dua kawasan kajian. Sepanjang tempoh kajian *Aedes albopictus* dan *Aedes aegypti* telah di kenal pasti sebagai

vektor demam denggi. *Aedes aegypti* didapati lebih tinggi pada bekas di dalam rumah berbanding dengan di luar rumah dan didapati lebih tinggi semasa musim kering berbanding dengan musim hujan. Populasi telur menunjukkan korelasi positif dengan hujan dan kelembapan, tetapi berkorelasi negatif dengan suhu. Kelimpahan bermusim populasi nyamuk di kawasan yang dilanda dan tidak dilanda tsunami paling terjejas oleh kelembapan dan hujan. Ujian kerentanan racun serangga menggunakan kit ujian WHO dan kertas yang di impregnasikan dengan 5% malathion telah dijalankan ke atas *Ae. aegypti* yang di tangkap dari kedua – dua kawasan. Hasil penyelidikan menunjukkan bahwa larva *Ae. aegypti* dari semua lokasi kajian di kawasan yang dilanda dan tidak di landa tsunami telah menunjukkan kerintangan rendah hingga menengah terhadap temephos. Manakala nyamuk dewasa *Ae. aegypti* dari kawasan yang dilanda dan kawasan tidak dilanda tsunami mulai terlihat kerintangan rendah terhadap malathion 5%.

ECOLOGICAL STUDIES OF *AEDES* MOSQUITOES IN BANDA ACEH, INDONESIA 5 YEARS AFTER TSUNAMI

ABSTRACT

Aceh was the province closest to the epicenter and the hardest-hit area by Indian Ocean earthquake that hit Northern Sumatra, the Nicobar and Andaman Island. A research was conducted to study the ecology of mosquito vector populations in tsunami-affected areas and in areas not affected by the tsunami in Banda Aceh, Indonesia. The abundance of *Aedes* mosquito populations as vectors of dengue in the area was studied using ovitraps from January to December 2010. In addition, a year long larval surveillance in the tsunami and non tsunami affected areas showed that the number of immature stages in the tsunami affected areas was higher than the non tsunami affected areas. The number of eggs collected was higher in the dry period compared to the wet period, and were found higher indoors than outdoors. In the survey of containers, 2436 containers contained larvae from 800 households in the tsunami and non-tsunami affected areas and a total of fourteen type of containers were recorded as common larval habitats indoor or outdoor in both areas. The containers included well, concrete tank, ceramic tank, plastic tank, water dispenser, bucket, refrigerator drip pans, drum, tin cans, earthen jar, glass plant pot, plastic plant pot, concrete pond and tyre. The most dominant containers were wells and tanks; the percentage of *Aedes* positive container was higher in the tsunami affected areas compared to the non tsunami affected areas. Plastic containers were the most commonly found containers during this study. Large-size containers were the most abundant found in both of the study sites. During the study period *Ae. albopictus* and *Ae. aegypti* were identified as the vectors of dengue fever. *Aedes aegypti* larvae were found higher in indoor container

compared to outdoor container, and found higher during the dry period compared to the wet period. The egg population showed a positive correlation with rainfall and relative humidity, but a negative correlation with temperature. The seasonal abundance of most mosquito populations in both the tsunami and non-tsunami affected areas were affected by humidity and rainfall. An insecticide susceptibility test using the WHO test kit and 5% malathion impregnated papers was carried out on four strains of *Ae. aegypti* larvae collected from both areas. The result showed that *Ae. aegypti* larvae from all study sites in the tsunami and non tsunami affected areas has developed low to moderate resistance to temephos. Whereas, *Ae. aegypti* adults from both of the study sites in the tsunami and non tsunami affected areas were starting to low resistance to malathion 5%.

CHAPTER I

INTRODUCTION

1.1 General Introduction

Dengue is the most prevalent and rapidly spreading mosquito-borne viral disease in the world. It has a worldwide distribution and is spreading over almost all tropical and subtropical countries (Gubler, 2006). An estimated of two billion people world-wide live in areas where the diseases is endemic (WHO, 1999). It is affecting more than 50 million people each year (WHO, 2002).

Indonesia is the largest country in the region with a population of 245 million. Almost sixty percent of the people live on the island of Java, which is most severely afflicted by periodic outbreaks of dengue disease (Suwandono et al., 2006). Epidemic Dengue Fever has been reported in all 27 Indonesian Provinces now whereas in 1968 only two provinces had reported dengue cases (Sumarmo, 1987; Richards et al., 1997). In Indonesia, dengue is a major annual public health problem causing cyclical epidemics in urban areas. Laboratory confirmed cases of dengue in Indonesia in 2004 were reported from the provinces of Aceh, Jambi, Banten, West Java, Central Java, South Kalimantan, Bali , West Nusa Tenggara and East Nusa Tenggara. Thus, Dengue Hemorrhagic Fever (DHF) is still a viral endemic disease which still represents a society health problem and is a serious problem in Indonesia, especially for population in urban areas (Sitio, 2008). Anon (2005) reported that the disease is a leading cause of hospitalization and death among children.

Banda Aceh is one of the dengue endemic areas of Aceh Province, Indonesia. Based on data from the Aceh Provincial Health Office, in 2008 ,74 villages out of 90 villages in Banda Aceh were positive with dengue and of which 53 of the villages were endemic with the dengue. During the same year there were 593 cases with five deaths. It is alarming that the number of dengue cases in Banda Aceh is increasing from year to year.

The earthquake and tsunami of 26th December 2004 in Aceh Province, had a further devastating effect throughout the area and shore line. The present of stagnant water created condition for mosquito vectors to multiply and potentially caused severe public health problem and endemic for dengue fever. The dengue vector mainly breeds in discarded containers and water storage jars, and such breeding sites may have been increased by debris from the tsunami filled with rainwater (Noji, 1997; Balaraman et al, 2005). Muriuki et al. (2012) found that malaria and dengue fever quickly became the major threat facing survivors of the tsunami in Aceh, Indonesia. The rainy season immediately after the tsunami, and extensive flooding quickly turned many areas where survivors were sheltering into vast brackish breeding sites for mosquitoes.

The spread of dengue in Banda Aceh which was caused by the floods due to the mess such as a lot of old bottles after the tsunami becoming mosquito breeding sites. The risk of vector borne diseases after a flood requires the presence of several risk factors in addition to the flooding itself, such as presence of the vector,the pathogen, the breeding sites, population migration to and from endemic areas, reduced access to health facilities for diagnosis and treatment, and disruption of prevention and control program (Noji, 1997).

Dengue fever is becoming a disease of public importance in Aceh Province, since mid-october 2008, where by 13 residents die to the dengue. It was speculated that the large-scale change of environment as a result of the tsunami might have produced new breeding sites for vector mosquitoes and influenced mosquito ecology, including density and species composition. It was considered important, therefore, to examine the mosquito breeding situation in areas affected by the tsunami. However, the average frequency of mosquito breeding sites around the tsunami affected areas, remains poorly understood in Banda Aceh after the tsunami

The seasonal abundance of the mosquitoes is correlated with the environment and the climate of the area. Floods or heavy rains in winter, spring and autumn will be followed by egg abundance (Russell, 1986). Seasonal variation in population density and distribution is common for *Ae. aegypti* since it is sensitive to changes in temperature and available moisture. Mosquito abundance is often positively related to precipitation (Ho et al., 1971) and this condition can provide fertile grounds for mosquito breeding (Ang and Satwant, 2001). Essentially, low mosquito populations are evident in the dry and cool seasons and they increase when temperatures increase and the wet season commences (Shultz, 1993). Differences in abiotic factors such as temperature, precipitation and humidity could have a major influence on the distribution of mosquito species (Teng and Apperson, 2000). Temperature affects the length of the gonadotrophic cycle, warm temperature and high moisture contribute to increase adult survival. Warmer temperatures shorten the extrinsic incubation period which increases dengue transmission in the hot, dry and rainy seasons (Watts et al., 1997; Tsuzuki et al, 2009;).

One of the most effective ways to control mosquito population that transmit disease is to reduce the number and types of mosquito breeding habitats in our community. All mosquitoes require a water source to lay their eggs, which in the hottest part of the month can hatch into larvae within a week. At the same time, it is vital that such methods be easily operated in order to streamline control programme to estimate vector density using the house index (HI) and the Breteau index (BI).

There are many cases of mosquito resistance towards insecticide that has been reported. For example, Mukhopadhyay et al. (2006) had concluded that in Rajahmundry town, *Cx. quinquefasciatus* mosquitoes, the vector of lymphatic filariasis were not responding to the recomended doses of DDT and Malathion. According to Macoris et al., (2003), the mosquitoes from Santos, which were clasified as resistant in the diagnostic test, showed the highest resistant ratio for both temephos and fenithtrotion.

Tsunami affected areas in South-East Asian has been warned by WHO about an increased risk of vector-borne diseases such as malaria and dengue fever (Pungasem et al, 2005). They found that adults *Ae. aegypti* were susceptible to fenitrothion, resistant to permethrin and highly resistant to DDT.

Dengue fever is transmitted to humans via the bite of infected *Aedes* mosquitoes. *Aedes aegypti* can adapt well to urban environments by breeding in clean or stagnant water in a wide variety of containers that collect rainwater such as tires, tin cans, pots and buckets. For example, following the flood disaster in Brazil in 2008, 57,010 dengue cases including 67 deaths were reported among victims. This epidemic was associated with the disruption of basic water supply and solid waste management services. Other risk factors included changes in human behavior (e.g., sleeping outside and movement from non-endemic to endemic areas) and changes in habitat that promote mosquito-borne disease transmission (WHO, 2008).

In Indonesia, malathion and temephos are two common organophosphate insecticides which are commonly used for controlling *Aedes* mosquitoes to control dengue haemorrhagic fever (DHF) transmission since 1970. The long term usage of these chemicals in controlling the target insect could be one of the possible factors that is related to the development of resistance in the dengue vectors (Mulyaningsih, 2004).

Vector control in an attempt to reduce the occurrence of dengue fever in the District of KutaAlam, Banda Aceh until now has not shown significant results. Counseling and health promotion efforts to pay more attention to public hygiene and environmental health care also notable to reduce the incidence of dengue.

1.2 Objectives of the studies

It was speculated that the large-scale change of environment as a result of the tsunami might have produced new breeding sites for vector mosquitoes and influenced mosquitoes ecology, including density and species composition. It was considered important, therefore, to examine the mosquito breeding situation in areas affected by the tsunami. Therefore, the present study will be a contribution to determine some of the *Aedes* mosquitoes ecology and the current distribution and breeding habitats of the dengue vectors in Banda Aceh after the tsunami, which is essential for the planning of an effective mosquito control programme in the future. For that reason the following are the specific objectives of the present study:

1. To document the epidemiology of dengue vector in Banda Aceh 5 years after the tsunami.
2. To determine the various *Aedes* mosquitoes immature stages breeding habitats in water holding containers of the vector indoor and outdoor in the tsunami and nontsunami affected areas in Banda Aceh 5 years after the tsunami .
3. To study the seasonal abundance of *Aedes* vector mosquito species in tsunami and non tsunami affected areas in Banda Aceh 5 years after the tsunami.

4. To study the relationship between *Aedes* mosquito abundance and its physical parameters (temperature, humidity, rainfall and precipitation).
5. To study the density of *Aedes aegypti* in the tsunami and non tsunami affected areas in Banda Aceh.
6. To determine the current susceptibility status of field *Aedes* mosquitoes larvae against temephos and adult mosquitoes against malathion in Banda Aceh 5 years after the tsunami.

CHAPTER II

LITERATURE REVIEW

2.1 Ecology of *Aedes* Mosquito

The ecology and distribution of various mosquito species is important in determining vector mosquito abundance and the prevalence of associated diseases (Okogun et al., 2003). Some aspects of human ecology greatly influence mosquito distribution (Gillet, 1971), species relative abundance and their survival (Evans, 1938). Often mosquito species groups, subgenus and genus have their own preferred habitat based on locations and conditions of the water body (Shannon, 1931). The physiochemical compositions of the water bodies are complicated to determine their condition and fauna composition. They include salts, dissolved inorganic and organic matter, degree of eutrophication, turbidity and presence of suspended mud. Others include presence or absence of plants, temperature, light and shade, hydrogen ion concentration, presence of food substances (living or dead), presence of predacious mosquito larvae, fishes, other insects, crustaceans and arachnids (Okogun et al., 2003).

Nevertheless, mosquitoes require water to complete their life cycle, and environmental sanitation of water-holding containers provides a basis for an area-wide management strategy for container-inhabiting mosquito populations (Nathan and Knudsen, 1991). It has been established previously in premise surveys for *Ae. aegypti* that prevalence of mosquito-positive containers varies between types of containers (Moore et al., 1978; Focks et al., 1981; Barker-Hudson etal., 1988; Nathan and Knudsen, 1991; Focks and Chadee, 1997), as well as between residences (Chadee, 2004). Accordingly, several methods for reducing the manpower needed for controlling *Ae. aegypti* have been proposed, including environmental sanitation or treatment efforts directed towards container types that are important sources of adult production and targeting specific residences regarded to be mosquito production 'hot spots' (Tun-Lin et al., 1995; Chadee, 2004). The importance of specific types of container as production sites has largely been addressed by determining prevalence rates of larva- or pupa-positive containers (Moore et al., 1978; Barker-Hudson et al., 1988; Chadee, 2004).

Mosquito is an insect that can accomodate well in different condition and surface of the earth. It can be found not only in tropical region, it also can be found in the artic region. The high arctic mosquitoes *Aedes impiger* and *Aedes nigripes* lay their eggs that are able to resist freezing and drying condition only around pond margins on the warmest sites, which are the first to become free of snow in spring . Mosquitoes are divided into about 3450 species and subspecies arranged altogether in 38 genera. They all belong to the family Culicidae which is divided into three subfamilies namely Toxorhynchitinae, Anophelinae (Anophelines), and Culinae (Culicines). The biological characteristic of the mosquitoes is different from one genus to another and also within species. However, all stages of life cycle of mosquitoes are the same (Kay et al.,1995).

Biological characteristics of *Ae. aegypti* mosquitoes seem to vary depending on particularities of each location (Rodhain and Rosen, 1997). Genetic differences have been found among subpopulations of these mosquitoes throughout molecular marker studies (Gorrochotegui-Escalante et al., 2000). Additionally, variability in vectorial competence among different subpopulations has been demonstrated (Beerntsen et al., 2000).

The risk of an epidemic is of course closely related to the adult vector biological and ecological factors (Kuno,1995); the life expectancy, the blood meal frequency, the extrinsic incubation periode and the abundance. After the emergence, all biological processes are dependent on temperature and for survival, on humidity (Gilpin and McClelland, 1979; Focks et al., 1993a). Abundance is supplied by the emergence of new adults and then is related to the immature stages of the mosquitoes: egg hatching, larval and pupal survival. These processes are related both to the human environment and to the climate. Indeed, *Ae. aegypti* is a domestic mosquito, which lays eggs preferentially in artificial containers left indoors and outdoors by people. Once embryonated, these eggs can survive up to 1 year until they are flooded and they hatch (Degallier et al., 1988; Russell et al., 2001; Saifur et al., 2013). Then, completion of the immature stages depends on continued presence of water in the container and on the water temperature. The notion of productivity of the environment can be defined as the amount of newly emerged adults produced per unit time, which is related to both weather and anthropic environment. Estimating this productivity by sampling the immature stages and their distribution among the environment is necessary and comply with the following three purposes. First, despite the lack of unequivocal relationships between the classical measures of immature stages densities as larval (or *Stegomyia*) indices (Focks, 2003) and adult population or dengue epidemic risk, they remain the most usual way to quantify mosquito infestation in a particular location and to compare between places. Second, as common management strategies involve in decreasing the emergence of adult vectors by the elimination of immature stages, it is necessary to know the distribution of immature stages to adapt these strategies to the environment as well as to estimate their efficiencies (Nagao et al., 2003). The last purpose deals with the parameterisation of climate-driven epidemic models.

For species that inhabit a range of climates, early reproduction could increase the fitness of individuals in regions subject to seasonal time constraints, such as onset of an unfavorable climate (Rowe and Ludwig, 1991). Unfavorable environments also may favor production of higher investment (i.e., larger) offspring because greater offspring size often increases offspring probability of surviving to adulthood (Fox and Czesak, 2000). Thus, individuals from populations at different latitudes may become locally adapted via selection on allocation of resources for survival, current reproduction, and future reproductive investment among offspring.

Unfavorable climatic effects that decrease the survival of both adult and juvenile mosquitoes are also likely to alter how reproduction is allocated over time and among offsprings. For individuals constrained by a short active season, early onset of reproduction is likely to increase fitness despite associated costs of reduced longevity and residual reproductive output. Conversely, for individuals that experience a longer active season greater reproductive output may result from apportioning energy to reproduction more evenly over time (Leinsham et al., 2008).

2.1.1 Mosquito and other insects after tsunami in Indonesia and other countries

Natural disasters may lead to infectious disease outbreaks when they result in substantial population displacement and exacerbate synergic risk factors (change in the environment, in human conditions and in the vulnerability to existing pathogens) for disease transmission. Natural disasters including floods, tsunamis, earthquakes, tropical cyclones (e.g., hurricanes and typhoons) and tornadoes have been secondarily described with the following infectious diseases including diarrheal diseases, acute respiratory infections, malaria, leptospirosis, measles, dengue fever, viral hepatitis, typhoid fever, meningitis, as well as tetanus and cutaneous mucormycosis (Isidore et al., 2012).

Close monitoring of public health problems in disaster hit areas is warranted to assess the risk of disease outbreaks, including vector borne diseases, for example dengue, and malaria. There is very little information that describe the relative importance of infectious diseases and injuries as a consequence of disasters due to natural hazards.

Malaria and dengue are the most important vector-borne diseases in Indonesia. Before the tsunami (2000–2004), both were endemic in most provinces and several epidemics occurred. However, the incidence of malaria in Aceh Province, remained relatively low, with, on average, 27 cases per 100,000 in 2000–2004, which is nine times less then the national average of 269/100,000 during this period (Guha-Sapir and Willem, 2009). Although dengue has caused increasing concern in Indonesia during the past decade, Aceh is among the provinces with the lowest reported incidence (2.4/100,000) between 2000 and 2004. In the four months after the tsunami, 987 confirmed malaria cases in Aceh Province were reported to the WHO, primarily in the west coastal areas, including Banda Aceh. This corresponds with the number of cases reported in previous years, and less than half of the number of cases reported in 2001. Only a few cases of dengue were reported to the Provincial Ministries of Health from the two northern districts of Aceh Barat and Aceh Utara. Among consultations in the International Committee of the Red Cross (ICRC) field hospital for Banda Aceh, 15 malaria cases were found, but no dengue cases (Guha-Sapir and Willem, 2009).

Observations made in one of the tsunami-hit areas in the Andaman district of the Andaman & Nicobar Islands, India, which had hitherto been a low endemic area for malaria with no major outbreaks of communicable diseases were presented there (Kaliannagoun et al., 2005). There is a need for extreme vigilance in view of vulnerability of these densely populated areas and extent of breeding grounds of the local vector, *Anopheles sundaicus* created by the tsunami.

The different situation noted by Wysong (2005) that hurricanes Katrina and Rita left devastation in their wakes, but they did not lead to increased rates of West Nile Virus (WNV) or other mosquito-borne illnesses as some feared. This was in spite of vast amounts of standing water left by the storms and booming mosquito populations because ecologically disruptive is going to displace birds, kill some mosquitoes in the hardest hit areas, and probably not be conducive to increasing the amount of virus transmission, and the other reason is as well, most hurricanes usually occur late in the year when arbovirus transmission cycles are naturally declining due to falling mosquito densities and lower temperatures (Wysong, 2005). He add that monitoring was done after other large hurricanes in Florida during 2004, but the areas where they hit did not have much in the way of West Nile activity, but really large mosquito population increases, there wasn't a pre-existing West Nile cycle to feed the system.

2.1.2 Dengue Fever and Dengue Haemorrhagic Fever

Globally, dengue and dengue haemorrhagic fevers are two of the most important epidemic diseases affecting more than 2.5 billion people at risk, annually 50 million dengue infections estimated occur with 500,000 cases of DHF and at least 22,000 deaths, especially in tropical countries (Gubler and Kuno, 1997; WHO, 2004). Within the Americas, *Ae. aegypti* is the urban vector of yellow fever, dengue fever (DF), dengue haemorrhagic fever and dengue shock syndrome and is distributed from the USA in the north to Argentina in the south, with only the Cayman Islands free of it (PAHO, 1994). Countries infested with *Ae. aegypti* mosquitoes usually suffer outbreaks of DF and each year an estimated 50 million people are infected, resulting in varying degrees of morbidity and mortality.

Nowadays, Dengue fever (DF) and Dengue haemorrhagic fever (DHF) are increasing in importance as millions of people are infected by these diseases annually. The disease affects hundreds of millions of people every year, and it is transmitted predominantly by *Aedes* species which has adapted to living near human habitations (Hales et al., 2002). Dengue fever and dengue haemorrhagic fever are caused by the dengue virus, which belongs to the genus *Flavivirus*, family Flaviviridae and consists of 4 dengue virus serotypes (DEN-1 – 4), all of which can cause dengue fever and dengue haemorrhagic fever (Miyagi & Toma, 2000). Infected people can be of all ages, social status, especially those living in densely populated urban areas throughout the tropical regions.

The incubation period after the mosquito bite is 3-8 days. Infants and young children often have a nonspecific febrile illness that can hardly be differentiated from other viral illness. The more severe cases of dengue fever are usually seen in older children and are characterised by a rapidly rising temperature ($\geq 39^0$C) that lasts 5-6 days, sometimes returning to almost normal in the middle of the febrile period (biphasic or saddle-back temperature curve). The febrile febrile period is accompanied by severe headache, retro-orbital pain, myalgia, arthralgia, nausea, and vomitting. Over half of infected people report a rash during the febrile period that is initially macular or maculopular and becomes diffusely erythematous, sparing small areas of normal skin (Ellerin et al., 2003). Minor hemorrhagic manifestations like ptechiae, epistaxis, and ginggival bleeding do occur. Severe hemorrhage is unusual. Dengue fever may be very incapacitating, but its prognosis is favourable and recovery generally occurs after 7-10 days of illness (Mairuhu et al.,2004). Dengue fever is seen in syndromes that are age-dependent (Halstead, 1980).

Dengue haemorrhagic fever or dengue shock syndrom proceeds through two stages (Halstead, 1980). The illness begin with abrupt onset of fever accompanied by dengue-like symptoms; during or shortly after the fall in temperature, the condition of the patient suddenly deteriorates, the skin becoming cold, the pulse rapid , and the patient becomes lethargic and restless. In some chldren the range of pulse pressure progressively narrows, the patient becomes hypotensive and if not treated, may die in as little as 4-6 hours.

Aedes aegypti and *Aedes albopictus* are the vectors for dengue fever and dengue haemorrhagic fever. *Aedes aegypti* is the principal vector of dengue viruses and yellow fever virus (Gubler, 2002; Lambrechts et al., 2010). *Aedes albopictus* has been repeatedly incriminated as a vector during dengue outbreaks, particularly in Southeast Asia (Shroyer, 1986). Jumali et al, (1979) compared the efficiency in transmission of Den -3 virus by oral route of *Ae. albopictus* and *Ae. aegypti* and found that both species were equally efficient.

Dengue and yellow fever are two of the most alarming (re-)emerging human tropical diseases, both transmitted by the mosquito *Ae. aegypti* in its urban form. As for dengue, 2,5 billion people live in areas at risk and an estimated 50 million cases occur every year, more than 250,000 of which are of the hemorrhagic form (Gibbons & Vaughn, 2002). Yellow fever affects an estimated 200,000 people each year, with 30, 000 deaths, occurring as accidental infection from endemic circulation among monkeys or as human epidemics (Gubler, 2004).

There was a suggestion that *Ae. aegypti* was originated from the new world, America. However, the origin of *Ae. aegypti* was from Ethiopia. This suggestion was backed by the discovery of 37 species which are in the same sub genus *Stegomya* in that region compared with 30 species in the Oriental region (Hawley et al., 1987).

Aedes albopictus known as the Asian Tiger Mosquito (ATM) is one of the mosquito species that is very successful in spreading their population around the world. It is a very important vector of diseases that comes from Asia and now starts to spread to the western hemisphere (Hawley et al.,1987). *Aedes albopictus* was originally indigenous to South-East Asia, islands of the Western Pacific and Indian Ocean. It has spread during recent decades to Africa, the mid-east, Europe and the Americas (north and south) after extending its range eastwards across the Pacific islands during the early 20th century. The majority of introductions are apparently due to transportation of dormant eggs in tyres (Gratz, 2004). Through *Ae. albopictus* has spread to a few countries through the international worn tires industries (Bellini et al., 1996). It is primarily a forest species that has become adapted to rural, suburban and urban human environments (WHO, 1999). In 1985, this mosquito was recognized as the most abundant mosquito that breeds inside man-made container in Houston, Texas (Hawley et al.,1987). Factors that affect the distribution of this species are altitude, temperature and distance from local cities that are nearby.

As a result of major demograpic changes, rapid urbanization on a massive scale, global travel and enviromental change the world – particularly the tropical world – faces enormous challanges from emerging infectious diseases. Dengue epitomizes these challenges. In the early years of the 21st century, we were collectively failing to meet the threat posed by dengue as the disease is spread widely and almost 40% of the world's population now live at risk of contracting it (Farrar et al., 2007).

Mosquitoes are responsible for the transmission of many medically important pathogens and parasites such as viruses, bacteria, protozoans, and nematodes, which cause serious diseases such as malaria, dengue, yellow and Chikungunya fever, encephalitis or filariasis (Kettle, 1995; Beaty and Marquardt, 1996; Lehane, 1991; Eldridge and Edman, 2000). Transmission can be mechanical or biological.

Due to their blood-sucking behaviour or because of their habit of biting humans for blood meal, mosquitoes are able to acquire the pathogens or parasites from one vertebrate host and pass them to another (Service, 1995). Highly efficient vectors have to be closely associated with the hosts and their longevity has to be sufficiently long enough to enable the pathogens/parasites to proliferate and/or to develop to the infective stage in the vector. For successful transmission, multiple blood-meals are necessary. In terms of morbidity and mortality caused by vector- borne diseases, mosquitoes are the most dangerous animals confronting mankind. They threaten more than three billion people, in the tropical and subtropical regions and have also substantially influenced the development of mankind, not only socio–economically but also politically (Becker et al., 2010).

In southeast Asia, *Ae. albopictus* has been incriminated as a secondary vector of dengue and *Ae. aegypti* as the principal vector of dengue viruses (Sulaiman et al., 1996). *Aedes albopictus* has extendeed its range to the coastal cities of Irian Jaya, the Solomon and Santa Cruz Islands, and Papua New Guinea. It has also been found in Brisbane and Darwin, Australia where the infestations were promptly eradicated (Elliot, 1980). *Aedes albopictus* inhabits all of Southeast Asia and parts of temperate Asia, where it transmits dengue fever virus, and possibly Japanese encephalitis virus (Hawley, 1988), *Dirofillaria immitis* (Dog heartworm) in Italy (Cancrini et al., 2003) and other patogens (Hanson et al, 1993). The ability of *Ae. albopictus* to transmit yellow fever and dengue viruses is endemic in United States , including eastern equine encephalitis, La Crosse encephalitis, Ross River Virus (Russel, 2002) and Western equine encephalomyelitis viruses (Shroyer, 1986; Scott et al., 1990; Mitchell, 1991). Eastern Equine encephalitis virus has been isolated from field population *of Ae. albopictus* in Florida (Mitchell et al., 1992). In Malaysia, dengue and chikungunya infections are both transmitted by *Ae. aegypti* and *Ae. albopictus* (Rudnick, 1965).

2.1.3 Ovitrap and Ovitrap Index for Mosquitoes Surveillance

The oviposition trap (ovitrap) is an important component in monitoring of the mosquito-borne diseases (Bentley and Day, 1989; Wan-Norafikah et al., 2012). This technique was used because ovitrap is a sensitive and efficient technique for detecting the population of *Aedes.* There are several methods used to survey *Aedes* mosquito to assess their population in dengue outbreaks areas. However, through larval survey, the most prevalent and productive mosquito larval habitats can be characterized. These characteristics can be linked to specific human activities, which is critical for identifying, focusing, and improving mosquito control efforts (Troyo et al. 2008).

Gravid *Ae. aegypti* mosquitoes display numerous oviposition strategies when a suitable site is encountered in the laboratory and in the field including dispersing their eggs from a single batch on successive occasions (Chadee and Corbet, 1990) or in different sites (Chadee and Corbet, 1987, Jorge and O’Connel, 2014), a feature often referred to as “skip oviposition” (Mogi and Morky, 1980). This feature is often exaggerated by a female’s tendency to avoid laying on surfaces that already bear her own eggs or those of conspecifics (Chadee et al., 1990). The selection of suitable oviposition sites by *Ae. aegypti* is a critical factor in their population dynamics and has important implications for vector control measures like source reduction and focal treatment of breeding habitats (Chadee, 1988). Chadee et al, (1990) and Apostal et al, (1994) reported that gravid mosquitoes disperse their eggs over several sites with approximately 11–30 eggs per oviposition container. These numbers of eggs have been consistently found in ovitraps (Fay and Eliason, 1966) since the introduction in most countries with *Ae. aegypti* populations (PAHO, 1994). Ovitraps have been used to monitor the population density (Reiter et al., 1991; PAHO, 1994), oviposition periodicity (Chadee and Corbet, 1987), efficacy of insecticide applications (Castle et al., 1999) and the presence or absence of *Ae. aegypti* within the selected areas of the countries (PAHO, 1994). However, no studies have been conducted to evaluate routine *Ae. aegypti* overlapping data to determine whether egg avoidance, super oviposition or skip oviposition can be gleaned from the proportions of eggs collected on a weekly basis.

In dengue endemic countries, ovitraps are especially useful in assessing the impact of such measures on the breeding and dispersal of local *Ae. aegypti* mosquito populations (Reiter and Nathan, 2001). Other less commonly used method than ovitraps is the adult collection using aspirators (Nasci, 1981). Ovitraps is highly sensitive for detecting the vector, and the adult collection provides information on the number of females per resident in an area but is not useful/utilized for routine control activities due to its high operational cost (Focks 2003). Ovitraps can also be used to determine the presence or absence of breeding populations of *Ae. aegypti* in locations where control measures are being considered. In addition, when large numbers of wild *Ae. aegypti* larvae and adults are required for laboratory tests, ovitraps provide a simple way to obtain substantial quantities of eggs. One of the most commonly employed *Ae. aegypti* ovitraps is the ‘CDC ovitrap’. This consists of a dark, water-filled container and a thin paddle of wood (usually slightly taller than the container and about one inch wide) that is placed in the container and used as an oviposition substrate. The paddle is often a piece of balsa wood or a tongue depressor, and can be covered in red velour or seed germination paper (Fay and Eliason, 1966).

Aedes surveillance using ovitraps is one of the cost-effective and most important tools of dengue control. Ovitraps provide a simple and convenient tool for *Aedes* surveillance. Previous studies indicated that ovitrap surveillance could be used for the prediction of dengue outbreak, especially in areas of low *Aedes* infestation, and has been recommended as a surveillance tool in dengue control (Lee, 1992; Tham, 1993; Focks, 2003). Setting ovitraps in public areas would serve as an alternative method of vector detection (Jacob and Bevier, 1969; Tanner, 1969; Furlow and Young, 1970; Mogi et al., 1990). Ovitrap data have been reported to be more sensitive than the traditional *Stegomyia* indices in detecting low population (Focks, 2003). Historically, ovitraps have provided useful data on the spatial and temporal distributions of *Ae. aegypti* and other container inhabiting mosquito species (Ritchie, 1984). Ovitrap data have also been successfully used to monitor the impact of various types of control measures involving source reduction and insecticide applications (Focks, 2003). In addition, the ovitrap method is capable of detecting mosquitoes from unexposed breeding sites and surrounding areas.

Recently, sticky ovitraps has been invented as new surveying methods (Ordonez-Gonzales et al., 2001), such as the MosquiTrap™ (Gama et al., 2007) and the CDC gravid trap (Reiter, 1983). However, this method does not provide egg population instead it captures gravid females to determine dispersal distances of mosquito. There have been many modifications to the clasical ovitraps, for example substituting black painted tins or black plastic beakers for glass bottles (Service, 1993). In studying the seasonal variations in relative abundance of *Ae. albopictus* and *Ae. aegypti*, Lee et al. (2013) used of a novel adult oviposition trap, the Gravitrap, in managing dengue cluster areas in Singapore, although it has an intensive dengue control program, dengue remains endemic with regular outbreaks. The Gravitrap is a simple, hay infusion-filled cylindrical trap with a sticky inner surface to serve as an oviposition site for gravid female *Aedes* mosquitoes, which is designed to lure and trap gravid female *Aedes* with a sticky lining. It exploits the skip-oviposition behavior of female *Ae. aegypti*, who distributes her eggs in multiple containers during each gonotropic cycle, a behavior that may increase offspring survival. There have been many modifications to the clasical ovitraps, for example substituting black painted tins or black plastic beakers for glass bottles (Service 1993).

Entomological parameters currently being used for *Aedes* spp. surveillance are *Aedes* Index (AI), Breteau Index (BI) and Container Index (CI). The formulae for these indices take into account only containers positive of *Aedes* species. However, the potential breeding containers devoid of larvae are not included in the formulae.

Indices that are recommended by the WHO to estimate the vector density for dengue fever, are House Index (HI), Container Index (CI) and Breteau Index (BI) (Tun-Lin et al., 1995; Scott and Morrison, 2003). To monitor *Ae. agypti* populations in terms of vector-borne disease transmission, at first the House Index (HI) was introduced which has been used for many years and was considered the most valuable (Luo et al., 2012). The Breteau Index (BI) and Container Index (CI) have been added to quantify the vector population more accurately (Luo et al., 2012) and they are still the most widely used, although according to Bouman et al. (2014) that HI and BI may no longer provide accurate reflexion of the dengue cases, furthermore, appropriately designed studies are required to elucidate the relationship between vector abundance and dengue transmission; standardizing study designs, particularly with respect to spatial heterogeneity; vector surveillance programs should sample adult mosquitoes and better knowledge of vector ecology is required. Among these three indices, BI is considered to be the most informative because it includes the number of houses inspected and infested containers. Its main limitation is that it fails to account for adults produced from containers (Carvalho et al., 2013; Balasubramanian et al., 2015). Seasonal Abundance of *Aedes* Mosquitoes

2.1.4 Seasonal Abundance of *Aedes* Mosquitoes

Aedes aegypti and *Ae. albopictus* are vector mosquitoes that have successfully adapted to urban habitats. However, *Ae. aegypti* is originally a forest species whereas *Ae albopictus* is a woodland species. Although there is evidence that *Ae. aegypti* may be competitively dominant in domestic urban premises, whereas *Ae. albopictus* has the advantage in outdoor and sylvatic surroundings, the two species are virtually ecological homologues, and coexcist in many regions even sharing the same breeding sites (Rudnick, 1965; Chan et al, 1971, Dieng et al., 2012; Saifur et al., 2012). *Aedes albopictus* occurs over a wide geographic range and encounters a wide range of ambient temperatures. The expansion of *Ae. albopictus* range in North America is likely to continue, and regional differences in temperature may affect its population dynamics, as is the case in other mosquitoes (Rueda et al., 1990). In tropical and sub tropical climates, *Ae. albopictus* is abundant all year round, however, in temperate climates such as the Midwestern United States and Japan, the active season for larval stages is limited to late spring through early fall, with larval abundance greatest in July- August (Mori and Wada, 1978; Toma et al., 1982).

In Indonesia, the seasonal pattern of dengue fever since the last five years is always high between January and June. In the dry season, the number of dengue incidence is still high. Lowest number of events throughout 2005 to 2006 was the month of October 2006 for 3936 cases. Pattern of development of DHF by month, different from one province to another province. In Jakarta and Bali, the incidence of dengue increased in recent years and are very high from January to June, as well as for most of the provinces in Indonesia. In North Sumatra, the incidence of dengue has increased and predominantly high in October to November, as well as in Aceh, West Sumatra, Riau and West Kalimantan. In 2007, dengue incidence remains high in the dry season. In Jakarta, high incidence of dengue was observed in 2005 until early 2006. Presumably because of the long wet season (Anon, 2007). Jakarta Province has the highest incidence of DHF among all the provinces in Indonesia (MOH, 2010). Moreover, the Jakarta Provincial Health Office reported that DHF has the highest IR (200,8/100,000 population) of all communicable diseases in 2010.

There has been several studies that have focused on how environmental factors affect tire-inhabiting mosquitoes (Yee, 2008). One of the most thorough studies was completed by Beier et al. (1983), who examined how water chemistry parameters and habitat variables affected mosquitoes in a large tire yard in Indiana. Shading by over hanging vegetation was an important factor affecting mosquito communities, and several measured factors (e.g., turbidity, color) appeared to affect the abundance of some species, but few habitat and water chemistry variables were correlated with mosquito abundances (Beier et al., 1983).

2.1.5 Physical Factors that Influence Mosquito Distribution and Abundance

One of the physical factor is rainfall. Rainfall is the most important factor that affects *Aedes* breeding (Khim, 2003). Rainfall provides a good breeding habitat for mosquitoes (Zyzak et al., 2002) and maintains the persistence of breeding sites (Patz et al., 2003). Some studies showed that there is an association between rainfall and dengue outbreak. In Malaysia, the epidemics of dengue from 1973-1982 were related to the two monsoons : SW monsoon in the first half, and NE monsoon in the second half of the year (Lo & Narimah, 1984). Moutchet et al., (1998) pointed out that temperature and rainfall influence malaria transmission; the former determines the length of the larval mosquito cycle and the sporogonic cycle of the parasite in the mosquito.

Reproduction of *Ae. aegypti* populations in tropical and subtropical zones occurs all year round and their abundance can either be associated with rainfall regimens (Chadee, 1991; Micieli and Campos, 2003). Generally *Aedes* breeds after rain, not during rainy days. With heavy rainfall, water in containers will overflow, and consequently larvae cannot survive in it (Lee & Cheong, 1987). In the study of adult females of *Ae. albopictus* in Kuala Lumpur, the highest peak can be seen in September, the lowest in May and these situations were closely related to rainfall (Sulaiman and Jeffery, 1986). According to Chan et al. (1971) in a study in Singapore, there was a few high and low peaks for *Ae. albopictus* adult female population between March, June-July and November-December. The densities of larvae and pupae were higher after two months of high peak of adult population.

In general, insects are exceedingly sensitive to temperature and rainfall regimes, tropical and temperate species frequently show great variations in seasonal abundance (Samways, 1995). Mosquitoes are sensitive to temperature change. If the water temperature rises, the larvae take shorter time to mature (Rueda et al., 1990) and consequently there is a greater capacity to produce more offspring during the transmission period. Adult female mosquitoes digest blood faster and more frequently in warmer climates, thus increasing transmission intensity (Gilles, 1953).

Temperature also the other physical factor that has been shown to affect population biology in the laboratory (Rueda et al., 1990; Tun-Lin etal., 2000), while models based on precipitation, temperature and atmospheric moisture explain much of the intra-annual variation in *Aedes* abundance (Moore 1985; Focks et al., 1993a and b) and dengue incidence (Focks et al., 1995; Jetten & Focks, 1997).

Rising temperatures might extend the transmission season for dengue virus and increase the rate of developmental sites for the primary vector, *Ae. aegypti*. Conversely, a high frequency of rainfall events would ensure that small artificial containers used as larval mosquito habitats, would remain flooded thereby expanding adult mosquito populations (Patz and Reisen, 2001).

Abundance is supplied by the emergence of new adults and then is related to the immature. These processes are related both to the human environment and to the climate. In addition to these climatological factors, cultural and socio-economic factors, particularly housing, may affect vector abundance and disease transmission (Kuno, 1995; Tun-Lin et al., 1995). As vector control programmes are heavily focussed on community involvement in environmental modification, it would clearly be an advantage to identify, and subsequently modify, community level behavioural and housing risk factors for *Ae. aegypti* (Nagao, 2003). However, indoor temperature may provide a suitable condition for *Aedes* breeding and mosquitoes generally prefer a cool shaded area for their biting and breeding activities (Evan, 1938; Okogun et al., 2003).

Temperature, rainfall and relative humidity are physical factors that influence mosquitoes (Lee, 1990). High relative humidity can give high hatching rates. With 100% humidity the eggs can hatch on filter papers. It is important to allow slow desiccation of eggs as the embryo takes time to developed prior to the drying process. The low relative