International Journal of Biological, Life and Agricultural Sciences
ISSN: 2415-6612
Vol:1, No:5, 2007

ABURAS Index: A Statistically Developed Index for Dengue-Transmitting Vector Population Prediction

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Abstract*—**"Dengue" is an African word meaning "bone breaking" because it causes severe joint and muscle pain that feels like bones are breaking. It is an infectious disease mainly transmitted by female mosquito, Aedes aegypti, and causes four serotypes of dengue viruses. In recent years, a dramatic increase in the dengue fever confirmed cases around the equator's belt has been reported. Several conventional indices have been designed so far to monitor the transmitting vector populations known as House Index (HI), Container Index (CI), Breteau Index (BI). However, none of them describes the adult mosquito population size which is important to direct and guide comprehensive control strategy operations since number of infected people has a direct relationship with the vector density. Therefore, it is crucial to know the population size of the transmitting vector in order to design a suitable and effective control program. In this context, a study is carried out to report a new statistical index, ***ABURAS Index, using Poisson distribution based on the collection of vector population in Jeddah Governorate, Saudi Arabia.

***Keywords*—**Poisson distribution, statistical index, prediction, Aedes aegypti**.**

I. Introduction

DENGUE is an infectious disease transmitted from person to person by a mosquito, Aedes aegypti, which is a major vector for the virus in different parts of the globe; Ae. albopictus is also considered as a secondary vector, Fig. 1.

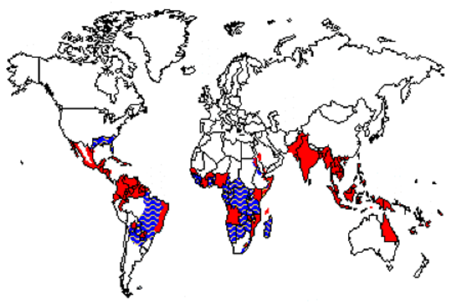

Fig. 1 Dengue Transmitting Vector World Wide

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The first recorded epidemics of dengue like disease occurred in 1635 in French West Indies, Batavia (Jakarta), and Cairo [2]-[7]. Dengue out-breaks were also reported from different parts of the world in the nineteenth and twentieth centuries. Over the past two decades, there has been a dramatic increase in the Dengue Hemorrhagic Fever (DHF) and Dengue Shock Syndrome (DSS) epidemics in South East Asian countries. World Health Organization (WHO) estimated that about 50-100 million cases of dengue are recorded from all over the world annually, and two fifth of the world population is at risk and more than one hundred countries have been affected by dengue or DHF/DSS epidemics. Since 1950, more than 500,000 hospitalized cases and approximately 70,000 deaths of the children have been recorded; infection rate among the children is as high as 64 per 1000 population [10].

Dengue is characterized by high fever, headache, pain in various parts of the body, prostration, rash lymphodenopathy, and leucopenia [3]-[7]. DHF is a severe febrile disease characterized by abnormalities of homeostasis and increased vascular permeability which may result into DSS [6]-[11]. Normally, cycles of dengue virus is transmitted from human-to-human by mosquito bites. Several species of mammals and lower primates act as reservoir of the dengue virus [9]. From feeding on an infected viraemic human, the female Aedes mosquito is able to transmit dengue virus after an extrinsic incubation period of 8-10 days. Aedes mosquito rests inaccessible areas behind the human dwellings; hence, the collection of these mosquitoes by hand catch is very difficult. However, the adult mosquitoes are being collected by either man-biting/landing or netting. These methods are considered as unethical issues for measuring the adult population. Therefore, attempts are being made to collect these mosquitoes through different types of traps developed by different companies. In this study, various types of traps have been tested to choose the most efficient one for the collection of Aedes population. As per our study, Balck Hole traps was considered as the most efficient traps, which was used in different parts of the study areas.

This paper describes a new statistical index to measure the size of adult mosquito population size.

II. Dengue in Jeddah Governorate, Saudi Arabia

Dengue fever made its first appearance in Jeddah city, Saudi Arabia, in 1994; and by the end of the year, approximately 300 cases were diagnosed and three dengue serotypes (Den1, Den2, and Den3) of viruses were reported [4]. Since that time continuous surveillance showed that dengue is no longer endemic in Jeddah city. The spread of the disease in Jeddah is due to its humid weather, lack of proper sewage disposal network, growth of slums, and the most important is its wide exposure to many different cultures through large number of pilgrims visiting the Holy city of Makkah via Jeddah as the transit gateway throughout the year. Hajj season provides a favorable opportunity for the introduction and exchange of pathogens of infectious diseases especially those coming from tropical and subtropical countries. In addition, some of the pilgrims may be in the incubation period of dengue infection and may actually be viraemic during Hajj season, infecting the mosquitoes and subsequently infecting the other pilgrims including local residents.

In 2006, dengue fever reported cases had risen drastically compared to the earlier recorded numbers. The government of Saudi Arabia has responded to the problem immediately by allocating more than one billion Saudi Riyals (more than two-hundred fifty US dollars) to combat the disease and to bring down the number of confirmed cases drastically. The government decision has identified roles and responsibilities among different government agencies and ministries including the Ministry of Municipality and Rural Affairs; Ministry of Health; Ministry of Agriculture, and Ministry of Water and Electricity.

The major role in combating dengue vector has been assigned to Jeddah Municipality through the Ministry of Municipality and Rural Affairs which has acted swiftly by establishing a Crisis Management Department (CMD) which has been staffed with highly qualified professionals in the field of Entomology, Biochemistry, Microbiology, Engineering, and interrelated disciplines.

CMD has taken the challenge seriously; and scientifically designed an Integrated Dengue Control Management Strategy (IDCMS) where many projects such as vector surveillance plus various control methods such as chemical, biological, and non traditional projects have successfully implemented to reduce the number of confirmed cases in the Governorate of Jeddah.

As mentioned earlier, one of the major pillars of the carefully designed IDCMS has been Mosquito Surveillance Project (MSP) which is operated simultaneously with the other control projects in the study area. More than five hundred mosquito traps have been geographically distributed in the governorate with the aid of recent processed satellite images and the Geographical Information System (GIS), Fig. 2. Different factors such as density of human population, number of recorded dengue cases, soil types, surface areas of breeding habitats including swamps and others have been considered for sites selection for placing the traps to collect Aedes population, Fig. 3.

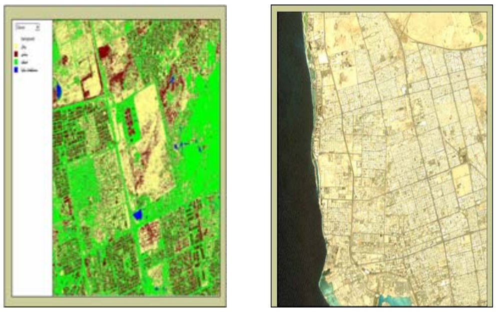

Fig. 2 Spot 5 Satellite Images

Fig. 3 Swamps Recorded for *Aedes* Mosquito Breeding in Jeddah

The adopted surveillance approach is to collect samples from the infested areas during the period from dawn to dusk with the help Black hole traps. Trapped mosquitoes are then brought to the laboratory for identification where the Aedes species are identified and male and female ratios are recorded every week, Fig. 4. Surveillance for Aedes aegypti is important in determining the distribution, population density, larval habitats in order to prioritize areas and seasons for vector control [10]-[12]. The correlation of different entomological indices in terms of actual disease transmission is difficult because there is always an inter-urban population movement, and fluctuation in adult mosquito population densities. The female Aedes population obtained through the surveillance traps is subjected to derive the index.

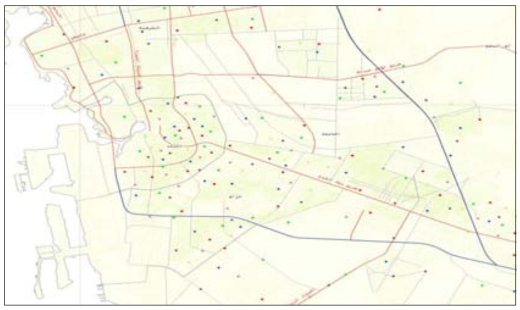

Fig. 4 GIS Sites for Fixing Mosquito Traps in Jeddah

III. The Conventional Indices

As per literature, conventional indices are in use to monitor the vector populations for dengue virus transmission, such as House Index (HI), Container Index (CI), Breteau Index (BI) and those indices are based on the aquatic immature stages only. However, none of them describes the adult mosquito populations.

The larvae are collected form different water holding containers infested with larvae and pupae. The indices used to monitor the immature stages are the House/Premises Index (HI), i.e., the percentage of houses infested with larvae and/or pupae with one or more habitats for Aedes aegypti or related species. The formula used is as follows:

$$HI = \frac{\text{Number of infested houses}}{\text{Number of inspected houses}} \times 100 \qquad (1)$$

The Container Index (CI), i.e., the percentage of water holding containers infested with larvae and/or pupae.

$$CI = \frac{\text{Number of infested containers}}{\text{Number of inspected containers}} \times 100 \qquad (2)$$

The Breteau Index (BI), i.e., the number of positive container per hundred houses inspected.

$$BI = \frac{\text{Number of infested containers}}{\text{Number of inspected houses}} \times 100 \qquad (3)$$

The emergence of adult mosquito population can be estimated by the pupal count (i.e., by counting all pupae found in each container [13]. The corresponding index is the Pupal Index (PI), i.e., the number of pupae per 100 houses.

$$PI = \frac{\text{Number of pupae}}{\text{Number of inspected houses}} \times 100 \qquad (4)$$

The above conventional indices are mainly used for the surveillance of immature stages of the mosquito in operational programs. Although certain methods are mentioned in WHO guideline [12] such as man-landing/biting collection, resting collection and ovi-position traps methods, no statistically based index for Aedes population prediction has been reported elsewhere.

IV. Statistically Developed Index for Aedes Population

It is obvious that all reported conventional indices focus on immature stages and no specific one has been developed for the Aedes adult population. Furthermore, although Aedes adult vector density has been developed so far, no specific and statistically-based index has been derived. In addition, such an adult index can provide valuable information on seasonal trends, transmission risks and dynamics, and the overall density in a given area.

In this paper, statistically-based index for adult Aedes population has been developed. The development approach has been mainly based on the Poisson distribution, Fig. 5. It is known that the Poisson distribution was introduced and named for the French mathematician S.D. Poisson. It describes wide range of random variables quite well in addition to its mathematical simplicity [1]. Poisson distribution is a useful one for many random phenomena; it provides a model for the relative frequency of number of rare events that occur per unit time, area, volume [5].

The Poisson probability mass function is as follows:

$$p(x) = \frac{\lambda^x e^{-x}}{x!} \qquad (x = 0,1,2,\ldots) \qquad (5)$$

where, λ is the mean number of events during a given unit time, area, or volume and e is natural logarithm. Among the important properties of the Poisson distribution is that both mean and variance are equal to λ.

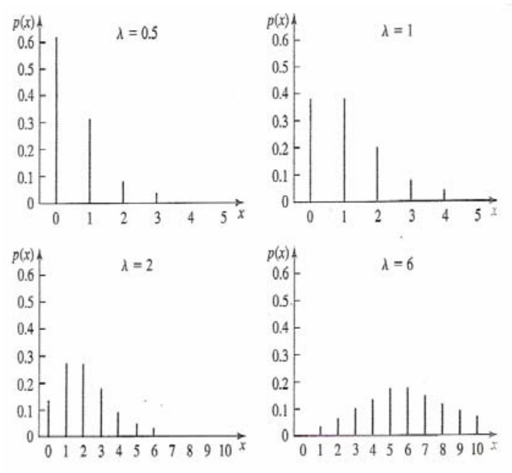

Fig. 5 Poisson Probability Mass Functions

In order to develop the statistically-based index for adult Aedes population, the available data in the study area has been used; Poisson distribution has been fit to the collected data and distribution parameters have been computed. The computed average represents the average number of mosquitoes per trap area.

Let X be the number of mosquitoes per trap then, the Expected value of [X] per week, E[Xw] = $\overline{X_{504}}$, where $\overline{X_{504}}$ represents the average number of mosquitoes collected in all traps per each international week.

However, the Expected number of mosquitoes = $\overline{X_{504}} \times n$, where n equals to the total number of distributed traps, i.e., 504 traps. In other words, the calculated average is multiplied by the number of traps to get the expected number of mosquitoes within the study area.

V. Results

A comparison between actual and predicted Aedes population based on the collected samples has been illustrated in Fig. 6. It is clearly shown that reliable and conservative prediction exists; however, the present data plays major role in drawing more accurate and consistent conclusions.

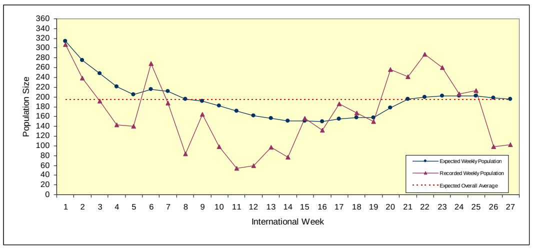

Fig. 6 Actual versus Predicted *Aedes* Populations

VI. Conclusion

Though conventional indices are being used in operational programs in different regions, no statistically-based measurement of Aedes adult population is being practiced. Poisson distribution, due to its nature and typical usage, has been used. The derived statistically-based index for the Aedes adult population could be applied by operational personnel involved in any dengue control programs, elsewhere. The actual and computed densities have shown good prediction correlation. In addition, it could be easily extended to predict the expected number of confirmed dengue cases.

Researchers involved in dengue control programs could easily utilize the presented approach and investigate different statistical distributions.

Acknowledgment

I would like to thank my colleagues at CMD, Jeddah Municipality for their valuable comments and observations.

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