The Use of GIS in Ovitrap Monitoring for Dengue Control in Singapore+

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Abstract

Ovitraps are used extensively in Singapore as a tool to monitor, detect and control *Aedes* populations. They give an approximate gauge of the adult population in an area and act as an early warning signal to pre-empt any impending dengue outbreaks. A Geographic Information System (GIS) was established in 1998 to develop a real-time *Aedes* mosquito control and monitoring system for spatial epidemiological study. The GIS monitors the network of 2000 ovitraps placed island-wide to better understand vector trends and disease patterns. Analysis is done on the ovitrap breeding data collected weekly to identify hotspots and risk areas where there is a danger of high *Aedes aegypti* infestation. Three ovitrap models had been developed to analyse the ovitrap breeding data collected. The analysis results are used to plan vector surveillance and control operations. This paper reports the experience of this control and monitoring methodology in Singapore.

Key words: GIS, Ovitrap, Dengue control, *Aedes*, Singapore.

Introduction

Singapore is a tropical island with a land area of 682.7 sq km and a population of four million, characterized by uniform temperature (mean daily ≈ 26.8°C), high humidity (mean daily ≈ 84.3%) and abundant rainfall (mean annual ≈ 2346 mm) throughout the year. The city-state lies just north of the equator near latitude 1.5 deg N and longitude 104 deg E.

Dengue is endemic in Singapore and has seen a recent resurgence despite an effective vector control programme based on a three-pronged approach that incorporates source reduction, public health education and law enforcement(1). Several factors resulted in the resurgence of dengue in Singapore. The immunity level of the population has declined(1) while adult densities of the *Aedes* vectors have

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+ As this paper is focusing on the use of GIS for ovitrap monitoring, therefore the author did not elaborate on the other layers that were used in GIS analysis. – Editor.

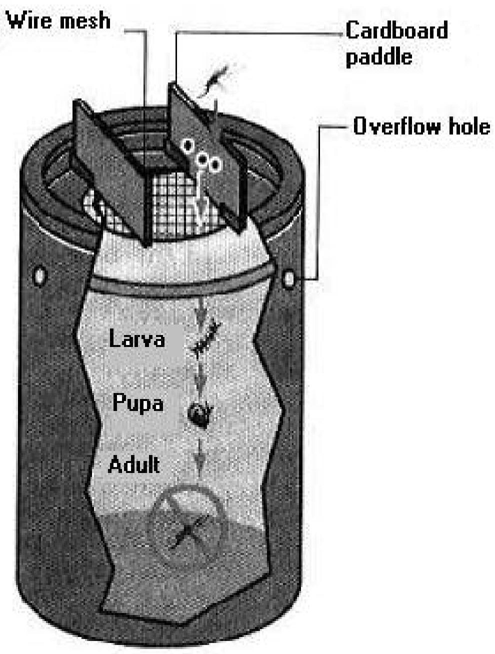
multiplied due to the rise in temperatures and increased rainfall[(2)]. Climatic changes have been reported to affect the biology and behaviour of the vectors, allowing them to develop higher competence for dengue transmission[(3)].

Ovitraps

Ovitrap surveys could be considered a sensitive and an efficient technique for detecting and monitoring *Aedes* populations at low densities. They are safe, economical and environment-friendly[(4)]. With only 10% of the island under active *Aedes* mosquito field surveillance due to limited manpower for vector control, the extensive use of ovitraps is an important resource to help collect data on *Aedes* population on a wider area and gauge the effectiveness of control efforts.

Currently, ovitraps (Figure 1) are used as a means of detecting *Aedes aegypti* presence as well as an approximate gauge of the adult population in an area. It can be used to estimate fairly well the population of adult mosquitoes in the environment by counting the number of eggs laid on the moist paddle. In this way, a sudden increase of mosquito population can be detected. Changes in the species breeding (*Aedes aegypti* to *Aedes albopictus* or vice versa) can also be detected. The ovitraps are checked weekly for breeding and the breeding samples, if any, are collected and identified by the laboratory. The ovitraps are then cleaned to remove any eggs that are stuck on the inner walls of the ovitraps, re-filled with cow grass solution which is much more attractive to the female mosquitoes than just water, and placed back in their positions. The paddles are collected and replaced with new ones. The collected paddles are checked under the microscope for eggs which are also counted.

Figure 1. **Diagram of an Ovitrap**



There are 2000 ovitraps placed on the island currently, 30% are placed inside premises, while 70% are placed outside premises under shade. Most of the premises are residences although there are some which are schools and commercial buildings. The bulk of the ovitraps are placed in dengue "sensitive areas (SAs)" where regular search-and-destroy rounds are carried out. Others are placed in previous SAs that had already been cleaned up, for early detection of any resurgence of the vector. Some are also placed in persistent complainants' homes to determine the mosquito species that cause the nuisance.

Geographic Information System (GIS)

A GIS is an automated computer-based system with the ability to capture, retrieve, manage, display and analyse large quantities of spatial and temporal data in a geographical context. The system comprises hardware (computer and printer), software (GIS software), digitized base maps, information and a whole set of procedures such as data collection, management and updating(5).

Specific diseases and public health resources can be mapped in relation to their surrounding environment and existing health and social infrastructures. Such information when mapped together creates a powerful tool for the monitoring and management of disease(6). GIS provides a graphical analysis of epidemiological indicators over time, captures the spatial distribution and severity of the disease, identifies trends and patterns and indicates where there is a need to target extra resources.

In 1998, a GIS was established in Singapore to research as well as to support operations on dengue control. Roads, residential buildings and other relevant databases were obtained and mapped to form the base map layer using Arcview GIS 3.2a. Other layers such as *Aedes* breeding sites, dengue case incidences, complainants' addresses, sensitive areas, weather data (rainfall, temperature and relative humidity) and other related information were also mapped into the GIS.

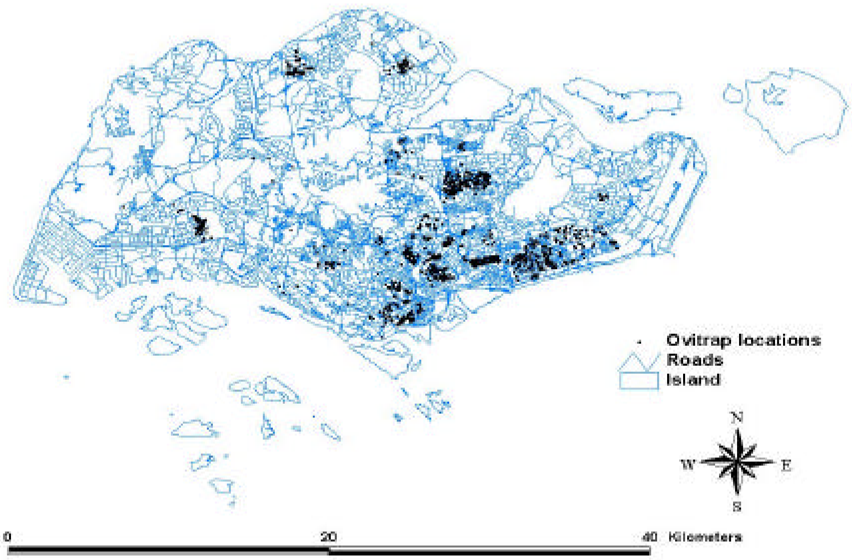
Application of GIS on ovitraps

An ovitrap layer comprising a spatial map and an attribute table was created in the GIS for monitoring and analysing the network of ovitraps placed island-wide to better understand vector trends and disease patterns (Figure 2). Every ovitrap placed is given a unique number for identification and its spatial location is stored in the GIS. The attribute table behind this ovitrap layer stores the ovitrap's identification number, the surveillance team in charge of the ovitrap, the date of the weekly collection, the address of the site, the housing type of the site (e.g. flat, house, school, etc.), the position of the ovitrap (indoor or outdoor), the status of the ovitrap (removed or missing), the species found in the ovitrap, the larval instars and pupal stages, the breeding density, the mixed breeding species types (e.g. *Aedes aegypti* and *Aedes albopictus*, *Aedes aegypti* and *Culex quinfasciatus,* etc.*)* and the dominant species type breeding in that ovitrap for that week. In the case of a mixed breeding, the species which had a higher density would be the dominant species. Decisions on operations and deployment of manpower are made using the ovitrap information as well as databases on diseases and mosquito surveillance results.

Routine monitoring of *Aedes aegypti*

Analysis is done on the results collected weekly to identify hotspots or risk areas where there is a danger of *Aedes aegypti* infestation, to pre-empt any impending dengue outbreak. As a huge amount of data is collected weekly, there is a need to sieve out only the important and useful information. A query is done to gather all the *Aedes aegypti* breeding ovitrap sites as this mosquito is known to be the primary vector

Figure 2. **Spatial distribution of ovitraps in Singapore**



in the transmission of dengue in Singapore(7). These ovitrap sites would be sorted by density and addresses to highlight high breeding areas and areas with many breeding ovitraps. These ovitrap sites are also clustered if there are two or more *Aedes aegypti* breeding ovitraps within a distance of 250 metres. This distance is the normal flight distance of the vector, which is not further than 240 metres in Singapore(8). The distribution of *Aedes aegypti* breeding in the ovitraps for each SA is also summarized weekly to highlight the "hot" SAs where total breeding density in ovitraps remains relatively high for a number of weeks when compared with other SAs. Another important indicator is the change in the dominant species of a particular ovitrap. If other mosquito species had been detected consistently and *Aedes aegypti* is suddenly found in the ovitrap, then that area will be placed on high alert and monitored carefully. This change means that the vector has invaded an area where it was not previously found and an outbreak might soon occur.

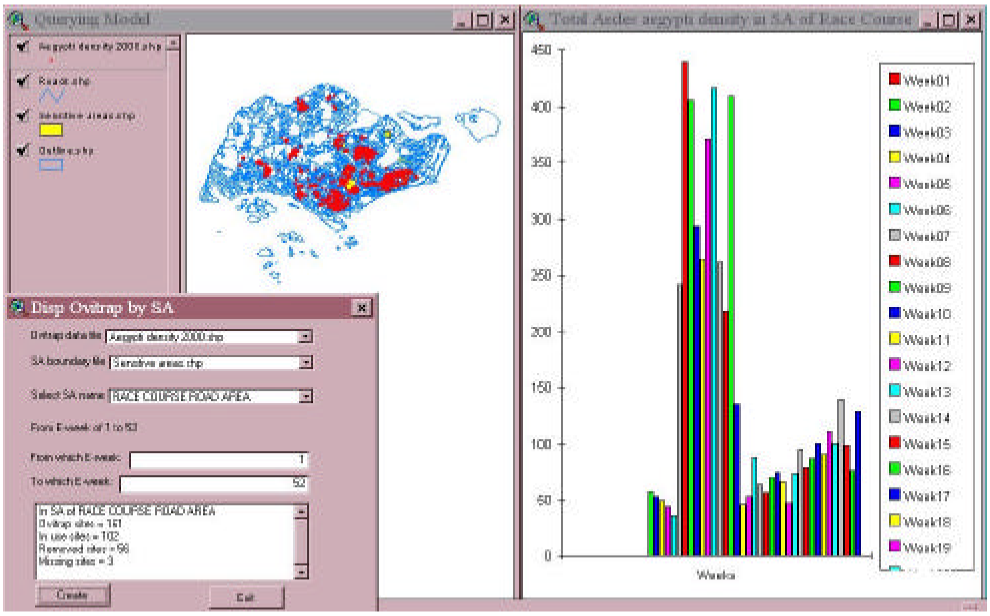
Ovitrap models

Three models had been developed to monitor, analyse and evaluate ovitrap breeding data to better understand the *Aedes* situation on the island for surveillance purposes.

Hotspot model

A hotspot ovitrap model was developed to display, identify and highlight ovitrap sites that have been breeding above a certain density level for a specific number of weeks during a defined time period. For example,

Figure 3



The inset shows the query model where we select the output data file as "*Aegypti* density 2000", SA as "Race Course Road Area" and week 1 to 52 to display total *Aedes aegypti* density by weeks for year 2000 in Race Course Road area. The bar graph is generated for the query, where the y-axis gives the total *Aedes aegypti* density and the x-axis with its different colour bars represents the weeks in the year 2000.

we set the density as greater than one larva or pupa per ovitrap and the time period as four weeks to identify ovitraps that had been breeding consistently for the past four weeks. This model is particularly useful for identifying areas that had been having high *Aedes aegypti* population density consistently for some time and should be paid extra attention. It can also be used to gauge whether control efforts in the area have been effective or successful.

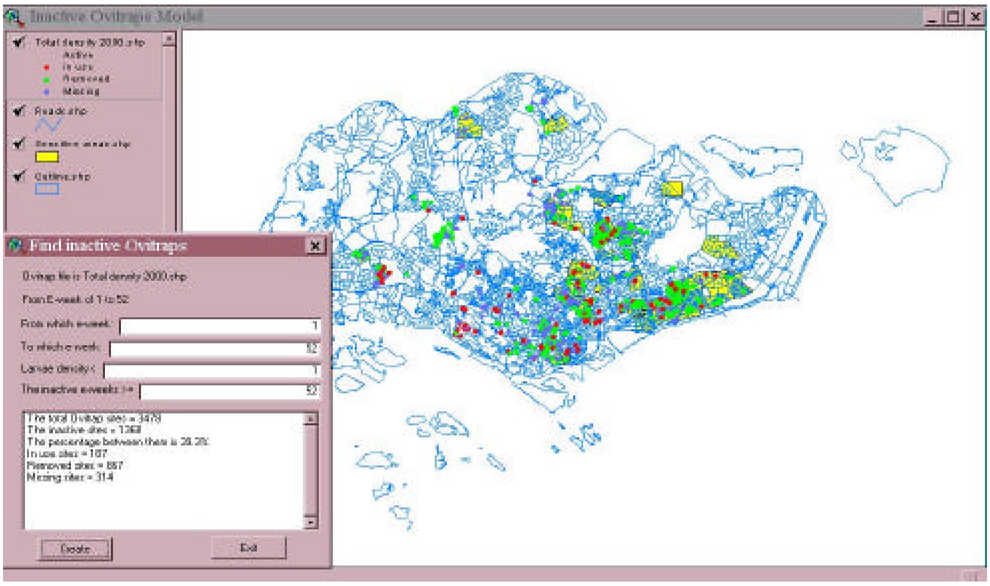
Query model

The query model was developed to generate and display bar graphs of total ovitrap breeding density for a specific SA or any selected area for a defined time period by weeks. With this model, surveillance teams are able to query the ovitrap breeding situation in an area for any defined time period. Figure 3 shows the query model and results displayed for Race Course Road for the year 2000.

Inactive ovitraps model

The inactive ovitrap model was developed to identify ovitrap sites with low or no breeding for a defined time period (Figure 4). These locations are then evaluated to see if there was a need for the ovitraps to be shifted to another location where breeding might be detected to promote more efficient use of the ovitrap.

Figure 4



The inset shows the inactive ovitrap model where we select the output file as "Total density 2000" which stores the breeding data, week 1 to 52, larval density < 1 and inactive weeks = 52 to identify all the inactive ovitraps in the year 2000 which are represented by red dots on the map.

Discussion

With the build-up of epidemiological and entomological databases, the next step would be to develop spatial analytical methods and models to test hypotheses concerning vector and disease relationships and the nature and processes of disease transmission. These modellings will involve the integration of GIS with standard statistical and epidemiological methods. The spatial modelling capacities offered by GIS can help one understand the spatial variation in the incidence of disease and its covariation with environmental factors and public health systems. Important technical and logistical innovations in data and data access for GIS are already available in the market. There has also been greater accessibility to global positioning systems and availability of inexpensive hand-held devices for using the system and the addition of direct-to-GIS data links to these systems[9].

Singapore will start using palmtops to gather field *Aedes* surveillance data in the near future. We are working to develop an optimal ovitrap sampling frame and eventually come up with an accurate ovitrap index as an indicator for actions. With the use of ovitraps and the GIS, the task of vector and disease surveillance will be brought to greater heights. Information will be available in realtime and other discoveries about the relationship between vector and the disease could be made possible through spatial analyses. A greater understanding of the vectors would bring us a step closer to eradicating dengue fever in Singapore.

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