THE MOSQUITO ONLINE ADVANCED ANALYTIC SERVICE: A CASE STUDY FOR SCHOOL RESEARCH PROJECTS IN THAILAND

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Abstract. The Mosquito Online Advanced Analytic Service (MOAAS) provides an essential tool for querying, analyzing, and visualizing patterns of mosquito larval distribution in Thailand. The MOAAS was developed using Structured Query Language (SQL) technology as a web-based tool for data entry and data access, web*Mathematica* technology for data analysis and data visualization, and Google Earth™ and Google Maps™ for Geographic Information System (GIS) visualization. Fifteen selected schools in Thailand provided test data for MOAAS. Users performed data entry using the web-service, data analysis, and data visualization tools with web*Mathematica*, data visualization with bar charts, mosquito larval indices, and three-dimensional (3D) bar charts overlaying on the Google Earth™ and Google Maps™. The 3D bar charts of the number of mosquito larvae were displayed along with spatial information. The mosquito larvae information may be useful for dengue control efforts and health service communities for planning and operational activities.

Keywords: mosquito, web database, *Aedes* larvae, Google Earth™, Google Maps™

INTRODUCTION

Aedes mosquitoes transmit dengue virus, responsible for dengue infection. Dengue fever is a leading cause for hospitalizations of children in Thailand (Phuanukoonnon *et al*, 2005). With the absence of an effective vaccine or chemotherapy, prevention of dengue is currently only possible by control of the principal vector (*Aedes aegypti*) and secondary vector (*Ae. albopictus*) (Hay *et al*, 2000; Stephenson *et al*, 2003; WHO, 2009), and by using personal protection from the bites of infected mosquitoes (WHO, 2009).

Active participation by the at risk human population is essential for control, especially by elimination of vector breeding sites (Chiaravalloti-Neto, 1997). A previous study showed education of students is a crucial factor for initiating community engagement and participation in the control of mosquito vectors (Regis *et al*, 1996). The school environment is ideal for development of dengue education modules, principally because of its division by age and level of knowledge, allowing teaching to be conducted at different levels of complexity. The teacher

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pupil relationship is conducive of participation in mosquito larva reduction efforts in their homes (Madeira *et al*, 2002). However, information alone is insufficient to effect behavioral changes. In this study, we developed the Mosquito Online Advanced Analytic Service (MOAAS) as an advanced tool for querying, analyzing, and visualizing patterns of mosquito larva distribution in Thailand.

MATERIALS AND METHODS

System architecture

The MOAAS was programmed using the computer languages Hypertext Markup Language (HTML), Java Server Page (JSP), and web*Mathematica* technology, while Apache Tomcat 6.0 and Microsoft SQL Server 2008 were used as the web server software and database management system, respectively (Fig 1).

JSP technology provides an easy way to create dynamic web pages and simplify the task of building web applications that work with a wide variety of web servers, application servers, browsers, and development tools (McPherson, 2012). A JSP page is simply an HTML web page that contains additional bits of code, which execute application logic to generate dynamic content. When the page is displayed in a user's browser, it contains both the static HTML content, and the dynamic information retrieved from the database. While HTML tags are processed by a user's web browser to display the page, JSP tags are used by the web server to generate dynamic content (Sun Developer Network, 2011).

Web*Mathematica* offers access to specific *Mathematica* applications through a web browser or other web clients. Web*Mathematica* adds interactive calculations and visualizations to websites by integrating *Mathematica* with the latest web server technology (Wolfram Research, 2011).

JSP is used for contacting Apache Tomcat and Microsoft SQL Server. Scripts written in JSP interpret the query keys input in the home page and retrieve suitable data from the Microsoft SQL Server database. In the system, we make JSP work in partnership with web*Mathematica* technology, so it generates graphic images and advanced statistical tools, such as the chi-square test, regression analysis and time series analysis.

System evaluation

The objective of the study was to evaluate student perceptions of the MOAAS. A questionnaire was given to the students after they had used the MOAAS for approximately one year. The questionnaire consisted of 13 questions under four main headings: evaluation of education materials, user-program interaction satisfaction, evaluation of MOAAS's features, and evaluation of the educational process.

We randomly selected four out of 15 schools from four regions in Thailand. A total of 124 students took part in the system evaluation. The questionnaire was given to the participants by their teachers. Participants were asked to fill out the questionnaire indicating their level of agreement with a statement using a five-point Likert scale. The students' anonymous responses were collected by their teachers, who then forwarded them to the system administrator.

RESULTS

We have developed a GLOBE (Global Learning and Observations to Benefit the Environment) Mosquito Protocol for Thailand in collaboration with scientists from the GLOBE Seasons and Biomes

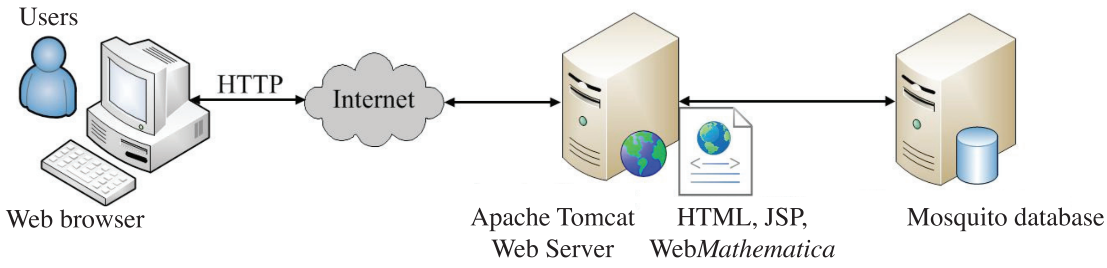


Fig 1–Overview of the system architecture.

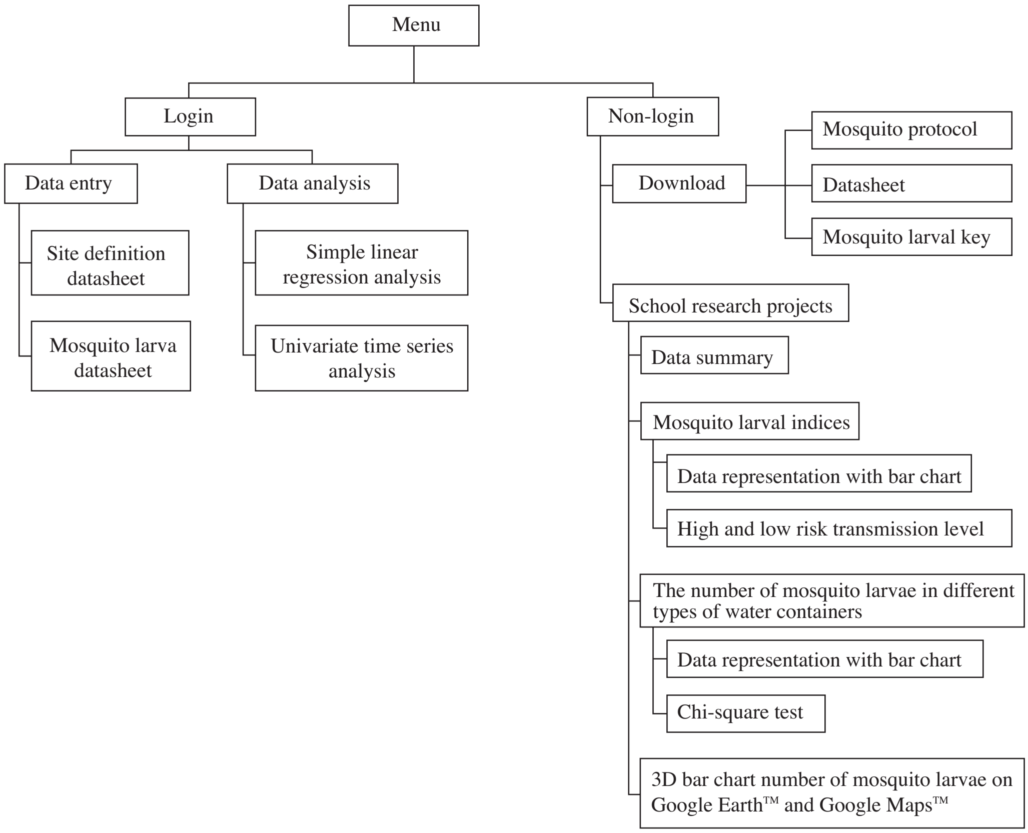


Fig 2–Summary of the functions of the system.

program, as well as those in Thailand. Participating teachers and students had a chance to learn about mosquito research and to conduct school research projects through the Mosquito Protocol, which the Institute for the Promotion of Teaching Science and Technology (IPST) in Thailand has explored in science classrooms. All certified participants are required to complete the Thailand GLOBE Mosquito Protocol Training in the mosquito larval survey, identification of mosquito larval species, data entry, data representation, data analysis and data interpretation.

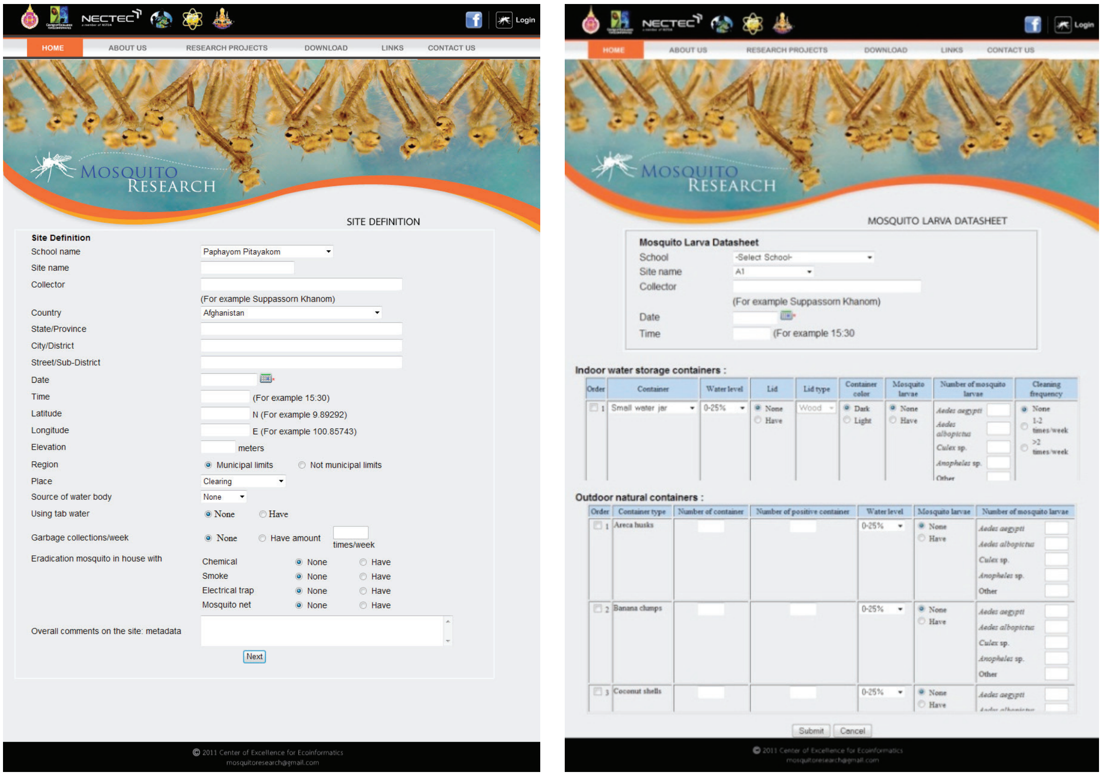
Fig 3-The MOAAS home page.

System description

The system was designed to be used by two groups of users: researchers and the general public. Users can access MOAAS with or without logging into the system. For security reasons, the login system requires a username and password obtained only from the system administrator. Following the login, users can choose two main functions: data entry and data analysis. Users not logged in have access to school research projects and the general information (Fig 2). Since December 2007, a prototype MOAAS has been available online at URL http://www.twibl.org/mosquito (Fig 3).

Data entry suite

Data entry can include one or more of the following factors: socio-economic data: *ie,* school, site name, collector, address, date, time, latitude, longitude, elevation, region, water source, water supply, garbage collection frequency, and mosquito eradication methods (Fig 4a); and mosquito collection data: *ie,* type of water container, water level, with/without lid, lid type, earthen/plastic container, container color, mosquito larva count,



(a) (b)

Fig 4–Data entry suite. (a) Site definition containing socio-economic data, and (b) mosquito larvae datasheet containing data regarding mosquitoes in both indoor and outdoor water storage containers.

species name, and water container cleaning frequency (Fig 4b). The MOAAS can have data input regarding socioeconomic variables by users from other countries. The MOAAS is designed to check for data consistency. For example, if users indicate "without lid" and then try to put the type of lid in the database, the MOAAS will not allow this. In addition, the system provides data accuracy checking by allowing the user to preview the data before adding the data to the mosquito database.

Data analysis tools

The statistical analysis tools provide the pages for uploading the data to the MOAAS server for real-time data analysis online, *ie*, regression analysis and time series analysis. Users can examine associations between variables using simple linear regression analysis (Fig 5a). They can also determine a predictive model and data validation from the model using univariate time series analysis (Fig 5b).

School research projects

The MOAAS generates a report according to the input parameters selected by the user. Users can visualize their monthly mosquito larva data in a bar chart format. Users can view the number of mosquito larvae in different water containers: *ie*, indoor/outdoor container, dark/light colored containers, containers

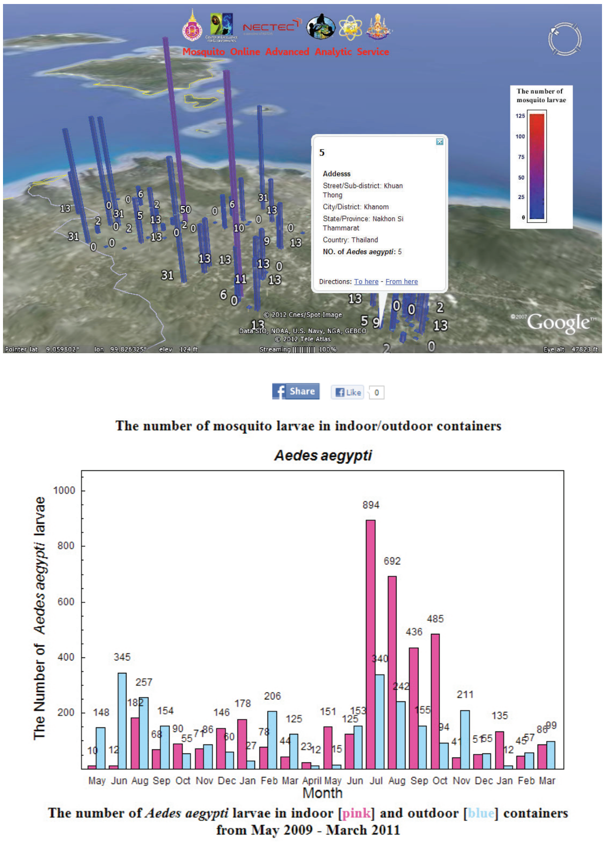
(a) (b)

Fig 5–Data analysis tools. (a) Regression analysis tool and (b) time series analysis tool.

with lids/without lids, earthen/plastic containers, and artificial/natural containers; mosquito larval indices (House Index, Container Index, and Breteau Index); and the mosquito larva distribution in 3D bar charts on Google Earth™. The users can visualize the number of mosquito larvae by 3D bar charts online via Google Earth™ and Google Maps™ by selecting the period and the mosquito larval species or by viewing all species (Fig 6a). Users can download the number of mosquito larvae in the 3D bar chart on Google Earth™ onto their local disk in the Keyhole Markup Language (KML) files format to display on Google Earth™. Users can compare the number of mosquito larvae in the different types of water containers using the chi-square test (Fig 6b, c). Users can "Share", "Like," or "Comment" on the results page via social networking services (*ie*, Facebook). Users can post the results

(a)

(b)



(c)

Mosquito larval statistics :

Container type	Sum	Maximum	Minimum	Mean
Indoor containers	4043	894	10	183.773
Outdoor containers	2957	345	12	128.565
Statistical test:				
$\chi^2_{0.05;1} =$ 168.485				
Reject null hypothesis at significance level 0.05: There were significant differences between number of mosquito larvae in indoor and outdoor containers				

Fig 6–School research projects. (a) GIS tool displaying the number and distribution of mosquito larva using 3D bar charts on Google Earth™, (b) graphic tool displaying the monthly mosquito larvae in indoor and outdoor containers and (c) statistical tool showing the max/min/mean results and the results from the chi-square test.

of the MOAAS to a Facebook page. They can view abstracts, posters, and conference proceedings. The system can report a data summary in a printable format.

System evaluation

The MOAAS was tested with actual data collected from 15 randomly selected schools from four regions in Thailand (Fig 7). Entomological and socio-economic data associated with dengue fever were collected by students at the selected schools.

Table 1 shows the results of the quantitative study derived from the questionnaires of the 124 students. The mean and standard deviation results for each statement, in a five-point Likert scale are also shown in Table 1. Students appeared to be satisfied with the quality of educational materials. They expressed their satisfaction with the interaction with the program's interface from which they could more easily adapt the data to suit the needs of their science classwork. They specifically indicated that the GIS tool and school research project sections were the most useful parts of the MOAAS features (Table 1), and were of the opinion the system provided valuable knowledge (4.290). The use of the MOAAS provided a high level of motivation for their learning process (4.306). Overall, the participating students found the MOAAS useful for conducting research regarding mosquito larvae and related fields (4.427) (Table 1).

DISCUSSION

The internet is an integral part of daily life in many countries. It is an increasingly important tool to reduce

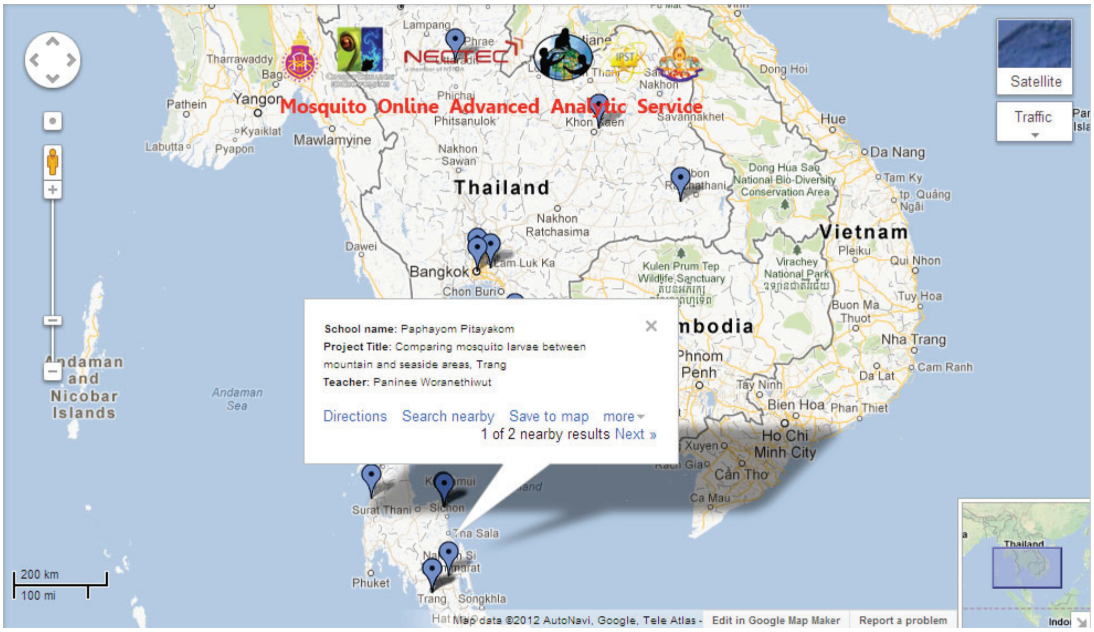


Fig 7–The 15 selected schools from four regions in Thailand with a description of the school project.

technological barriers and make it easier for users from different geographical locations to access decision support models and tools (Papic *et al*, 2009). Databases are an essential, widely used technology for biomedical research projects (O'Connor *et al*, 2009). A web database and Geographic Information System (GIS) technology are increasingly used in medical and health education, health science, and environmental science research (Harris *et al*, 2009; Herzberg *et al*, 2009; Ng *et al*, 2009; Papic *et al*, 2009; Simão *et al*, 2009; Wang *et al*, 2009; Wright *et al*, 2009).

The system can be accessed from anywhere via the internet. Web-based solutions result in significantly lower deployment costs. Web browsers are available for most popular hardware and operating systems and provide access to a variety of servers. It is not necessary to install vender-specific database access drivers on individual client computers, thereby lowering both licensing costs and administrative overhead. A variety of simple and complex user interfaces (check boxes, radio buttons, pull down menus and text boxes) can easily be designed using HTML. The HTML interface can accommodate multimedia information in the display.This allows even beginners to successfully complete their operation (Inoue *et al*, 2003).

As part of the Java technology family, JSP technology enables rapid development of web-based applications that are platform independent. JSP technology separates the user interface from content generation, enabling designers to change the overall page layout without altering the underlying dynamic content. Besides JSP, there are other software programs for creating a web-based server system, such as Active Server Page (ASP) or Hyper-

Table 1
Questionnaire about students' perceptions towards the MOAAS. Each statement was given a score of 1-5 using a five point Likert scale.

Evaluation of educational materials	Mean ± SD
Is the quality of the educational material (texts, images) adequate?	3.895±0.844
How compatible is the educational material with the mosquito project?	4.234±0.664
User-program interaction satisfaction	
Is information structured in a meaningful and consistent way?	4.234±0.688
How easily were the materials adapted to the science class?	4.113±0.665
How familiar do you feel with the terminology used?	4.492±0.821
Evaluation of MDS's features	
How useful is the data entry suite?	4.048±0.835
How useful is the data analysis tool?	4.250±0.792
How useful is the GIS tool?	4.468±0.801
How useful is the school research project section?	4.339±0.697
How useful is the download section?	4.137±0.790
Evaluation of educational process	
Does the system stimulate your search for knowledge?	4.290±0.814
Does the system provide motivation for participating in the mosquito project?	4.306±0.745
Do you find the system useful for doing research about mosquito larvae or related fields?	4.427±0.723

text Preprocessor (PHP) (Sun Developer Network, 2011). We adopted JSP because web*Mathematica* is based on *Mathematica* and two standard Java technologies: Java Servlets and JSP. Servlets are special Java programs that run in a Java-enabled web server, which is typically called a "servlet container" or sometimes a "servlet engine". There are different types of servlet containers that can run on different operating systems and architectures. The servlet containers can also be integrated into other web servers, such as the Apache web server (Wolfram Research, 2011). JSP can easily generate KML files for the GIS tool and advanced statistical tests by using web*Mathematica*. KML files are used to display geographic data in many applications, including Google Earth, Google Maps, Google Maps for mobile, NASA WorldWind, ESRI ArcGIS Explorer, Adobe PhotoShop, AutoCAD, and Yahoo! Pipes (Google Developers, 2012).

In 1992, the Ministry of Public Health and the Ministry of Education in Thailand began to integrate information about dengue into the primary school curriculum. Since 1998, vector control and health education specialists have worked throughout the country, applying larvicide and fogging during the epidemic season (Nagao *et al*, 2003). The intervention has not been sufficient for dengue control, and high risks of dengue transmission continue to exist in several regions of Thailand (WHO, 2009). Therefore, the MOAAS was developed to create online data entry and data visualization regarding *Aedes* mosquito larvae associated with dengue transmission. The mosquito larval occurrence data in the study sites are suitable for monitoring epidemics for early warning purposes

(Nagao *et al,* 2003). These monitoring products are automatically updated when new data become available.

Vector-borne and other infectious diseases place tremendous public health burdens on developing countries. Even when management solutions are available, many are not economically feasible to implement in areas with the greatest need. Therefore, a part of the new frontier in infectious disease research must be adapting technologically advanced and costly concepts for disease management to operational use in resource-poor environments through the development of low-cost tools and solutions (Lozano-Fuentes *et al,* 2008).

The emergence of Virtual Globe software systems (*ie*, Google Earth™) has revolutionized the traditional way of using geospatial information, making global geospatial information accessible to and usable by the general public instead of only by highly-skilled domain experts (Boulos, 2005). Google Earth™ is an excellent example of a freely accessible tool with great potential for improving public health (Lozano-Fuentes *et al,* 2008). The MOAAS has integrated Google Earth™ and Google Maps™ to display geospatial information, showing mosquito larval distribution in 3D bar charts on Google Earth™ and Google Maps™, which has helped scientists, teachers, and students visualize the dengue risk areas. Previous findings showed topography, season, and type of water container impacted the number of *Aedes* larvae in Thailand (Thavara *et al,* 2001; Wongkoon *et al,* 2005, 2007). Together with the mosquito larvae data in the system, a 3D bar chart can be created in Google Earth™ and Google Maps™ as an interactive map that displays the number of mosquito larvae, and the monthly number of mosquito larvae, in different types of water containers. Users may gain insight into how these conditions affect the *Aedes* larval occurrence. These tools can be used for vector control programs to guide prevention, surveillance, and control efforts in high risk areas. They can also be used to inform public health offices or local decision-makers about spatial risk patterns (Lozano-Fuentes *et al,* 2008). The results of real-time on-line statistical testing are useful for the users to find some immediate relationship.

In conclusion, this system helps to identify dengue risk areas and design effective dengue control strategies. The MOAAS provides advanced tools for querying, analyzing, and visualizing patterns of mosquito larval distribution in Thailand. If there were more data in the system for other areas of Thailand and other countries in the world, the additional information could be used for better decision-making regarding mosquito larva control and dengue transmission prevention.

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REFERENCES

Boulos MN. Web GIS in practice III: creating a simple interactive map of England's Strategic Health Authorities using Google Maps API, Google Earth KML, and MSN Virtual Earth Map Control. *Int J Health Geogr* 2005; 4: 22.

Chiaravalloti-Neto F. The population's knowledge concerning dengue fever, vectors, and control measures in São José do Rio Preto, São Paulo State. *Cad Saúde Pública* 1997; 13: 447-53.

Google Developers. Keyhole Markup Language. Mountain View, CA: Google, 2012. [Cited 2012 Nov 20]. Available from: URL: https://developers.google.com/kml/documentation/

Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)-A metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 2009; 42: 377-81.

Hay SI, Myers MF, Burke DS, *et al*. Ethology of interepidemic periods of mosquito-borne disease. *PNAS* 2000; 97: 9335-9.

Herzberg D, Marsden N, Kübler P, *et al*. Specifying computer based counselling systems in health care: A new approach to user-interface and interaction design. *J Biomed Inform* 2009; 42: 347-55.

Inoue M, Hasegawa S, Suyama A, Meshitsuka S. Automated graphic image generation system for effective representation of infectious disease surveillance data. *Comput Meth Prog Bio* 2003; 72: 251-6.

Lozano-Fuentes S, Elizondo-Quiroga D, Farfan-Ale JA, *et al*. Use of Google Earth™ to strengthen public health capacity and facilitate management of vector-borne diseases in resource-poor environments. *Bull World Health Organ* 2008; 86: 718-25.

Madeira NG, Macharelli CA, Pedras JF, Delfino MCN. Education in primary school as a strategy to control dengue. *Rev Soc Bras Med Trop* 2002; 35: 221-6.

McPherson S. JavaServer Pages: a developer's perspective. Redwood City: Oracle, 2012. [Cited 2012 May 20]. Available from: URL: http://www.oracle.com/technetwork/articles/javase/jsp-135132.html

Nagao Y, Thavara U, Chitnumsup P, Tawatsin A, Chansang C, Campbell-Lendrum D. Climatic and social risk factors for *Aedes* infestation in rural Thailand. *Trop Med Int Health* 2003; 8: 650-9.

Ng CKC, White P, Mckay JC. Development of a web database portfolio system with PACS connectivity for undergraduate health education and continuing professional development. *Comput Meth Prog Bio* 2009; 94: 26-38.

O'Connor MJ, Shankar RD, Parrish DB, Das AK. Knowledge-data integration for temporal reasoning in a clinical trial system. *Int J Med Inform* 2009; 78S: S77-85.

Papic V, Rogulj N, Pleatina V. Identification of sport talents using a web-oriented expert system with a fuzzy module. *Expert Syst Appl* 2009; 36: 8830-8.

Phuanukoonnon S, Meuller I, Bryan JH. Effectiveness of dengue control practices in household water containers in Northeast Thailand. *Trop Med Int Health* 2005; 10: 755-63.

Regis L, Furtado AF, Oliveira CMF, *et al*. Integrated control of the filariasis vector with community participation in an urban area of Recife, Pernambuco, Brazil. *Cad Saüde Püblica* 1996; 12: 473-82.

Simão A, Densham PJ, Haklay M. Web-based GIS for collaborative planning and public participation: An application to the strategic planning of wind farm sites. *J Environ Manage* 2009; 90: 2027-40.

Stephenson I, Roper J, Fraser M, Nicholson K, Wiselka M. Dengue fever in febrile returning travellers to a UK regional infectious diseases unit. *Travel Med Infect Dis* 2003; 1: 89-93.

Sun Developer Network. Java Server Pages Technology - Comparison with ASP. Redmond: Microsoft, 2011. [Cited 2011 Sep 20]. Available from: URL: http://www.microsoft.com/sqlserver/en/us/default.aspx

Thavara U, Tawatsin A, Chansang C, *et al*. Larval occurrence, oviposition behavior and biting activity of potential mosquito vectors of dengue on Samui Island, Thailand. *J Vector Ecol* 2001; 26: 172-80.

Wang S, Xia J, Yu L, Li C, Xu L, Zheng L. Realization of simulations for blinded internal pilot study based on web. *J Biomed Inform* 2009; 42: 262-71.

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

Wolfram Research. web*Mathematica* technology. Champaign: Wolfram Research, 2011. [Cited 2011 Sep 20]. Available from: URL: http://www.wolfram.com/products/webmathematica/technology/

Wongkoon S, Jaroensutasinee M, Jaroensutasinee K. Larval infestations of *Aedes aegypti* and *Ae. albopictus* in Nakhon Si Thammarat, Thailand. *Dengue Bull* 2005; 29: 169-75.

Wongkoon S, Jaroensutasinee M, Jaroensutasinee K, Preechaporn W. Development sites of *Aedes aegypti* and *Ae. albopictus* in Nakhon Si Thammarat, Thailand. *Dengue Bull* 2007; 31: 141-52.

Wright A, Bates DW, Middleton B, *et al*. Creating and sharing clinical decision support content with Web 2.0: Issues and examples. *J Biomed Inform* 2009; 42: 334-46.