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RESEARCH ARTICLE

RISK ASSESSMENT OF ZIKA VIRUS AND OPTIMIZATION OF MOSQUITO SURVEILLANCE IN THE PORT AND CITY OFCHITTAGONG, BANGLADESH

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ABSTRACT

Several mosquito species and mosquito-borne pathogens are capable of invading new geographic regions and exploiting niches that are similar to their natural home ranges where they may pose a serious threat to spreading pathogens. Zika virus is spreading throughout the world, posing significant health risk to human populations, particularly pregnant women and their infants.Invasion by infected mosquitoes through marine and air ports are a likely route of invasion of Zika virus. The mosquito species most capable of transmitting Zika virus, *Aedes aegypti* and *Ae. albopictus*are both found in Bangladesh. Identifying likely invasion sites and optimizing strategies for detection and control are critical in preventing the spread of Zika virus in Bangladesh. The BioTEMS TIGER model was used to analyze abiotic and biotic factors influencing Zika infected *Aedes*species, should they enter through the port of Chittagong. BioTEMS was used to identify areas at high risk for the introduction of Zika virus, recommended zones for integrated mosquito management, and sites for mosquito surveillance at the port and the surrounding area of the city of Chittagong, Bangladesh.

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INTRODUCTION

Aedes, Zika virus, invasive species, maritime ports, biological agents, mosquito, arbovirus Zika virus and several other viruses are spreading rapidly on a global scale. Several mosquito species are capable of invading new geographic regions and exploiting niches that are similar to their natural home ranges. These mosquitoes, and the pathogens they carry, may pose significant medical and veterinary health risks in naïve populations. The principle factor responsible for the introduction of disease vectors are air and ship transport (Lodge, 2006; Tatem*et al,* 2006; Meyerson *et al*, 2007). Zika virus infected humans may also be an additional source of transport and infection to local mosquitoes as well as other humans through sexual contact and blood (WHO, 2016).The current study was conducted to determine whether the maritime port of Chittagong, Bangladesh, is at risk for invasive introduction of Zika infected mosquitoes and/or infected humans and provide information to plan control efforts, conduct public information campaigns and optimize surveillance of *Aedes* species and virus.

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MATERIALS AND METHODS

The author is familiar with the ecosystem in and around Chittagong as well as other areas in Bangladesh, having worked in the region as a medical entomologist and preventive medicine officer in the late 1990's. ArcGIS, Statistica and BioTEMS were used to analyze geographic information and conduct data analysis. The Bioagent Transport and Environmental Modeling System (BioTEMS) is used to analyze abiotic and biotic factors and produce risk and vulnerability assessments for biological agents and infectious diseases. BioTEMShas been used to provide support and assist in risk and vulnerability assessments for military facilities, presidential inaugurations, national conventions, and for public health projects in several countries (Kollars, 2015; Kollars, 2016). BioTEMS has also be used with the Hazard Prediction and Assessment Capability (HPAC) to analyze bioagents, to determine environmental survival and reaerosolization of infectious agents and to optimize placement of surveillance systems, e.g. the Biological Integrated Detections System (BIDS).The BioTEMS TIGER model (T-transport, I-introduction, G-gap infiltration, E-escalade, and R-residence &recruitment), is used to identify areas at highest risk for invasive mosquito species, vector-borne disease, and to optimize surveillance and control efforts (Kollars *et al*, 2016).Areas at risk of Zika virus and integrated mosquito management (IMM) zones were developed based on the BioTEMS TIGER model in the event Zika virus is introduced. Recommended IMM surveillance sites around the port and city were also identified. BioTEMS and ArcView were used to produce output into Google Earth.

RESULTS AND DISCUSSION

The BioTEMS TIGER model prediction of the risk of Zika virus falls within areas of Zika risk previously published (Monaghan *et al*, Samy*et al*, 2016).However, unlike other models, BioTEMS includes probable sites for invasion, and provides information for optimizing IMM in high risk areas. The BioTEMS TIGER model determined an risk assessment of 83%forinvasion of Zikavirus into Chittagong through the port, within an approximately16 km^{2}high risk area (Invasive Zone) within the port and city of Chittagong City northwest of the Karnaphuli River and 4 km^2 to the southeast of the river. Areas where the infection may spread (Gap Zone) includes another 174 km^{2}where monitoring and testing of mosquitoes and mosquito control through pesticide application and source reduction should be conducted. Recommended sites for surveillance in around the port area and city were identified to assist local officials in preventive medicine and IMM plan development (Fig. 1).

The people of Bangladesh suffer from a number of mosquito-borne diseases, such as malaria, dengue, chikungunya and Japanese encephalitis virus (AFPMB, 2001; Sultana *et al*, 2013). *Aedes aegypti* and *Ae. albopictus* commonly occur in and around dwellings in Chittagong (Indrani et al. 2010) posing a threat from dengue and chikungunya, and now possibly Zika virus. One case of prior local exposure of Zika virus has been reportedin Bangladesh, having occurred in Chittagong. This old stored sample from 2014 was tested in 2016 and found to be positive (ProMed, 2016).The port in Chittagong receives goods from the global market, including areas known to have Zika virus outbreaks, such as Panama (Fleet Mon, 2016; CDC, 2016a). There is a high risk of Zika becoming established in Bangladesh because of several factors;established populations of *Ae. aegypti* and *Ae. albopictus*, import of goods from Zika infected areas, suitable biotic and abiotic variables for vector and virus. The BioTEMS TIGER model has accurately predicted high risk areas of Zika virusin various countries, including Rio de Janeiro and Miami. However, history shows that models should only be used as a planning tool and not totally relied upon for the final decision. O'Donnell (2016) reported, "In Tampa, county mosquito control technicians conducted backpack spraying, dropped larvicide dunks in standing water and trapped mosquitoes around a 300-yard radius.

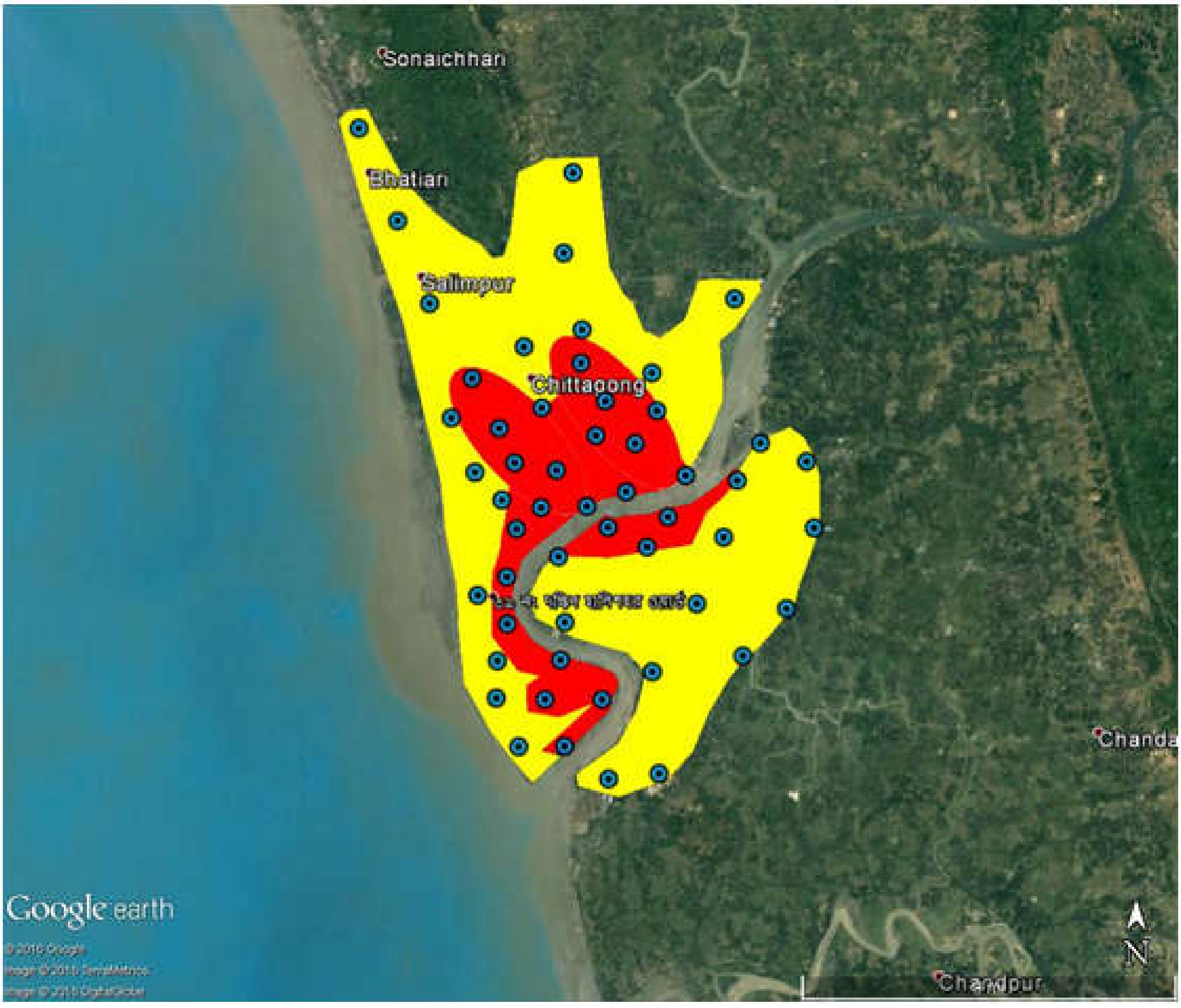

Figure 1. Areas in the Port and City of Chittagong at high risk of Zika virus (red) and recommended integrated mosquito management (yellow) should Zika virus be introduced through the Miami Port. Blue circles are recommended sites for surveillance traps for *Aedesaegypti* and *Ae. albopictus*.

The *Aedes aegypti* mosquito known to spread the Zika virus typically travels a maximum of only 150 yards in its lifetime."However this statement may oversimplify the complexity of factors contributing to the introduction and subsequent distribution of mosquitoes and vector-borne diseases; e.g. biotic and abiotic factors affecting the dispersal of mosquito species and the pathogens. *Ae aegypti* and *Ae albopictus*may fly hundreds of meters within less than one week. For example, in Rio de Janeiro, both species flew at least 800 m within six days (Honório*et al*, 2003). In Miami, the dispersal paradigm proposed by public health authorities for the movement of *Ae aegypti* and *Ae albopictus*may not be accurate, and may have caused an underestimation of both risk and mosquito control measures. Preplanning and preventive measures may ameliorate or delay the invasion of Zika virus through the port of Chittagong. However, due to the single documented case being previously recorded two years in the past, Zika virus may already be established in Chittagong. A critical factor in the control of *Aedes* species and reducing the risk of the dispersal of Zika virus is choosing the proper pesticide and optimally applying the pesticide to maximize effect. Investigating the periods of activity and distribution of local *Aedes* populations is necessary if control is to be obtained. Naled is commonly used by mosquito control districts to control adult mosquitoes (CDC, 2016b). Relying solely on aerial spray of naledfrom aircraft to control adult *Aedes* may meet with failure. In addition,naled is only effective for a few hours in areas that have much cover; populations may rebound in a week or so (Sutherland *et al*, 1978; Howard *et al*, 1997).Other pesticides such as malathion are also effective in controlling adult mosquitoes, however testing for pesticide resistance should be incorporated into the IMM. Using backpack sprayers and truck mounted application of pesticides, in addition to aerial spraying from aircraft, should be a part of the IMM strategy for controlling adult *Aedes*. For larval control, *Bacillus thuringiensis israelensis* (Bti), can be used to reduce *Aedes*.

Bti can be applied by air craft, back pack sprayers, ULV truck mounted spraying, and by hand placement of granules or briquettes. Insect growth regulators (IGR) such as methoprene and ethoxyl pyridine can be utilized in sprays.Entobac with Bti is a new pesticide which has been formulatedfor use either in delivery devices hung from trees or structures or used within spray systems. This new pesticide is the first pesticide that is effective against both adult and larvae mosquitoes(Yalwala, 2016). Further research into using binary pesticides, e.g. Bti with IGR and Bti with deltamethrin are being conducted by the author. The possible invasion of arboviruses through ports, both aviation and maritime, is not a new concept (Gardner *et al*, 2013.In addition to epidemiologic surveillance of Zika patients, optimizing placement of mosquito surveillance traps and implementing diagnostic testing of mosquitoes should be conducted. Surveillance efforts should be conducted in both human and mosquito populations in the port and city of Chittagong as well as in other ports identified as being at risk for introduction of Zika virus. The author recommends using BG Sentinel Traps for surveillance of *Aedes* mosquitoes if funds are available, however the gravid *Aedes* trap may be low cost alternative (Johnson et al. 2016). Active epidemiologic surveillance of mosquitoes and human populations should be conducted before the Zika virus invades and throughout the public health management effort. Models such as the BioTEMS TIGER model can be used to assist public health and mosquito control leaders in making decisions to remediate and prevent outbreaks of mosquito-borne diseases.It is imperative national and international efforts are made to expand surveillance and testing efforts of mosquitoes and human populations in Chittagong. In addition, a rapid response effort should be, with equipment and pesticides pre-positioned in order to rapidly respond to a Zika invasion through the port in Chittagong or other areas in Bangladesh, that are identified as high risk areas.

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