Biomedical Research and Clinical Practice

Research Article ISSN: 2397-9631

Integrated mosquito management and estimating direction and rate of dissemination of Zika virus infected mosquitoes in the port area of Mangalore, India

Thomas M Kollars Jr*

College of Health Sciences, Liberty University, USA

Abstract

Several mosquito species are capable of invading new geographic regions and exploiting niches that are similar to their natural home ranges where they may introduce, or reintroduce, pathogens. In addition to initial invasion, introduction of new genotypes into established populations may also occur. Zika virus is spreading throughout the world, posing significant health risk to human populations, particularly pregnant women and their infants. India currently has active dengue and chikungunya virus circulating in the mosquito and human populations. The BioTEMS TIGER model and ArcGIS were used to analyze abiotic and biotic factors influencing potentially Zika infected *Aedes* species, should they enter through the sea port in Mangalore, India. The model has been validated by overlaying documented and suspected concurrent Zika cases and comparing published high-risk areas for Zika virus in Australia, Florida and Brazil. In addition to Zika introduction/invasion zones being identified, output indicates surveillance and integrated mosquito management should expect larger zones than local authorities may be considering. Surveillance sites at ports should be identified and prioritized for pathogen and vector control to reduce the import of mosquitoes infected with Zika virus. Providing higher resolution predictive maps may assist local public health officials in reducing the threat of Zika virus invasion through port areas into India.

Introduction

Zika virus (ZIKAV) continues to spread across the globe. Establishing patterns of invasion and spread into new geographic areas is critical for protecting the public health of naïve human populations. Since this time several publications on the nature of the spread of ZIKAV in geographic regions have been published. The principle factor responsible for the introduction of disease vectors is air and ship transport [1,2]. In addition to the import of infected mosquitoes, introduction of ZIKAV into a new geographic area can occur when local mosquitoes bite infected travelers and become infector or when people become infected through contaminated blood or through sex [3]. Many of the models published are of low resolution, and although excellent models for looking at global information, they provide little insight into the spread of ZIKAV in local communities. Mosquito-borne diseases pose a significant health risk to the population in India, as well as imposing an economic burden on the government for mosquito surveillance, control and health care of *Aedes aegypti* and *Ae. albopictus*, the primary invasive vectors of dengue, chikungunya and ZIKAV [4].

The port in Managlore is the 9th largest port in India and receives cargo and cruise ships from countries where ZIKAV is at epidemic levels, e.g. Brazil [5,6]. Because Mangalore is an important international port both for container as well as cruise ships, the potential for invasion and introduction of mosquitoes and/or people infected with Zika virus should be evaluated to assist integrated vector management planning. A survey of *Aedes* mosquito species was conducted in India in 2010 in the housing and operational sites in the Mumbai Port Trust area. *Aedes albopictus* inhabits the distinct environment of the Mangalore Port [1,7]. It is suggested that *Ae. albopictus* breeding sites and pesticide resistance be examined in the Mangalore port areas as in Mumbai, *Ae. aegypti* was found primarily breeding in fire buckets in port areas with a high level of insecticide resistance to temephos and fenthion [8]. The same conditions may also exist in Mangalore Port. How mosquito-borne pathogens might spread from the port area in Mumbai through suitable vectors is not known. Because of the number of mosquitoes around airports, public health officials in Mumbai conducted surveillance and control measures at a radius of 400 m surrounding the airport. However, this distance for control may not be adequate. Similar conditions may exist also in the port in Mangalore. The Bioagent Transport and Environmental Modeling System (BioTEMS) was used to provide information should ZIKAV invade through the maritime port in Mangalore. Public health officials at the local level in Mangalore would benefit from information concerning sites of possible invasion of ZIKAV infected mosquitoes or humans and sites for expanded areas of integrated mosquito management (IMM), including surveillance and control, to prevent the establishment or reduce the risk of ZIKAV in the community.

Materials and methods

ArcGIS geospatial analysis software, Statistica statistical software and Bioagent Transport and Environmental Modeling System (BioTEMS) were used to analyze geographic information and conduct data analysis. BioTEMS utilizes up to several hundred abiotic and biotic

Correspondence to: Thomas M. Kollars, Jr, College of Health Sciences, Liberty University, USA, Tel: 912 681 3489; E-mail: tkollars@liberty.edu

Key words: *Aedes, arbovirus, invasive species, port security, biological agents, India*

Received: February 15, 2018; **Accepted:** February 23, 2018; **Published:** February 28, 2018

factors to produce risk and vulnerability assessments for biological agents and infectious diseases. Examples of biotic and abiotic factors include; pathogen strain, vector/host relationship, vectorial capacity, host/vector physiology, colonization ability, population dynamics of hosts and vectors, soil, shade, and weather conditions, such as wind, temperature, precipitation. Analytical methods within BioTEMS includes; artificial intelligence, fuzzy logic, niche analysis, random forests and general additive regression and statistics. As the former Epidemiologist of the USAR Consequence Management Unit and as the Brigade Surgeon for the 415th Chemical Brigade, BioTEMS was used in risk analysis and vulnerability assessment for biological weapons of mass destruction, including; *Bacillus anthracis*, *Francisella tularensis*, *Yersinia pestis*, and Crimean-Congo hemorrhagic fever virus, etc. [9]. These assessments were used during consequence management planning for military facilities in the U.S. and internationally, government facilities and during presidential/national conventions. BioTEMS has also be used with Hazard Prediction and Assessment Capability (HPAC) to analyze bioagent information and to optimize placement of Bioagent Integrated Detection System (BIDS). In addition to applications for biological weapons defense, BioTEMS has been used for infectious disease modeling and planning.

The BioTEMS TIGER model was developed to assist in identifying areas at highest risk for invasive mosquito species and pathogens and to optimize surveillance and control efforts [10] Within the BioTEMS TIGER model; Transport- identifies the point of origin, method and rate of transport to a locality, Introduction- point of initial introduction/immigrant haplotypes and preliminary spread into a locality, Gap- determines the area where vector/pathogen initially spreads once it has gained a foothold, Escalade- incorporates abiotic and biotic resistance to invasion, and Residence and recruitment - incorporates factors and area where vector/pathogen adds to genetic diversity or becomes endemic and recruits con-specifics. The BioTEMS model has been used to identify areas at risk for ZIKAV and identify areas for integrated mosquito management in maritime ports in Miami, Tampa, and Mayport Naval Port in Florida, and the ports of Rio de Janeiro and Fortaleza, in Brazil [11,12]. Areas at risk of Zika virus and IMM zones were developed based on the BioTEMS TIGER model should Zika virus be introduced through the Port of Mangalore, located in southwestern India. BioTEMS and ArcView were used to produce output into Google Earth. Surveillance sites for mosquito and epidemiologic surveillance were identified using niche analysis, such as breeding sites, predicted vector mosquito density, probable mosquito/human interaction, e.g. container vs tree-hole breeding sites.

Results and discussion

The port in Mangalore was identified and analyzed using BioTEMS for import of ZIKAV into Mangalore, two airport areas and two maritime port areas (Figure 1). The rate of spread of Zika infection in the mosquito population and human population was estimated to be 30% faster northward (Figure 1) as measured by weeks. Approximately

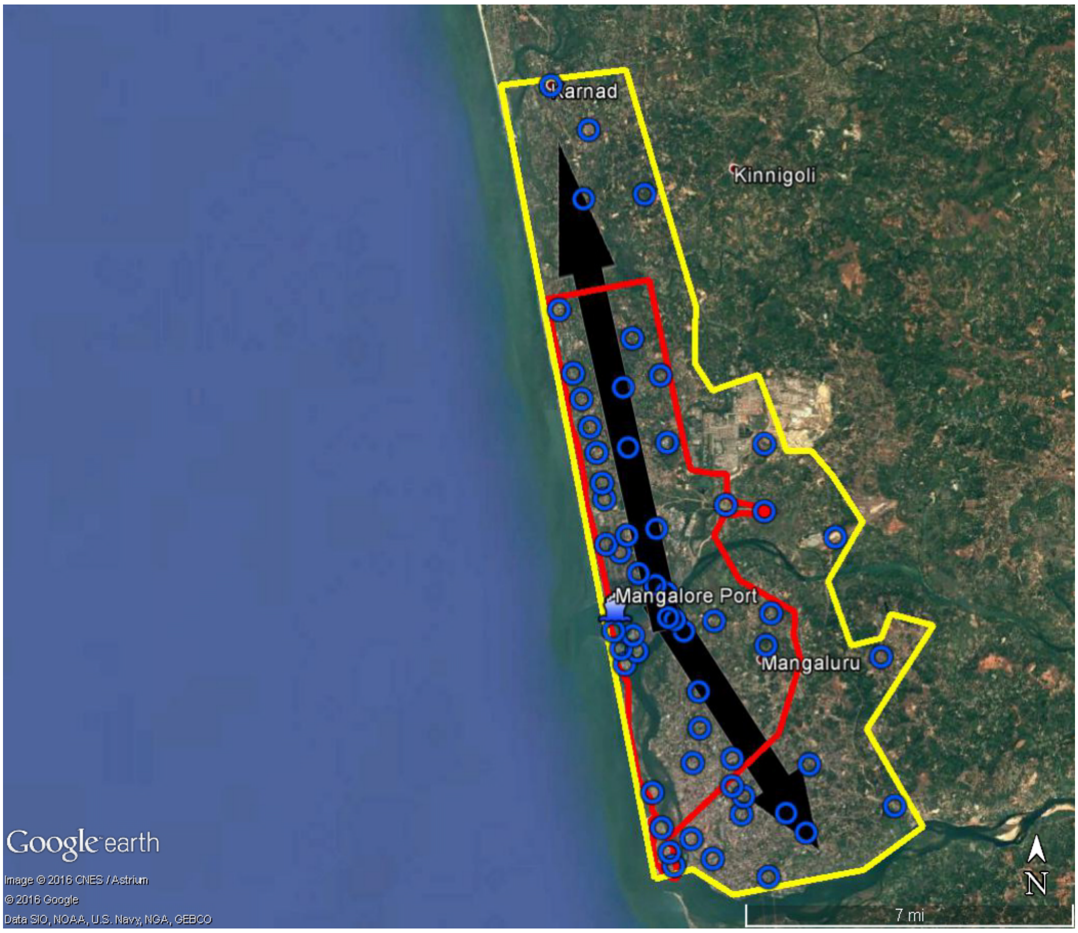

Figure 1. Areas in the Greater Mangalore area at high risk for the introduction of Zika virus (red) and recommended integrated mosquito management (yellow) should Zika virus be introduced through the Mangalore port. Recommended surveillance sites for mosquito surveillance (blue circles). Black arrows indicate major direction of movement of infected mosquitoes. Estimated rate of spread 30% faster to the north than south.

84 km^2 of Mangalore is at risk for introduction and spread of ZIKAV during the initial invasion of the virus through mosquitoes or humans in the port areas infecting local *Aedes* mosquitoes. Approximately 212 km^2 of Mangalore and its surrounding area, is at risk for Gap infiltration of ZIKAV infected mosquitoes. Surveillance sites around the ports as well as throughout the greater Mangalore area were identified to assist in surveillance. The BioTEMS model has been used to identify areas at risk for ZIKAV and identify areas for integrated mosquito management in maritime ports in Miami, Tampa, and Mayport Naval Port in Florida, and the ports of Rio de Janeiro and Fortaleza, in Brazil. Import of ZIKAV into Mangalore and other ports in India is of high probability if the port of origin lies has local cases of ZIKAV. BioTEMS predicted that if ZIKAV was imported into the Mangalore port, it would rapidly spread through the mosquito population, endangering the human population.

The occurrence of pesticide resistance in mosquitoes is an emerging problem in India, including Mangalore [13]. Due to resistance to temephos and fenthion in *Aedes* vectors in India, alternative pesticides must be sought. Recently a new pesticide was tested which has both adulticidal and larvacidal activity, is non-toxic and has been tested in port areas and when used in applicators such as the ProVector Tube, the pesticide remains active up to 3 months [10,14]. The ProVector tube can be hung in air and maritime ports as well as on ships to help reduce the risk of ZIKAV infected mosquitoes from being imported into Mangalore. The technology used in the ProVector allows for the adult mosquito to ingest the pesticide and then transport the pesticide to larval breeding sites. In approximately 7 days the adult mosquito dies and if the mosquito lands in water, the larval mosquitoes die as well. The ProVector may provide a useful tool in killing larva mosquitoes in various breeding sites, including the fire buckets. In the event an infected traveler infects local mosquitoes, the presence of ProVector applicators, or other long lasting environmentally safe pesticides, can reduce the mosquito population and reduce the risk of ZIKAV spreading.

In conclusion, caution should be taken when identifying control and surveillance sites for *Aedes* species. Reports of the flight ranges of *Aedes aegypti* range from 150 to over 3,000 m and from 200 to 800 m for *Ae. Albopictus* [15,16]. The flight range and habitats of *Aedes* could be identified in Mangalore to assist authorities in better controlling this medically important species. In the assessment for ZIKAV, seaports should be considered as they often play a critical role in the invasion of *Aedes*, this includes recruitment of new haplotypes [17]. Identifying the correct pesticide to avoid resistance or environmental contamination is an important aspect if IMM. The possible invasion of arboviruses through ports, both aviation and maritime, is not a new concept [18]. Focusing control efforts primarily on travelers and not including ports of entry may do a disservice to the population to whom public health officials are trying to protect. Integrated mosquito management plans should be put into place before ZIKAV arrives ashore, either through infected mosquitoes or infected humans.

References

1. Tatem AJ, Hay SI, Rogers DJ (2006) Global traffic and disease vector dispersal. *Proc Natl Acad Sci U S A* 103: 6242-6247. [Crossref]
2. Meyerson L, Mooney H (2007) Invasive Alien Species in an Era of Globalization. *Frontiers Ecol Env* 5: 199-208.
3. Hills S, Russell K, Hennessey M, Williams C, Oster A, et al. (2016) Transmission of Zika Virus Through Sexual Contact with Travelers to Areas of Ongoing Transmission-Continental United States. *MMWR Weekly* 65: 215-216.
4. Shepard DS, Halasa YA, Tyagi BK, Adhish SV, Nandan D, et al. (2014) Economic and disease burden of dengue illness in India. *Am J Trop Med Hyg* 91: 1235-1242. [Crossref]
5. http://www.seafreightcalculator.com/133/20ft-container-tramandai-brazil-to-new-mangalore-india-port-to-port-shipping-sea-freight/
6. http://www.seascanner.com/cruises-south-america-to-mangalore-g24-h715
7. Kay BH, Ives WA, Whelan PI, Barker-Hudson P, Fanning ID, et al. (1990) Is Aedes albopictus in Australia? *Med J Aust* 153: 31-34. [Crossref]
8. Kumar K, Sharma A, Sarkar M, Chauhan A, Sharma R (2014) Surveillance of Aedes aegypti (L.) Mosquitoes in Mumbai International Seaport (India) to Monitor Potential Global Health Risks. *J of Ins* 2014: 1-5.
9. Kollars TM (2008) BioTEMS-Biology based modeling to determine bioagent fate. Chemical Biological Weapons Delivery Methods and Consequence Assessment Modeling Conference. National Geospatial Intelligence Center: Weapons Intelligence, Nonproliferation and Arms Control.
10. Kollars, TM Jr, Kollars PG, and Hulsey B (2016) Reducing the Risk to Marine Ports from Invasive Mosquito Species, Zika, Dengue, Chikungunya viruses and Filariasis. *Intl J Med* 4: 70-73.
11. Kollars TM Jr. (2016) Assessing likely invasion sites of Zika virus infected mosquitoes in civilian and naval maritime ports in Florida. *Res Rep Trop Med* 7: 1-6.
12. Kollars TM, Kollars, JW (2017) The invasion of Zika virus into Rio de Janeiro and Fortaleza, Brazil, inside out or outside in? *Ann Comm Med Pract* 2: 1-4.
13. Tiwari S, Ghosh SK, Ojha VP, Dash AP, Raghavendra K (2010) Reduced susceptibility to selected synthetic pyrethroids in urban malaria vector Anopheles stephensi: a case study in Mangalore city, South India. *Malaria J* 9: 179. [Crossref]
14. Yalwala S, Kollars JW, Chrisostim JW, Kasembeli G, Senessie C, et al. (2016) Preliminary report on the reduction of adult mosquitoes in housing compounds in western Kenya using the ProVector Flower and Entobac bait pads containing Bacillus thuringiensis israelensis with honey bait. *J Med Ent* 53: 1242-1244. [Crossref]
15. Reiter P, Amador MA, Anderson RA, Clark GG (1995) Short report: dispersal of Aedes aegypti in an urban area after blood feeding as demonstrated by rubidium-marked eggs. *Am J Trop Med Hyg* 52: 177-179. [Crossref]
16. Liew C, Curtis CF (2004) Horizontal and vertical dispersal of dengue vector mosquitoes, Aedes aegypti and Aedes albopictus, in Singapore. *Med Vet Entomol* 18: 351-360. [Crossref]
17. Futami K, Valerrama A, Galdi M, Minakawa N, Rodriguez M, et al. (2015) New and Common Haplotypes Shape Genetic Diversity in Asian Tiger Mosquito Populations from Costa Rica and Panama. *J Econ Ento* 108: 761-768. [Crossref]
18. Gardner L, Sarkar S (2013) A global airport-based risk model for the spread of dengue infection via the air transport network. *PLoS One* 8: e72129. [Crossref]