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ACTROP 3347 1–8
ARTICLE IN PRESS

Acta Tropica xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Acta Tropica

journal homepage: www.elsevier.com/locate/actatropica

Characterization of the spatial and temporal dynamics of the dengue vector population established in urban areas of Fernando de Noronha, a Brazilian oceanic island

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A R T I C L E I N F O

Article history:
Received 28 November 2013
Received in revised form 2 April 2014
Accepted 5 April 2014
Available online xxx

Keywords:
Dengue vector
Mosquito surveillance
Aedes monitoring system
GIS
Ovitrap
Bti

A B S T R A C T

Aedes aegypti has played a major role in the dramatic expansion of dengue worldwide. The failure of control programs in reducing the rhythm of global dengue expansion through vector control suggests the need for studies to support more appropriated control strategies. We report here the results of a longitudinal study on *Ae. aegypti* population dynamics through continuous egg sampling aiming to characterize the infestation of urban areas of a Brazilian oceanic island, Fernando de Noronha. The spatial and temporal distribution of the dengue vector population in urban areas of the island was described using a monitoring system (SMCP-*Aedes*) based on a 103-trap network for *Aedes* egg sampling, using GIS and spatial statistics analysis tools. Mean egg densities were estimated over a 29-month period starting in 2011 and producing monthly maps of mosquito abundance. The system detected continuous *Ae. aegypti* oviposition in most traps. The high global positive ovitrap index (POI = 83.7% of 2815 events) indicated the frequent presence of blood-fed-egg laying females at every sampling station. Egg density (eggs/ovitrap/month) reached peak values of 297.3 (0 – 2020) in May and 295 (0 – 2140) in August 2012. The presence of a stable *Ae. aegypti* population established throughout the inhabited areas of the island was demonstrated. A strong association between egg abundance and rainfall with a 2-month lag was observed, which combined with a first-order autocorrelation observed in the series of egg counts can provide an important forecasting tool. This first description of the characteristics of the island infestation by the dengue vector provides baseline information to analyze relationships between the spatial distribution of the vector and dengue cases, and to the development of integrated vector control strategies.

1. Introduction

Dengue has been considered the most rapidly spreading mosquito-borne viral disease in the world and is currently the most prevalent human arboviral infection, with approximately one half of the world's population living in endemic countries (Brady et al., 2012). The current scenario suggests that this disease will continue to be a global threat in the near future, until a vaccine providing good protection against all the DENV serotypes is available. Reducing mosquito vector populations and vector-human contacts are currently the available dengue prevention strategies. *Ae. aegypti*

Abbreviations: Bti, *Bacillus thuringiensis israelensis*; s-ovt, sentinel ovitrap; FN, Fernando de Noronha; POI, positive ovitrap índex; KDE, kernel density estimator; SMCP-*Aedes*, Sistema de Monitoramento e Controle Populacional de *Aedes*; IBAMA, Instituto Brasileiro do Meio Ambiente (Brazilian Institut of Environment); PE, State of Pernambuco, Brazil; RN, State of Rio Grande do Norte, Brazil.

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http://dx.doi.org/10.1016/j.actatropica.2014.04.010
0001-706X/© 2014 Published by Elsevier B.V.

(Diptera: Culicidae), the main vector of dengue virus, is a mosquito highly adapted to the human house in tropical and subtropical environments, mostly between latitudes 35°N and 35°S (WHO, 2009). This species has played a major role in the dramatic expansion of dengue worldwide in the last half-century, due to its high efficacy as a virus transmitter and its close proximity to humans (Lambrechts et al., 2010; Scott and Takken, 2012). In the last decades, our understanding on dengue epidemiology has been improved by several studies on the *Ae. aegypti* biology that provided information on its survival strategies in anthropic environments and on virus transmission. Nevertheless, the failure to reduce the global expansion of dengue through vector control suggests the need for further studies.

Seasonal dengue transmission with peaks occurring in hot-wet periods of the year has been observed in different latitudes, except for the equatorial region where no temporal variations in mosquito densities were found (Rios-Velasquez et al., 2007). The temporal pattern of virus transmission is generally attributed to the dynamics of *Ae. aegypti* population, as some studies have shown clear associations between climatic variables and mosquito abundance and/or dengue transmission (Barrera et al., 2011, Johansson et al., 2009). Moreover, some authors indicate that these associations depend on local characteristics, suggesting that variations in rainfall and temperature may have diverse local effects (Barrera et al., 2011; Honório et al., 2009a; Johansson et al., 2009; Regis et al., 2013; Vezzani and Carbajo, 2008). Further studies describing annual data sets on *Ae. aegypti* population dynamics under diverse environments are important to strengthen our understanding of the factors influencing the vector seasonal abundance and to support the design of control interventions.

There are growing experimental evidences and increasing practical use showing traps as an appropriated strategy to monitor *Ae. aegypti* and *Ae. albopictus* populations in urban spaces. Different models of ovitraps have been shown as effective monitoring tools able to generate quantitative information on mosquito abundance and distribution when integrated to surveillance systems (Albieri et al., 2010; Bellini et al., 1996; Carrieri et al., 2011; Honório et al., 2009a; Khatchikian et al., 2011; Regis et al., 2008, 2009, 2013). Eggs laid in ovitraps are a direct evidence of reproductively active females with biting-vitelogenic-oviposition activity, i.e. in active phase of potential viral transmission. In fact, in a field-scale study in Puerto Rico it was recently shown that *Ae. aegypti* oviposition was significantly correlated with dengue incidence (Barrera et al., 2011).

The state of Pernambuco, Northeast Brazil, was re-infested by *Ae. aegypti* in 1984, and 3 years later the first autochthonous dengue cases were registered in Recife city, caused by DENV-1. In Fernando de Noronha Island, 545 km away from Recife, the first dengue cases occurred 14 years later and were attributed to the same serotype (Cordeiro et al., 2008). Here, we report the results of a longitudinal study on *Ae. aegypti* population dynamics gathered in a long-lasting survey through continuous mosquito eggs sampling. The purpose of this study was to characterize the infestation of urban areas by assessing the temporal and spatial distribution of *Ae. aegypti* in 15 villages of the oceanic island Fernando de Noronha. To achieve this aim, a monitoring system based on mean egg density data continuously collected through a sentinel ovitrap network (Regis et al., 2009, 2013) was used to follow the mosquito density oscillations.

2. Materials and methods

Ethics Statement. This study was reviewed and approved by the Ethics Committee of the CPqAM-Fiocruz-PE, Brazil (CAAE No. 0095.0.095.000.10). Before being established, the SMCP-*Aedes* system was approved by the District Health authorities and the Health Communitarian Council of Fernando de Noronha Island, in August 2010. The system was operationally integrated to the routine activities of the Dengue Control Program and operated by the District Health personnel. In agreement with the Brazilian rules for dengue control in endemic areas, a written consent for house visits and mosquito surveillance by local health authorities is not required in areas where the presence of the vector is confirmed. The scientific team had full access to all data generated by the SMCP-*Aedes* system, and the Health staff had access to all results generated by data analysis by the scientific team.

2.1. Study design

The spatial distribution of the dengue vector population in the urban areas of a South Atlantic island was described based on *Aedes* egg sampling coupled with a system using GIS and spatial statistic analysis tools for quantitative assessment of mosquito populations. Mean egg densities were monthly estimated over 29 consecutive months. The study was implemented in a joint effort between the local health managers and staff and the scientific team.

2.2. Study area

Fernando de Noronha, a district of the state of Pernambuco, is an archipelago of 21 islands and islets in the Atlantic Ocean. It is a UNESCO World Heritage Natural Site. Its Marine National Park, an Environmentally Protected Area, occupies 70% of its territory and includes the last reminiscent insular Atlantic forest and the sole oceanic mangrove in the South Atlantic. The archipelago is thus considered of extreme biological relevance for the Coastal Marine Zone biodiversity conservation (Ministério do Meio Ambiente, 2002). It is located at latitude 03°45′S to 03°57′S and longitude 32°19′W to 32°41′W, 545 km northeast of Recife city, the capital of Pernambuco. The main and sole inhabited island also called Fernando de Noronha (FN) has an area of 17.017 km^2, being 10 km long and 3.5 km wide at its maximum, and a population of 3012 (IBGE, 2010) living in fifteen villages (Fig. 1). Over 60,000 tourists are brought annually to the island by three regular daily flights, from Recife-PE and Natal-RN, the capital of the State of Rio Grande do Norte, and by seasonal cruises.

The climate is tropical oceanic with two well-defined seasons: a rainy season from February to July and a dry season from September to January. Variations in temperature are minor throughout the year, with the mean higher temperature oscillating from 28 to 30.9 °C and the lower temperature from 24 to 25 °C; the relative air humidity is 81%. Household water is derived from collection of rainwater, seawater desalination, groundwater wells and two reservoirs. According to the Instituto Brasileiro do Meio Ambiente (IBAMA) (2010) 89.5% of the population is supplied by public supply systems, however the demand for water on the island is greater than the supply, and the buildings have cisterns and tanks for water storage. Only 65.7% of households are connected to the sewage system, 31% have septic tanks and 3.3% release their sewage into the environment. The sewage treatment is carried out in two stabilization ponds.

The first dengue cases in FN were recorded in May 2001 when 343 infection cases were notified (Cordeiro et al., 2008). A total of 687 dengue cases were notified from 2001 to 2012. During the present study the House Index-HI estimated by the Dengue Control Program every 2 months and based on visual search for mosquito larvae-pupae, ranged from 0.03 to 1.64, and the Breteau Index from 0.03 to 1.94. The control program is based on Bti as a larvicide monthly applied to water stored in containers for domestic use and the elimination of potential mosquito sources.

Please cite this article in press as: Regis, L.N., et al., Characterization of the spatial and temporal dynamics of the dengue vector population established in urban areas of Fernando de Noronha, a Brazilian oceanic island. Acta Trop. (2014), http://dx.doi.org/10.1016/j.actatropica.2014.04.010