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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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ABSTRACT

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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(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.

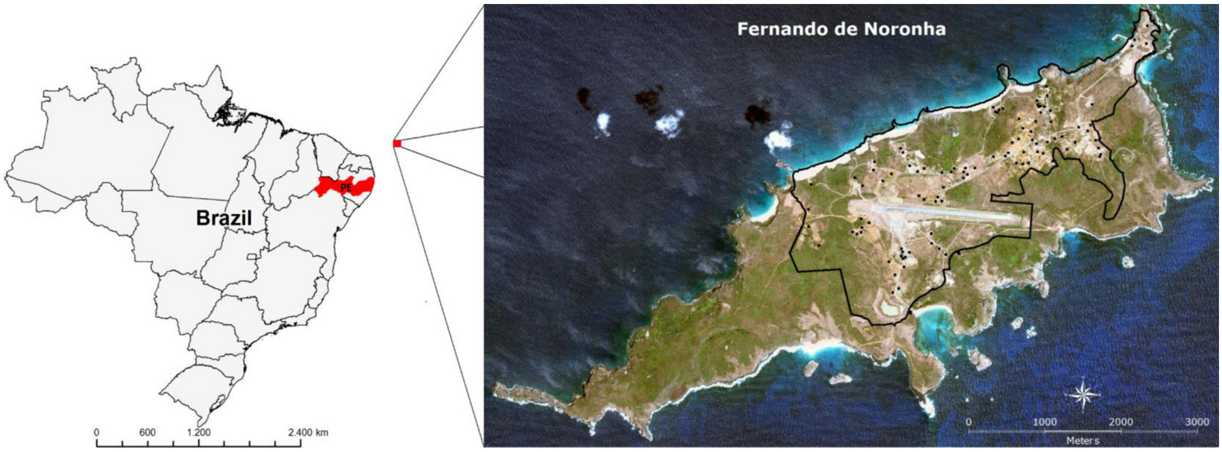

Fig. 1. The study site. Fernando de Noronha is the sole inhabited island of Fernando de Noronha archipelago, located at S3°45′ to S3°57′ and W32°19′ to W32°41′, and at 545 km northeast of Recife City, the capital of Pernambuco, Brazil. The territory including the inhabited area encompassing 15 villages is bordered by a black line. Small black dots indicate the location of the 103 sentinel-ovitraps.

2.3. Routine mosquito survey

The SMCP-*Aedes*, a monitoring system for urban *Aedes* populations (Regis et al., 2009), was used in this study. It is an all-integrated approach to collect, store, analyze and disseminate information on the spatial–temporal distribution of the estimated density of *Aedes*, based on data that are systematically collected through ovitraps and integrated through open geospatial technologies. A sentinel-network consisting of 103 sentinel-ovitraps (s-ovt) containing 1 L of water, *Bacillus thuringiensis israelensis* (Bti) as a larvicide and two 75 cm^2 paddles as oviposition support was set up in fixed sampling stations, where one s-ovt was installed per station. Each s-ovt containing an identification code was hung 1 m above ground level in the outdoors, in the shade and protected from rainfall. Paddles, water and Bti were replaced in the monthly inspections of the s-ovt. The paddles (206 per month) were sent to Fiocruz-PE for egg counting using SDP, a semi-automatic egg counting system (Silva et al., 2011). Monthly egg counting data were automatically entered in the SMCP-*Aedes* geographical database, from January 2011 to May 2013.

2.4. Preliminary survey

Before starting the routine monitoring, a pre-study survey was carried out under the local environmental conditions. Collected eggs were counted 5 and 28 days after s-ovt were installed in the field. For this, the paddles were replaced by new ones after 5 days and these new paddles were recovered 23 days later.

2.5. Ovitrap number and distribution

The sentinel network was set up covering the inhabited areas of the 15 villages each having a minimum of 14 and a maximum of 172 buildings. Because of this particular distribution of the inhabited areas in FN, fragmented into small and isolated clusters, the method adopted in the SMCP-*Aedes* to define the number of the s-ovt (Regis et al., 2009) was not applied. The number of s-ovt was defined according to the number of buildings: five traps for villages with 14–30 buildings, seven and eight traps in villages having 56 and 89 buildings respectively and ten for villages with >100 buildings. Geographical coordinates of trap location were recorded using a Global Positioning System (GPS) and entered into the SMCP-*Aedes* geographical database.

2.6. Aedes species identification

A sample of 4157 fourth instar larvae (L4) reared from field-collected eggs at the insectarium of FIOCRUZ-PE were used for species identification; 1087 of them were originated from eggs recovered from the s-ovt network in March 2010, 1000 in October 2011 and 2070 in July 2012. In all cases, *Ae. aegypti* was the only species found.

2.7. Climatic data

Temperature and rainfall data were obtained respectively from CTPEC-INPE (www.cptec.inpe.br) and APAC (www.apac.pe.gov.br).

2.8. Data analysis

The egg density, measured as the mean number of eggs per s-ovt per month, is presented as a mean value followed by the minimum and maximum values per month to allow a better description of this variable, which has a distribution with high dispersion.

To investigate the association between climatic variables and egg density we analyzed the partial autocorrelation function in the mean eggs series to take into account the possible temporal autocorrelation and build an autoregressive model including the rainfall (cubic millimeters) accumulated over the previous 2 months and the monthly average temperature as independent variables. The IBM SPSS Statistics for Windows, Version 19.0 was used.

A spatial smooth kernel density estimator (KDE) (Bailey and Gatrell, 1995) was used to produce surface maps of eggs collected in the s-ovt network over successive counting cycles, in order to identify vector density hot spots. Although KDE represents a simple alternative to analyze focal behavioral patterns, it does so by estimating the intensity of the point process throughout the study region. Most importantly, the outputs of data analysis should be readily readable and understood by Health staff at all levels, as described in Regis et al. (2013). For the experiments in FN the KDE parameters were a quadratic function of the KDE kernel with a bandwidth of 300 m. The same grid and color definitions were applied for all cycles, in order to compare results across time. Analyses were performed with TerraView (www.dpi.inpe.br/terraview), an open GIS application.

Table 1
Initial and final solutions for the autoregressive model AR(1) including rainfall and mean temperature as independent variables.

		Estimates	Std error	*t*	Approx sig	Akaike's information criterion
Initial solution						
Non-seasonal lags	AR1	0.663	0.152	4.37	0	292.16
Regression coefficients	Rainfall	0.144	0.084	1.713	0.1	
	Mean temp	−8.697	20.267	−0.429	0.672	
Constant		343.874	556.599	0.618	0.543	
Final model						
Non-seasonal lags	AR1	0.686	0.143	4.797	0	290.22
Regression coefficients	Rainfall	0.146	0.083	1.757	0.092	
Constant		105.264	33.741	3.12	0.005	

3. Results

3.1. The infestation of the island in August 2010

Results of a preliminary mosquito survey carried out for a 5-day period in August 2010 showed the deposition of *Aedes* eggs in most traps located in all villages across the island, yielding a 81% positive ovitrap index (POI) (60–100% per village) and a mean density of 40.2 eggs per trap per 5-day period. When the survey period was extended to 28 days, a 97.1% POI (80–100% per village) was recorded and the mean density increased to 328.8.

3.2. Continuous mosquito survey

The continuous collection of eggs deposited in an average of 97.1 s-ovt recovered per month was performed throughout 29 egg counting cycles from January/2011 to May/2013, yielding an overall of 2815 events. Out of this, 2356 (83.7%) traps contained at least one *Aedes* egg, yielding 377,154 *Aedes* eggs laid in s-ovt along the whole period in all villages. Monthly POI ranged from 61.4% in December 2012 to 98.2% in March 2011. Values lower than 80% occurred only during the dry season.

Egg density, measured as the mean number of eggs per s-ovt per month, reached peak values of 180.6 (0 – 987) (March) and 159.1 (0 – 1076) (September) in 2011, and 297.3 (0 – 2020) (May) and 295 (0 – 2140) (August) in 2012. The lowest egg densities were observed from November to February, in the dry season (Fig. 2).

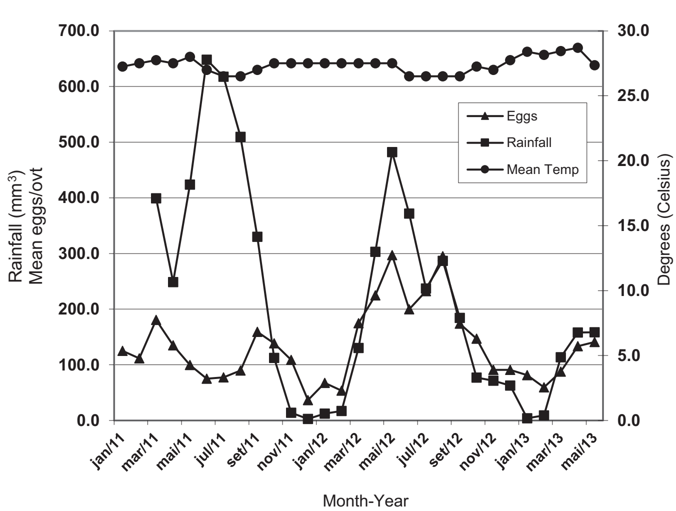

Fig. 2. Rainfall, temperature and mosquito egg counts in Fernando de Noronha. Mean number of mosquito egg per sentinel-ovitrap per month in Fernando de Noronha Island, mean temperature (Celsius degrees) from January 2011 to May 2013 and precipitation in the two previous months, starting in March 2011, showed as the sum of 2-month rainfall.

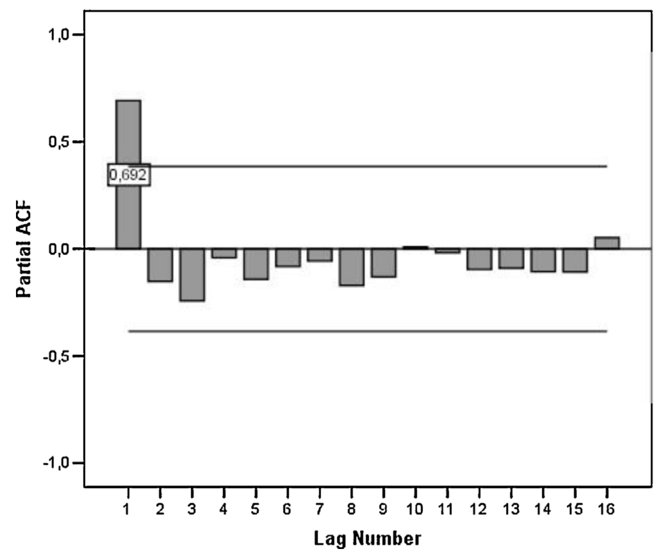

Fig. 3. Partial autocorrelation function for eggs counts from March 2011 to May 2013.

The first step to analyze the association between climatic variables and egg density was the calculation of the partial autocorrelation function for the eggs count series (Fig. 3). The results showed a significant autocorrelation only for the lag 1. An autoregressive model AR(1) including rainfall and mean temperature as independent variables was then performed and the results points to no significance for the temperature parameter (Table 1). Fig. 4 shows a scatter plot for the mean eggs count observed and fitted by the final model for the period from March 2011 to May 2013.

To analyze the spatial distribution of mosquitoes, KDE maps based on eggs laid on paddles recovered at days 27th to 29th at every month were ready and available for the Health teams until the day 14th of the following month. The maps showed a heterogeneous spatial distribution of eggs over the urbanized spaces, particularly visible in months with high infestation such as August/2012 (Fig. 5). By comparing the results across time through KDE maps produced with the same legend for all cycles the system allowed for visual identification of trends in eggs densities, showing critical periods and areas, month-to-month (Fig. 5). For cycles showing very low egg density, the KDE maps legend was adjusted to visually highlight critical areas (Fig. 6) as an instrument for supporting control actions of the fieldwork teams.

4. Discussion

The monitoring system applied provided continuous activation of a 103-ovitrap network sampling approximately 10% of the buildings in the island, from January/2011 to May/2013. Based on monthly trap inspection, the system detected continuous *Ae.*

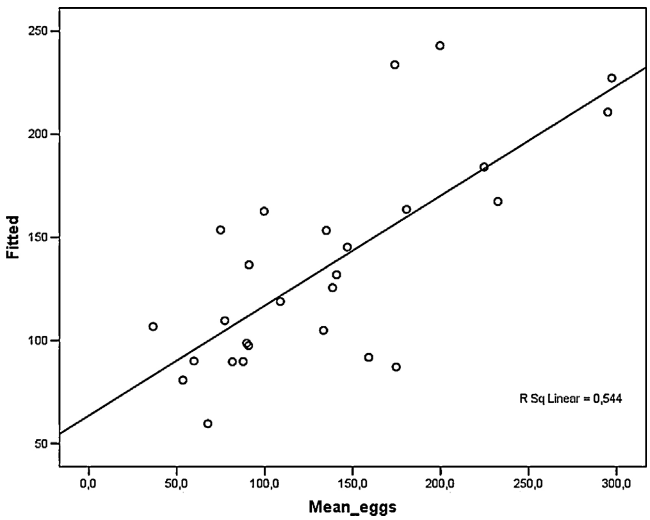

Fig. 4. Observed and estimated number of mosquito eggs in Fernando de Noronha by the final AR(1) model including rainfall as independent variable over a 27-month period, from March/2011 to May/2013.

aegypti oviposition in most sites. The high overall positive ovitrap index (POI = 83.7%) observed reveals a mosquito population widely established and demonstrates the presence of blood fed-laying egg females at every sampling station during most of the time over a 29-month period.

The presence of *Ae. aegypti* in FN was first recorded along with the first dengue cases, in May 2001. A high number of dengue cases (343) occurred that year, affecting 16% of the inhabitants (Cordeiro et al., 2008); according to the local Health Department the infected people lived in twelve out of the fifteen villages, indicating that mosquito invasion and spread to the villages occurred before May 2001. Thus, although no record of previous occurrence of this species in FN was found, its establishment certainly occurred before DENV started circulating in the island. As there are official records of autochthonous dengue cases on the island since then, it can be inferred that the scenario of infestation found in 2010 reflects the existence of a stable population of *Ae. aegypti* established in FN for at least 9 years. Aerial and maritime daily traffic between FN and two continental cities, Recife-PE and Natal-RN, both endemic for dengue, facilitates the introduction of mosquitoes in the island, and there are plenty of reasons for this species to become widely established soon after its introduction: climatic factors are highly favorable to fast development of mosquitoes year round, and aquatic habitats suitable for *Aedes* oviposition are abundant. Indeed, due to the difficulties that the islanders have to acquire domestic gadgets, the habit of accumulating idle objects that cannot be discarded into the environment in their homes and backyards is not unusual, and, as there is no water abundance the habit of storing water is also common.

Although widely spread, the *Ae. aegypti* population in the island is not as dense as those observed in other regions of Pernambuco State. The infestation levels found in other cities using the same monitoring system were all higher than those recorded in FN. In Recife, Santa Cruz do Capibaribe and Ipojuca (Regis et al., 2008, 2013), the POI was over 95%, against 84% in the island, and monthly egg density values fluctuating within the magnitude of 37–295 eggs/trap/cycle in FN were low when compared to values higher than 1500 observed in other cities. It is noteworthy that in these three cities regular dengue transmission was established several years before the first dengue cases arose in the island.

The larvae hatched from field collected eggs were all identified as *Ae. aegypti*. *Ae. albopictus*, other invasive *Aedes* species that lays eggs in ovitraps, does not seem to occur in urban areas of the

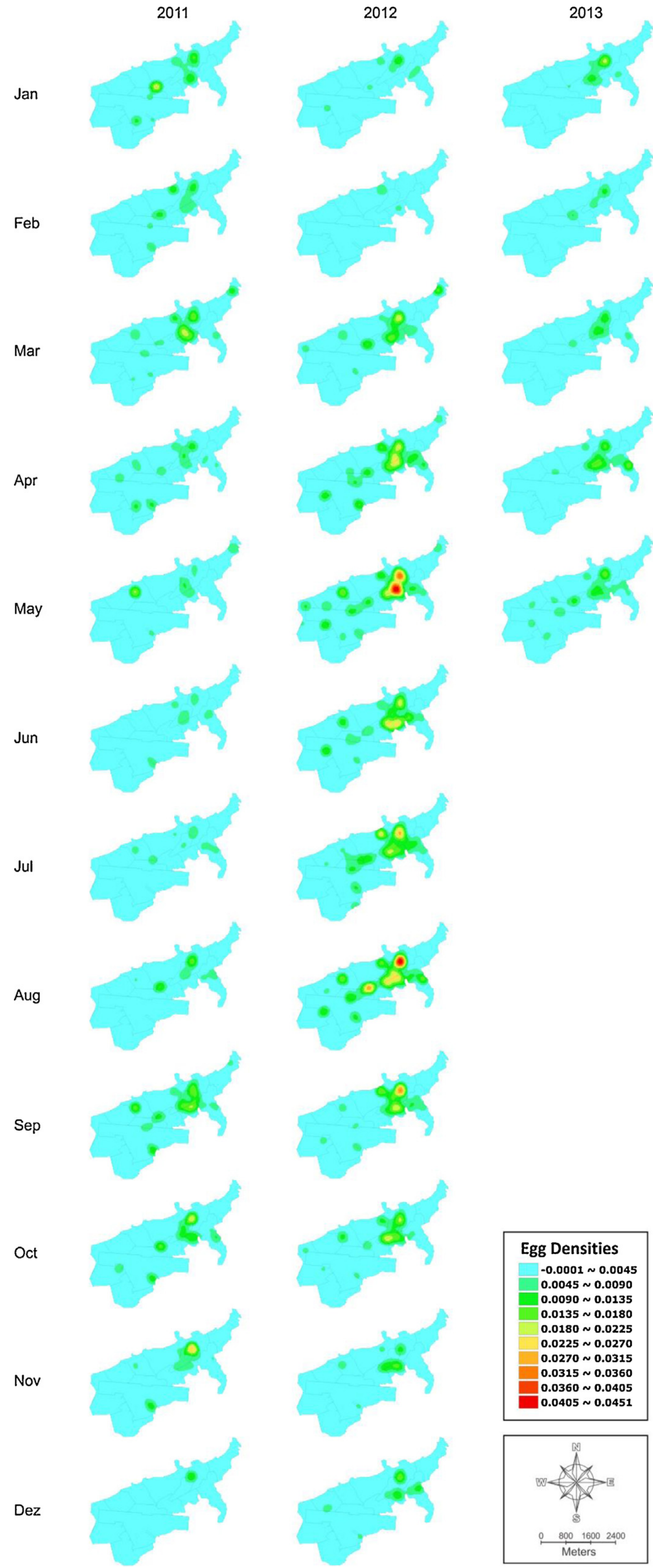

Fig. 5. Spatial and temporal distribution of mosquito eggs in Fernando de Noronha. Month-to-month comparison of the estimated egg densities over the study period through kernel maps produced with the same legend, showing critical periods and areas.

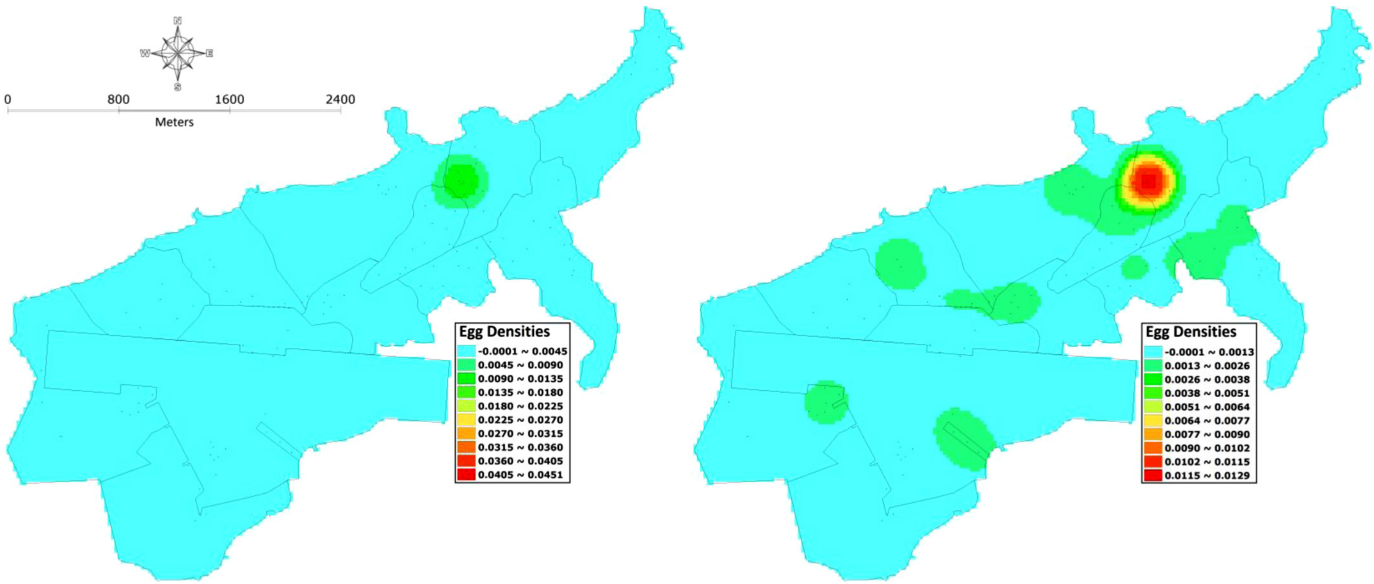

Fig. 6. Spatial distribution of egg density in December 2011. KDE maps showing smoothed egg densities for the same collection cycle, as produced with a common legend (left) aiming to compare maps from different months and the modified legend KDE map (right) for the same month, highlighting areas of high egg density.

island, or its presence is too low to be detected (frequency less than 1:1000), as no specimen was found among more than four thousand *Aedes* larvae identified to the species level. Nevertheless, this is not enough to state that *Ae. albopictus* is not present on the island, as all collections were made strictly around households. Due to its ecological plasticity we cannot discard the possibility that *Ae. albopictus* could be present in another areas of the island. Studies on the dipterofauna of FN are very scarce (Couri et al., 2008; Serafini et al., 2010). Alvarenga (1962), the only published reference found on the occurrence of Culicidae, reported the presence of two species in the island: *Aedes taeniorhynchus* and *Culex pipiens fatigans*.

An association between the observed temporal patterns of DENV transmission and the dynamics of seasonal abundance of its vector has been reported by several authors based on studies performed in urban areas at different latitudes (Barrera et al., 2011; Honório et al., 2009b; Lana et al., 2013). Temperature and rainfall are climatic factors most often stated as determinants of the seasonality of *Ae. aegypti* abundance. While the role of temperature in a large scale is clearer in latitudes with broader seasonal variations but seems to be absent near the equator (Honório et al., 2009b; Micieli and Campos, 2003; Mogi et al., 1988; Rios-Velasquez et al., 2007), the effect of rainfall seems to be largely modulated by local characteristics related to the retention and fate of the rainwater in each place at a small scale, as neighborhood or even the household.

In Fernando de Noronha, where the rainfall regime delimits a dry and a rainy season, 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 these counts, can provide an important forecasting tool. In regards to temperature, we have previously observed its positive influence on *Ae. aegypti* abundance in a city not very far from FN, despite small annual variations in temperature (Bonat et al., 2009). Since temperature oscillations in FN are even more subtle, with little amplitude throughout the year, the absence of an association between temperature and mosquito density is not surprising. It is worth mentioning that this is valid for the local temperature range 24–30 °C, and that a mosquito population may respond differently to an equally small variation in amplitude but within a different temperature range, for example between 18 °C and 24 °C.

As in previous mosquito surveys conducted elsewhere in Pernambuco (Regis et al., 2008, 2013), the results of this study showed the focal nature of the distribution of *Ae. aegypti* populations over urban spaces. The visual observation of this phenomenon in maps is of sound practical interest for vector surveillance and control programs (Regis et al., 2013). Heterogeneous spatial distribution of dengue vector populations has been demonstrated in different world geographical areas, as for instance in Peru (Getis et al., 2003), Thailand (Chansang and Kittayapong, 2007), Australia (Williams et al., 2007), Puerto Rico (Barrera, 2011), Saudi Arabia (El-Badry and Al-Ali, 2010), and Brazil (Honório et al., 2009b; Regis et al., 2008, 2013), and clustered spatial pattern of dengue cases has also been demonstrated (Flauzino et al., 2009; Khormi and Kumar, 2011; Mammen et al., 2008). This highlights the relevance of the use of surveillance systems that are able to show the spatial distribution of the vector, indicating in an understandable way, the sites to be prioritized for control interventions.

The surveillance system applied in this study is sensitive enough to characterize the infestation level of a site through a fast 5-day survey. However, for operational reasons a 1-month interval between visits was chosen, according to previous successful experiences elsewhere (Regis et al., 2009, 2013). This time interval is appropriate in regards to trap safety once s-ovt are treated with a Bti-based biolarvicide. The system was operated without great effort using modest resources and produced timely month information on the spatial dynamics of the vector populations expressed as maps that are easily understood by health field teams. On the other hand, these are information useful to feed mathematical models that can help understanding the dynamics of dengue diffusion and subsistence (Medeiros et al., 2011). An analysis of the relationships between vector spatial concentration and dengue cases in FN in 2011–2012, including aspects such as human population density and people displacement, will be published elsewhere.

The data on infestation of Fernando de Noronha produced by the official program for dengue control during the study period (2011–2013) differ greatly from the infestation scenario revealed through egg collections with ovitraps. The House Index indicated the occurrence of *Ae. aegypti* larvae/pupae in the island, however in less than 2% of the inspected houses.

Besides being an island, FN has several villages separated from each other, a good condition for testing different approaches to control mosquitoes, either individually or integrated in different combinations. The data generated are particularly useful as a baseline for planning control strategies tailored to the local conditions. An integrated vector control strategy involving expanded larviciding coverage with Bti, massive use of ovitraps loaded with Bti and the release of sterile males was designed for the island based on the infestation patterns described here, which highlights the priority areas for intervention. The applicability and safety of the symbiotic bacterium *Wolbachia* will also be considered to be used in FN, aiming to reduce dengue virus transmission capacity by the vectors (De Barro et al., 2011; Popovici et al., 2010; Walker et al., 2011).

It is known that a drastic reduction of a mosquito population within any place will require appropriate knowledge, planning, efforts, time and well-established strategies. For instance, we have recently shown that 2 years of sustained control pressure targeting simultaneously eggs and larvae were required to reach a sharp reduction of *Aedes* population in a middle-size city (Regis et al., 2013). This highlights the impressive plasticity of *Ae. aegypti* population, a colonizer of highly unstable habitats, whose survival is supported by a fast population growth and fast recovery (Schofield, 1991).

5. Conclusion

Our results revealed the dynamics of a population of *Ae. aegypti* that has been established over all inhabited areas of Fernando de Noronha, with changes in population densities, which revels seasonal and spatial focal distribution. This first report on the characteristics of the island infestation by the main dengue vector represents an important step for further studies that may contribute to improve our understanding on its population, thus providing baseline information to the development of further rational approaches on vector control.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.actatropica.2014.04.010. These data include Google maps of the most important areas described in this article.

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