Preventive Veterinary Medicine 110 (2013) 549–553

Contents lists available at SciVerse ScienceDirect

Preventive Veterinary Medicine

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

Short communication

Analysis of climatic and environmental variables associated with the occurrence of West Nile virus in Morocco

Paolo Calistri[a,*], Carla Ippoliti[a], Luca Candeloro[a], Abdennasser Benjelloun[b,d], Mehdi El Harrak[c], Belkadi Bouchra[d], Maria Luisa Danzetta[a], Daria Di Sabatino[a], Annamaria Conte[a]

[a] Istituto Zooprofilattico dell'Abruzzo e del Molise 'G. Caporale', Via Campo Boario, 64100 Teramo, Italy
[b] Central Command Post, Gendarmerie Royale, Route de Zaer, BP 5039, Rabat, Morocco
[c] Biopharma Laboratory, Avenue Hassan II, 10100 Rabat, Morocco
[d] Laboratory of Microbiology and Molecular Biology, University Mohamed V, Faculty of Science, B.P.1014, Rabat, Morocco

ARTICLE INFO

Article history:
Received 27 December 2011
Received in revised form 31 January 2013
Accepted 3 February 2013

Keywords:
West Nile virus
Remote sensing
Morocco

ABSTRACT

West Nile disease (WND) is one of the most widespread mosquito-borne infectious diseases in the World. In Morocco the first WND cases were reported in equines in 1996. After an apparent epidemiological silence, WND re-occurred in 2003 and in 2010, when the disease was reported in equines living in the central and north-western part of the country. Eco-climatic variables are known to influence the mosquito presence and abundance and, therefore, the probability of occurrence of mosquito-borne infections. The remote sensed values of Land Surface Temperature (LST), Normalised Difference Vegetation Index (NDVI) and rainfall registered from 2001 to 2010 were evaluated for a possible association with the occurrence of WND cases in 2003 and in 2010. In the zones where WND cases occurred, NDVI values recorded in 2003 and 2010, from June to November, were significantly higher than those registered during the same months in the rest of the decade. Rainfall data showed higher peaks in 2003 and 2010, when the number of days with extreme rainfall was significantly higher during 1–2 months before the occurrence of WND cases. Temperature does not seem to play an important role in Moroccan epidemiological conditions.

1. Introduction

West Nile virus (WNV) is a mosquito-transmitted *Flavivirus* belonging to the Japanese encephalitis antigenic complex of the Family *Flaviviridae* (Karabatos, 1985). It is transmitted primarily by the bite of mosquitoes being infected by feeding on viraemic birds (Kulasekera et al., 2001). Birds represent the vertebrate amplifying hosts (Komar et al., 2001), responsible for the virus maintenance in the environment and migratory species can be considered the main responsible for the geographical spread of the infection (Calistri et al., 2010). Humans, equines and other mammals are regarded as incidental or dead-end hosts. In the last decades an increasing number of cases of West Nile Disease (WND) was observed in equines and humans in the Mediterranean basin (Calistri et al., 2010).

Eco-climatic variables are known to influence the mosquito presence and abundance and, therefore, the probability of occurrence of mosquito-borne infections. Suitable climatic and environmental conditions influencing the abundance of mosquitoes and the density of susceptible hosts are the main factors influencing the occurrence of WND cases (Cantile et al., 2000). Several eco-climatic variables were found to be significantly associated with WND occurrence in many studies (Cantile et al., 2000; Mongoh et al., 2007; Ward, 2005, 2007, 2009). WNV was

* Corresponding author. Tel.: +39 0861332241; fax: +39 0861332251.
E-mail address: p.calistri@izs.it (P. Calistri).

0167-5877/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.prevetmed.2013.02.011

first detected in Morocco in 1996 (Tber Abdelhaq, 1996). After an apparent epidemiological silence, WND cases were notified in September and October 2003 in the province of Kénitra and, then, in August 2010, in the Rabat-Sale-Zemmour-Zaer and Tadla-Azilal regions, respectively in the north-western and central part of Morocco.

The aim of this study was to explore the differences between temperature, rainfall and vegetation index values recorded in 2010 and in 2003 and those recorded during years with no apparent WND cases. In particular, the values of Land Surface Temperature (LST), Normalised Difference Vegetation Index (NDVI) and precipitations from 2001 to 2010 were investigated. The following hypotheses were tested:

- temperature was not a critical variable in Moroccan epidemiological conditions, given the latitude of the country,
- higher NDVI values were associated with years of WND occurrence in equines (2003 and 2010), thus supporting the apparent multi-annual cyclicity observed in the occurrence of WND cases,
- the occurrence of WND cases was linked to extreme rainfall of previous months.

2. Materials and methods

2.1. Description of study areas

The province of Kénitra (in the region of Gharb-Chrarda-BéniHssen, in the north-western Morocco), which was involved in 2003 WNV transmission, is located in an extremely humid area that includes several wetlands and rice fields flooded by channels from the Sebou River. A natural bird reserve, Sidi Boughaba, is located 15 km southeast of Kénitra, along one of the migratory Europe-sub-Saharan routes (Schuffenecker et al., 2005). The climate is Mediterranean, with dry, hot summers and wet winters from October to April. The same climate can be observed in the Rabat-Sale-Zemmour-Zaer region, where WND occurred in 2010. In the same year other WND cases were notified in the region of Tadla-Azilal, in the central part of Morocco, which is characterised by a dry sub-humid climate.

2.2. WND cases

In Morocco WNV transmission was firstly detected in 1996 when the disease was notified in 94 equines and one person (Tber Abdelhaq, 1996). In September and October 2003 WND cases were notified in 9 equines in the province of Kénitra, in the municipalities of Ouled Slama, Ameur Seflia and Mograne, located 20–30 km northeast of Kénitra city, close to the delta of river Sebou and the Atlantic Ocean. No abnormal mortality in birds was observed and no human cases were reported at that time (Schuffenecker et al., 2005). The virus isolated from infected equines in 1996 and in 2003 belonged to WNV lineage 1, clade 1a (Schuffenecker et al., 2005). In August 2010 the disease was reported in the coastal areas of Rabat-Sale-Zemmour-Zaer region (north-western of Morocco) and in the region of Tadla-Azilal (central part of Morocco), involving four provinces and twelve municipalities. A total of 25 cases of neuroinvasive disease were confirmed in equines to the end of September 2010 (OIE, 2010).

Only in few cases the geographical coordinates of the infected farms were recorded by GPS (Global Positioning System), whereas the geographical location was estimated in the majority of cases through the name of the village and the help of local veterinarians, who visually validated the farm's location using high resolution images (Image©GeoEye – Google Earth. 2011. Google, Inc.).

In consideration of the possible error of geographic locations and taking into account *Culex* dispersal range (Reeves et al., 1948; Hassan and Onsi, 2004), a circular area of 10 km radius was arbitrarily drawn around each case location, thus creating the following circular polygons (Fig. 1):

- ten polygons containing WND cases occurred in 2010 ("zone 2010"),
- two polygons containing WND cases occurred in 2003 ("zone 2003").

2.3. Remote sensed climatic data and statistical analyses

The remote sensed datasets used in the analyses were: MODIS Land Surface Temperature & Emissivity (MOD11A2), MODIS Vegetation Indices (MOD13Q1) and precipitations (TRMM – Tropical Rainfall Measuring Mission project). Data from 2001 to 2010 were downloaded for the period 2001–2010 and converted into a unique coordinate system (WGS84/UTM/zone 30). Values recorded between June and November of each year were used in the analyses. The choice of limiting the analysis to this period of the year was based on the epidemiology of the disease, the dates of cases notification in 2003 and 2010 and the expected disease incubation period in equines.

The mean value of all pixels falling within each polygon was calculated for each NDVI image (16-days period). The resulting dataset of 11 NDVI values for each polygon and year was analysed by paired comparison through the Wilkoxon Rank Sum test to identify any significant difference between the years of WND occurrence and the rest of the decade (2003 vs. others, 2010 vs. others). Since multiple comparisons ($n = 10$) were performed, the significance of the difference was set to 0.005 (p-value of 0.05 divided by the number of comparisons according to the Bonferroni's rule) (Miller, 1991).

The 95th percentile of the monthly distribution of the amount of precipitation was calculated from the rainfall dataset (mm/day). The number of days with precipitations above the 95th percentile value (considered as a possible quantification of "extreme rainfall") was tested by chi-square test to identify the years with a number of "extreme rainfall" days significantly higher than expected.

A degree-day model (Zou et al.) was also applied to test the role of temperature. For the two zones involved in 2003 and 2010 WNV circulation, degree-day values were calculated using an on-line calculator available at http://www.ipm.ucdavis.edu/WEATHER/index.html. The value of lower threshold was set at 14.3 °C (Zou et al.,