Human movement can explain heterogeneous propagation of dengue fever in Cambodia

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1. Introduction

Dengue fever is the most important arboviral disease worldwide and a major public health problem in tropical and sub-tropical areas. It is endemic in Cambodia where it causes high hospitalisation and mortality rates among children. In the absence of a vaccine, control is limited to vector control measures. Understanding the forces driving spatial spread is essential in low income countries to aid better allocation of resources, and control measures implementation. In this study, we analyse dengue fever national surveillance data to characterize its spatio-temporal pattern of propagation in Cambodia from 2002 to 2008.

2. Material and methods

The data

Cambodia National surveillance recorded 109,332 dengue cases during 2002-2008. Cases were declared on a clinical basis. We calculated dengue weekly incidence rates in each of the 183 districts. Population data were interpolated linearly using two national censuses. Assuming that dengue epidemic patterns would be highly stochastic in low populated areas, we discarded the 48 districts with less than 20 people per km² from the analysis.

Temporal analysis

We used wavelet analysis (Torrence, 1998) to filter incidence rates in the 0.8-1.2 year periodic band. This spectral technique also allowed us to extract the phase of this annual component of incidence and to calculate time lags between annual epidemics in different districts (Figure 1).

Spatial analysis

The study of dengue incidence maps revealed two geographic areas seminal in the propagation of dengue fever: the national road between Phnom Penh and Siem Reap and the Mekong river (see Fig. 2a). To reveal spatial heterogeneity, we performed, each year, an analysis of covariance:

\[ Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \times X_4 + \epsilon \]

with the annual mean of temporal lag time series relative to the district #306, X₁ the corresponding distance separating districts centres, and X₄ the geographic area “Mekong” or “National Road” (Fig. 2a). Separate regressions were then performed in each geographic area to evaluate the speed of propagation of the annual epidemic.

3. Results

Figure 1: Apparent dengue haemorrhagic fever weekly incidence rates in each of the 135 districts where population density is higher than 20 people per km² in Cambodia. Districts are ranked by increasing distance to Phnom Penh from bottom to top.

Figure 2: Phase of the weekly incidence rates computed in the 0.8-1.2 periodic band in two geographic areas. a. Map of the two geographic areas chosen. Grey districts have less than 20 people per km². b. Phase of districts along the Mekong River (red in Fig. 2a), presented from the most southerly to the most northerly from bottom to top. c. Phase of districts along the National Road (blue in Fig. 2a), presented from West to East from bottom to top. The arrows indicate districts: 1, #306, 2, Phnom Penh (Fig. 2b) and #104 (Fig. 2c).

Figure 3: Linear regressions between the mean annual temporal lag of the annual epidemic in each district and the distance, relative to the district surrounding Kampong Cham (#306) from 2002 (a) to 2007 (f). Colours represent the geographic localization of each district, according to Fig. 2a. The number of districts included in the analysis changes every year, according to whether an epidemic occurred in the district (Table 1). Error bars represent the 95% CI associated with the mean. Normality and homoscedasticity of residuals was confirmed using the Shapiro-Wilk and the Bartlett tests respectively (alpha level 0.05).

The results of the ANCOVA confirmed the heterogeneity of propagation within the country: each year, the speed of propagation of the epidemic, as estimated by the inverse of the regression coefficient, varied from 0.55 km per week (Fig. 3a) to 0.76 km per week (Fig. 3f). In 2007, there was a significant higher along the national road than along the Mekong River (mean annual speed of 11 km per week).

In 2007, there has been a major epidemic characterised by a four fold increase in dengue incidence, a higher synchronisation of the epidemics, an acceleration of the speed of propagation along the Mekong River (Fig. 3f).

4. Discussion

Propagation is heterogeneous according to the type of road: first empirical proof of the role of human movement in the propagation of dengue.

Starting point in rural areas.

2007: serotype 2 replacing serotype 3.

Implications for operational purposes: treat starting points in priority.

Limits of the study: surveillance biases, but wavelet technique very robust.

References:


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