International Journal for Parasitology xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

International Journal for Parasitology

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

Assessment of the national schistosomiasis control program in a typical region along the Yangtze River, China

Yi Hu [a,b,c,d], Si Li [a,b,c,d], Congcong Xia [a,b,c,d], Yue Chen [e], Henry Lynn [a,b,c,d], Tiejun Zhang [a,b,d], Chenglong Xiong [a,b,d], Gengxin Chen [f], Zonggui He [f], Zhijie Zhang [a,b,c,d,*]

[a] Department of Epidemiology, School of Public Health, Fudan University, Shanghai, China
[b] Key Laboratory of Public Health Safety, Ministry of Education, Shanghai, China
[c] Laboratory for Spatial Analysis and Modeling, School of Public Health, Fudan University, Shanghai, China
[d] Collaborative Innovation Center of Social Risks Governance in Health, School of Public Health, Fudan University, Shanghai, China
[e] School of Epidemiology, Pubic Health and Preventive Medicine, Faculty of Medicine, University of Ottawa, 451 Smyth Rd, Ottawa, Ontario, Canada
[f] Schistosomiasis Station of Prevention and Control in Guichi Distirct, Anhui Province, China

ARTICLE INFO

Article history:
Received 19 July 2016
Received in revised form 13 September 2016
Accepted 22 September 2016
Available online xxxx

Keywords:
Schistosomiasis
Bayesian spatio-temporal model
Zero-inflated binomial distribution
Probability contour map
Yangtze River Basin
China

ABSTRACT

Schistosomiasis remains a major public health problem in eastern China, particularly along the Yangtze River Basin. The latest national schistosomiasis control program (NSCP) was implemented in 2005 with the main goal of reducing the rate of infection to less than 5% by 2008 and 1% by 2015. To assess the progress, we applied a Bayesian spatio-temporal model to describe dynamics of schistosomiasis in Guichi, Anhui Province, China, using annual parasitological and environmental data collected within 41 sample villages for the period 2005–2011. Predictive maps of schistosomiasis showed that the disease prevalence remains constant and low. Results of uncertainty analysis, in the form of probability contour maps (PCMs), indicated that the first goal of "infection rate less than 5% by 2008" was fully achieved in the study area. More longitudinal data for schistosomiasis are needed for the assessment of the second goal of "infection rate less than 1% by 2015". Compared with the traditional way of mapping uncertainty (e.g., variance or mean-square error), our PCMs provide more realistic information for schistosomiasis control.

1. Introduction

Schistosomiasis is an acute and chronic, neglected tropical parasitic disease that is distributed in tropical and subtropical areas of the world (Gray et al., 2010). It remains a serious public health problem worldwide and the global burden of schistosomiasis has been estimated to be 3.31 (95% confidence interval (CI): 1.70–6.26) million disability-adjusted life years (DALYs) (Krishnamurthi et al., 2013). According to the World Health Organization (WHO), at least 249 million people were estimated to receive preventive treatment for schistosomiasis in 2013 (http://www.who.int/mediacentre/factsheets/fs115/en/). Schistosomiasis japonica, caused by the parasitic trematode *Schistosoma japonicum*, has significant impact on human health and socioeconomic development in certain regions in the People's Republic of China. It is estimated that more than 50 million persons nationwide are at risk (McManus et al., 2010); approximately 116,000 persons are still infected (Lei et al., 2015). Major foci of endemicity are found in marsh and lake areas along the Yangtze River Basin where the elimination of transmission has proven difficult due to vast areas of *Oncomelania hupensis* (i.e., the intermediate host snail) habitats (Zhou et al., 2005).

Over the past six decades, China has made great strides toward reducing the prevalence of schistosomiasis japonica, largely through a strategy based on chemotherapy and snail control (Zhou et al., 2007). Despite this achievement, schistosomiasis has re-emerged in the past decade as a result of changes in ecological and socio-economic factors such as effects of global warming, changes in patient susceptibility to infection and re-infection, increasing population mobility, changes in snail habitats and distribution via ecosystem changes as a result of human activities (e.g., the Three Gorges Dams and the South-North Water Conversion Project) (McManus et al., 2009; Collins et al., 2012). To reach the aggressive control target of reducing the infection rate to less than 5% by 2008 and 1% by 2015, respectively, the latest National Schistosomiasis Control Program (NSCP) was implemented in 2005 using integrated control measures (Wang et al., 2009), which have been aiming at reducing the roles of bovines and humans as infection sources. Nevertheless, there is still a concern that the

* Corresponding author at: School of Public Health, Fudan University, 130 Dong'an Road, Xuhui District, Shanghai 200032, China. Fax: +86 21 54237410.
E-mail address: epistat@gmail.com (Z. Zhang).

http://dx.doi.org/10.1016/j.ijpara.2016.09.003
0020-7519/

disease would re-emerge not only due to the presence of infected snails found along the Yangtze River (Yang et al., 2013) but also other multiple infection sources (e.g., mice, goats, dogs) (Zhou et al., 2012). A study is therefore needed that assesses the progress of the integrated control strategy within those regions along the Yangtze River.

In this context, health agencies have to assess schistosomiasis risk in order to understand the effectiveness of the integrated control strategy and decide whether further actions are needed. Thus, continuous maps of schistosomiasis prevalence are required. The improvement of national and local surveillance systems in the past decade provides good quality longitudinal parasitic data. In this study, we built a hierarchical Bayesian spatio-temporal model which allowed us to catch the complex spatio-temporal dynamics of schistosomiasis prevalence and associated environmental covariates in Guichi, Anhui Province, East China, a typical schistosomiasis-endemic region along the Yangtze River. We first describe schistosomiasis prevalence in Guichi using annual village level parasitological data for the period 2005–2011, and briefly discuss the hierarchical spatio-temporal model. We then proceed to use the model to map the continuous schistosomiasis prevalence in the study area. In closing, we assess the progress of the NSCP.

2. Materials and methods

2.1. Study area

Guichi, situated in the middle-lower reaches of the Yangtze River Basin (Fig. 1) is one of the highest endemic areas of schistosomiasis japonica in the People's Republic of China (Zhao et al., 2005). It covers an area of approximate 2500 km^2 and is comprised of 207 villages. Major rivers include the Yangtze River in the northwest and the Qiupu River in the middle. The humid subtropical and monsoonal climate, with an average annual temperature of approximately 16 °C and annual rainfall of approximately 1600 mm, provides an ideal environment for the survival of *O. hupensis* (Zhang et al., 2008).

2.2. Parasitological data

The *S. japonicum* infection prevalence data for 2005–2011were provided by the local anti-schistosomiasis station in Guichi. The data were collected annually through village-based field surveys using a two pronged diagnostic approach: screening by a serological test of all residents 5–65 years old and confirmed by Kato-Katz stool examination (Yu et al., 2007). The blood sample was first collected from each participant and subsequently subjected to an indirect haemagglutination (IHA) test for IgG antibodies against *S. japonicum* and the stool sample was collected from seropositive individuals and was examined for schistosome eggs in feces using a traditional approach of the Kato-Katz thick smear examinations (three slides for each sample). The database used in this study consisted of 41 sample villages (shown in Fig. 1), which were selected from the database of the annual schistosomiasis survey with the criteria that a village should be surveyed every year and the number of examined individuals within the village should be over 100. Additional details describing the process of data collection have been reported elsewhere (Zhang et al., 2008).

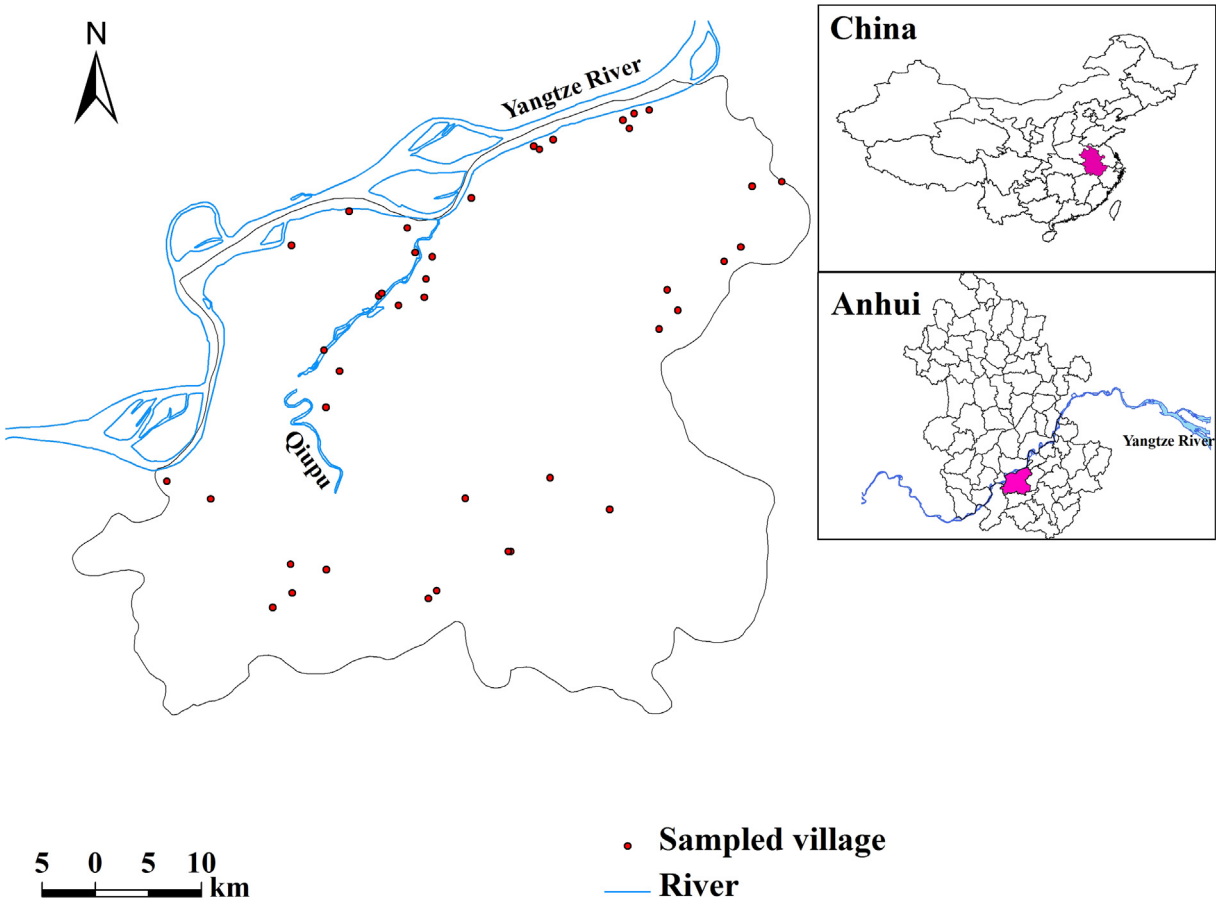

Fig. 1. Endemic area of schistosomiasis in Guichi, Anhui, China. The river along the county border is the Yangtze River and the Qiupu River is within the county border.

Please cite this article in press as: Hu, Y., et al. Assessment of the national schistosomiasis control program in a typical region along the Yangtze River, China. Int. J. Parasitol. (2016), http://dx.doi.org/10.1016/j.ijpara.2016.09.003