



Schistosomiasis transmission and control in China[☆]



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ABSTRACT

In the last 60 years, great progress has been made in controlling and preventing schistosomiasis in China. However, due to the ecosystem changes caused by the construction of the Three Gorges Dams and the South-north Water Conversion Project, the effects of climate change, the scarcity of a highly sensitive surveillance and response system, schistosomiasis is still considered as a major public health problem and is listed among the top infectious diseases in the country prioritized for control and elimination. Based on the epidemiological pattern of schistosomiasis and ecological characteristics of the vector snail, endemic areas of schistosomiasis in China were categorized into three types: (i) plain region with waterway networks, (ii) mountainous and hilly regions, and (iii) marshland and lake regions. China aims to reach the criteria of transmission control threshold of less than 1% in the lake and marshland provinces and reach transmission interruption threshold in hilly provinces of Sichuan and Yunnan by the end of 2015. The purpose of this article is to use the deterministic model proposed in our earlier study in (Chen et al., 2010) to simulate the schistosomiasis infection data from other lake and marshland provinces, including Hunan, Jiangxi and Anhui. Our simulations demonstrate that the model can reasonably mimic the schistosomiasis infection data from these lake and marshland provinces. Thus, similar control and prevention measures can be designed and proposed for these provinces. We will also try to use the model to simulate the schistosomiasis infection data from Sichuan and Yunnan provinces in the mountainous and hilly regions where cattle farming is not as popular and important as in the lake and marshland provinces and find out that different control and prevention strategies are required.

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1. Introduction

Schistosomiasis is an acute and chronic disease caused by parasitic worms *Schistosoma*. It is the second most socioeconomically devastating parasitic disease after malaria (The Carter Center). Globally, at least 249 million people required preventive treatment for schistosomiasis in 2012 (WHO, 2014). Six parasite species have been reported to be able to infect humans, including *Schistosomiasis haematobium*, *Schistosomiasis japonicum*, *Schistosomiasis mansoni*, *Schistosomiasis intercalatum*, *Schistosomiasis mekongi* and *Schistosomiasis malayensis* (Wang et al., 2013). These parasites live in certain types of freshwater snails (intermediate hosts). The infectious and larval form of the parasite, known as cercariae, emerge from the snail, hence contaminating water. Humans and other

mammals (definite hosts) can become infected when their skin comes in contact with contaminated freshwater. The transmission cycle continues when definite hosts suffering from schistosomiasis contaminate freshwater sources with their excreta containing parasite eggs which hatch in water.

Schistosomiasis japonica is mainly prevalent in China, the Philippines, and parts of Indonesia. One feature of the life cycle of this parasite, which distinguishes it from the other human schistosome species, is that a wide spectrum of potential definitive hosts, including over 40 species of domestic and wild mammals (cattle, buffaloes, swine, goats and rats, whereas sheep, rabbits, and horses (Chen and Feng, 1999)) are suspected of being potential reservoirs, which complicates transmission patterns. The second characteristic of *S. japonica* is that the intermediate host snail *Oncomelania hupensis* is amphibious rather than aquatic. Effectively controlling schistosomiasis or even eradicating it in some areas does not necessarily mean that it cannot re-emerge, because of its complicated transmission process (Liang et al., 2006).

S. japonica has existed in China for more than 2100 years (Mao and Shao, 1982; McManus et al., 2010). In 400 BC, there were descriptions of schistosomiasis in “*Zhouhou Beiji Fang* (Handbook

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of Prescriptions for Emergency)", which was the first handbook of clinical first aids in China. In 1977, *S. japonicum* eggs were identified in a female corpse dating back to the Western Han dynasty (206 BC–9 AD), which was exhumed in Changsha, Hunan Province, where schistosomiasis still persists today. In 1978, *S. japonicum* eggs were also found in another corpse buried 100 years earlier in Jiangling County, Hubei Province, which is also an endemic area of schistosomiasis now.

In the first half of the 20th century, the epidemics of schistosomiasis in some areas of China were so bad that the disease wiped out some towns and villages entirely. An investigation in Gengtou Village, Baifu Township, Fengcheng County, Jiangxi Province, in 1954, showed that only two persons were left alive, while in the middle of the 19th century, there were approximately one thousand households in the big village according to the record of the township. Approximately 90% of the deaths were supposed to be due to schistosomiasis (Chen and Feng, 1999). In the 1950s, *S. japonica* was epidemic throughout 12 provinces in China. Over the past 60 years, China has made tremendous progress in treating and controlling schistosomiasis and the disease was successfully eradicated in some provinces. By 1995, five provinces (Guangdong, Shanghai, Fujian, Guangxi, and Zhejiang) had blocked the transmissions of *S. japonica* (National Institute of Parasitic Diseases). However, transmissions still occur in Hunan, Hubei, Jiangxi, Anhui and Jiangsu provinces along the Yangze River, and Sichuan and Yunnan provinces in the mountainous and hilly regions.

Although great achievements have been made for controlling schistosomiasis in China, there are still many major challenges such as the existing extensive snail habitats with complicated environments, ecosystem changes caused by the construction of the Three Gorges Dams and the South-north Water Conversion Project, the effects of climate change, the scarcity of a highly sensitive surveillance and response system, and the access of infected persons to health care (Collins et al., 2012). Today, schistosomiasis is still considered as a major public health problem and is listed among the top infectious diseases (along with HIV/AIDS, tuberculosis, and hepatitis B) in the country prioritized for control and elimination (Ross et al., 2013; Wang et al., 2008). By the end of 2011, a total of 454 counties (cities, districts) were endemic with schistosomiasis, of which 103 reached transmission control threshold and 274 reached transmission interruption threshold. China aims to reach the criteria of transmission control threshold of less than 1% in the lake and marshland provinces and reach transmission interruption threshold in hilly provinces of Sichuan and Yunnan by the end of 2015 (WHO Representative Office China).

Based on the epidemiological pattern of schistosomiasis and ecological characteristics of the vector snail, endemic areas of schistosomiasis in China were categorized into three types: (i) plain region with waterway networks, (ii) mountainous and hilly regions, and (iii) marshland and lake regions (Mao and Shao, 1982). In Chen et al. (2010), we proposed a deterministic model to describe the human-cattle-snail transmission dynamics of schistosomiasis and used the model to simulate the schistosomiasis infection data from Hubei Province which is in the lake and marshland regions. The purpose of this article is to further use the deterministic model in Chen et al. (2010) to simulate the schistosomiasis infection data from other lake and marshland provinces, including Hunan, Jiangxi and Anhui. Our simulations demonstrate that the model can reasonably mimic the schistosomiasis infection data from these lake and marshland provinces. Thus, similar control and prevention measures can be designed and proposed for these provinces. We will also try to use the model to simulate the schistosomiasis infection data from Sichuan and Yunnan provinces in the mountainous and hilly regions where cattle farming is not as popular and important as in the lake and marshland provinces and find out that different control and prevention strategies are required.

2. Mathematical modeling

Let $S_H(t)$ and $I_H(t)$ denote the density of susceptible and infected human population, $S_C(t)$ and $I_C(t)$ denote the density of susceptible and infected cattle population, and $S_S(t)$ and $I_S(t)$ denote the density of susceptible and infected snail population at time t , respectively. The schistosomiasis model is a system of six ordinary differential equations (see Chen et al., 2010):

$$\begin{cases} \frac{dS_H}{dt} = -\beta_{SH}S_HI_S + r_HI_H, \\ \frac{dI_H}{dt} = \beta_{SH}S_HI_S - r_HI_H, \\ \frac{dS_C}{dt} = b_C(S_C + I_C) - \beta_{SC}S_CI_S + r_CI_C - d_C S_C - k_C S_C(S_C + I_C), \\ \frac{dI_C}{dt} = \beta_{SC}S_CI_S - r_CI_C - d_C I_C - k_C I_C(S_C + I_C), \\ \frac{dS_S}{dt} = b_S(S_S + I_S) - \beta_{HS}S_SI_H - \beta_{CS}S_SI_C - d_S S_S - k_S S_S(S_S + I_S), \\ \frac{dI_S}{dt} = \beta_{HS}S_SI_H + \beta_{CS}S_SI_C - d_S I_S - k_S I_S(S_S + I_S). \end{cases} \quad (1)$$

The parameters are described as follows:

| | |
|-------------------|--|
| β_{SH} | – transmission rate from infected snail to human; |
| r_H | – recovery rate of infected human; |
| b_C | – natural birth rate of cattle; |
| β_{SC} | – transmission rate from infected snail to cattle; |
| d_C | – death rate of infected cattle; |
| $(b_C - d_C)/k_C$ | – carrying capacity of cattle; |
| r_C | – recovery rate of infected cattle; |
| b_S | – natural birth rate of snail; |
| β_{HS} | – transmission rate from infected human to snail; |
| β_{CS} | – transmission rate from infected cattle to snail; |
| d_S | – death rate of infected snail; |
| $(b_S - d_S)/k_S$ | – carrying capacity of snail. |

The basic reproduction number, defined as the expected number of secondary infections produced by an index case, is defined as follows (Diekmann et al., 1990, 2010; van den Driessche and Watmough, 2002):

$$R_0 = \sqrt{\frac{b_S - d_S}{b_S k_S} \left(\frac{\beta_{SH} N_H \beta_{HS}}{r_H} + \frac{\beta_{SC} \beta_{CS} (b_C - d_C)}{k_C (b_C + r_C)} \right)}, \quad (2)$$

which is composed of two parts: the influence of infectious humans and infectious cattle.

In Chen et al. (2010), we used the model to simulate the schistosomiasis infection data from Hubei Province from 2005 to 2007. By carrying out sensitivity analyses of the basic reproduction number on various parameters, we noticed that the transmission of *S. japonicum* between cattle and snails plays a more important role than that between humans and snails in the endemicity of schistosomiasis in Hubei Province. In the following, we will use the model to simulate the schistosomiasis infection data from other provinces in China. We will classify these provinces as marshland and lake regions, mountainous and hilly regions, and plain regions with waterway networks, and discuss some useful and effective schistosomiasis control measures in these provinces.

3. Marshland and lake regions

Marshland and lake regions including the areas on the banks of the Yangze River and surrounding lakes of different sizes in Hunan, Hubei, Jiangxi, Anhui, and parts of Jiangsu provinces. The human

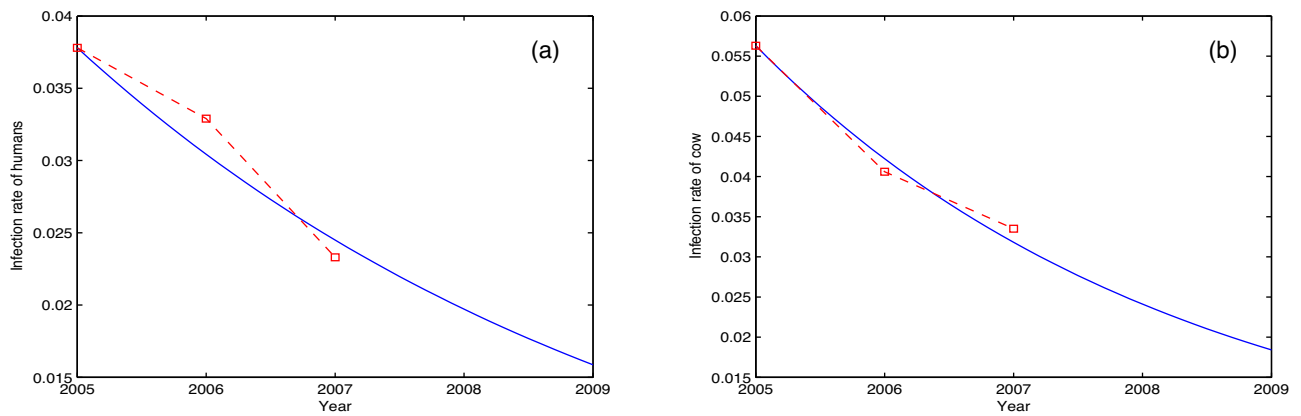


Fig. 1. (a) Numerical simulations of (a) the infection rate of humans and (b) the infection rate of cattle compared with the data from Hubei Province from 2005 to 2007 (see Chen et al., 2010).

infection is mainly related to agriculture, fishing and household works. The most endemic areas of schistosomiasis are this type of regions. Cattle are important in the transmission of schistosomiasis in these regions. Water levels are unstable and snail elimination is not easy.

In Chen et al. (2010), we used model (1) to numerically simulate the infection rates of humans and cattle of Hubei Province, which are given in Fig. 1 for the sake of comparison.

The other areas in the marshland and lake regions have similar environmental factors as in Hubei. Fig. 2 shows the simulations by model (1) comparing with the reported schistosomiasis infection data (2005–2010) from Hunan, Jiangxi, and Anhui provinces, respectively. These simulations demonstrate that although the infection rates are decreasing, schistosomiasis is still endemic in the marshland and lake regions, in particularly in Hunan Province.

The simulations indicate that our model (1) based on Hubei Province is also suitable for Hunan, Jiangxi, and Anhui provinces. Thus, the suggestions given in Chen et al. (2010) for Hubei Province are also effective for other provinces in the marshland and lake regions. Thus, traditional strategies in controlling schistosomiasis including chemotherapy, health education, livestock chemotherapy, and snail control in risk areas are all important to control schistosomiasis infection. Furthermore, it is important to break the snail-cattle transmission cycle in order to control and eventually to eradicate schistosomiasis in these regions. That is, more comprehensive surveillance on cattle, early diagnosis and chemotherapy of cattle are crucial for the control and prevention of schistosomiasis.

4. Mountainous and hilly regions

Though the transmissions of *S. japonica* had been blocked in some mountainous and hilly provinces such as Fujian, Guangdong,

Guangxi (Office of Endemic Diseases Control, 1996), the disease is still endemic and indeed serious in Sichuan and Yunnan provinces. In these regions, snails can be found in seepage water, in caves, terraces, on barren land, and even on rock precipices that are not easily accessible. Thus, to eliminate snails is very challenging. Also in these regions, bovines are scarce. Instead, rodents and dogs may feature as infection reservoirs in some of the mountainous and hilly regions. In China, it is estimated that there are 80–200 millions (Zhang et al., 2011). Especially in rural areas, about 70 percent of households keep dogs.

We simulate the infection rates in Yuannan and Sichuan provinces (Fig. 3) using model (1). Some parts of the two provinces are also endemic areas, although the infections there are now much lower than that in the 1950s (Liang et al., 2006). The transmission of schistosomiasis in the two provinces are similar because of their similar environmental factors. There is also evidence showing the reemergence of schistosomiasis transmission in some areas where it had formerly been controlled or eliminated. There is an example of three villages in Sichuan. The mean prevalence of infection was 63% in 1987 and 8% in 1995, but rebounded to 45% by 2000 (Liang et al., 2007). It is still far way from the elimination of schistosomiasis transmission in these areas.

From Fig. 3, we can see that the infection rates of cattle by our simulations based on model (1) are higher than the reported data in Yunnan and Sichuan provinces. Thus, we conclude that definitive hosts should include not only cattle but also other animals such as dogs or rats. We could run simulations for the two provinces by model (1) with variables S_C and I_C representing susceptible mammals and infective mammals instead of susceptible cattle and infective cattle, respectively. Thus, the transmission between snails and mammals should be focused on. Unfortunately, we do not have the exact data for those mammals from these two provinces.

In these regions, schistosomiasis is only endemic in some counties, while it is well controlled in most other counties. For

Table 1
Regional schistosomiasis data from Sichuan Province in 2010 (Sichuan Health Yearbook, 2010).

| County | Endemic villages | Population in endemic villages (Ten thousands) | Estimated people infected (Ten thousands) |
|------------|------------------|--|---|
| Chengdu | 209 | 446.67 | 0 |
| Deyang | 85 | 166.81 | 759 |
| Leshan | 71 | 55.58 | 14 |
| Liangshan | 78 | 68.87 | 241 |
| Yaan | 43 | 36.61 | 72 |
| Meishan | 93 | 186.47 | 1198 |
| Mianyang | 56 | 73.73 | 267 |
| Neijiang | 5 | 1.45 | 0 |
| Pangzhihua | 4 | 4.61 | 0 |
| Yibin | 2 | 4.37 | 0 |
| Ziyang | 18 | 8.21 | 0 |

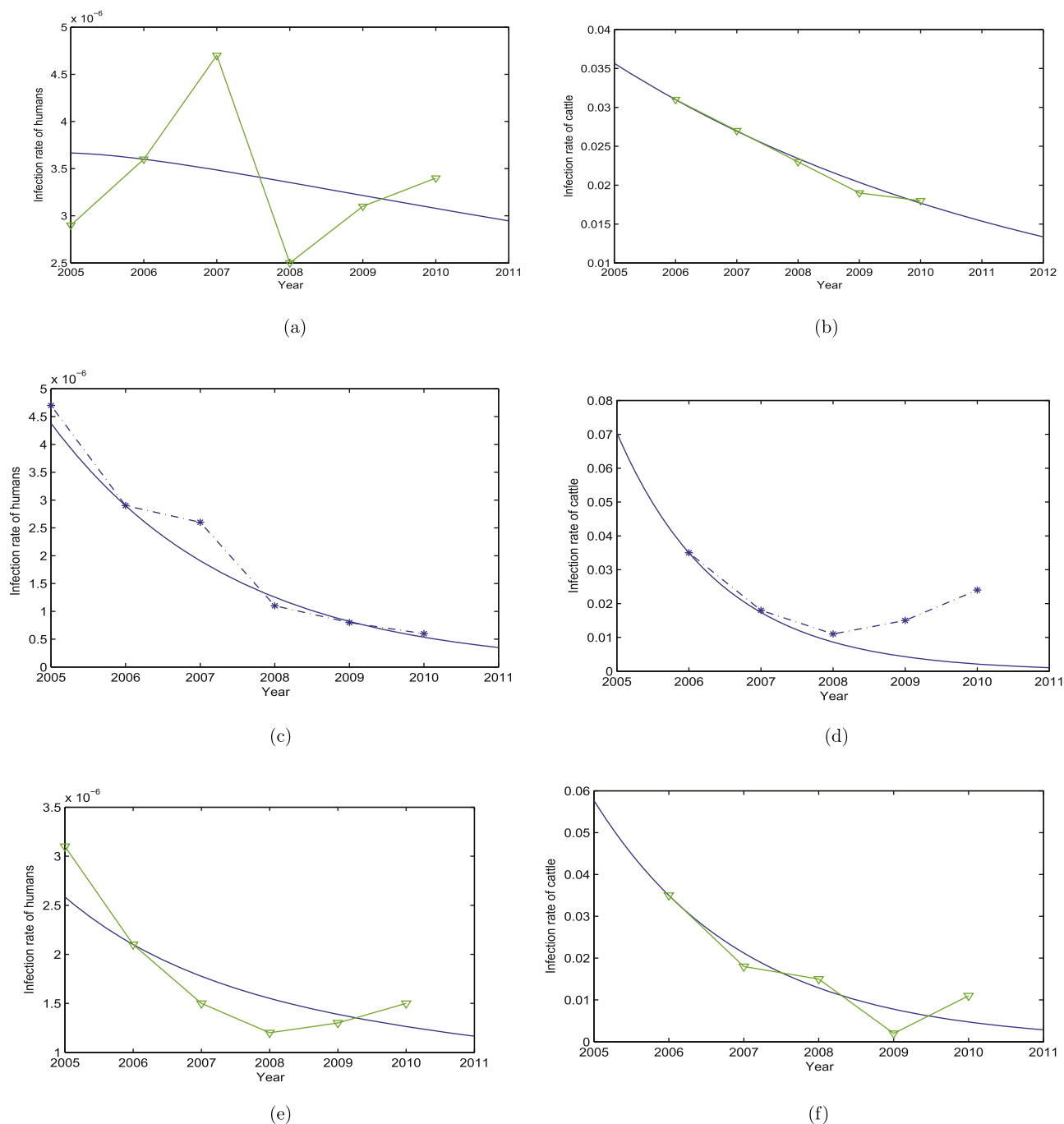


Fig. 2. (a) Simulations of the infection rates of humans and cattle from model (1) compared with the reported data from 2002 to 2010 in (a, b) Hunan Province; (c, d) Jiangxi Province; and (e, f) Anhui Province. The smooth solid curves represent the simulated infection rates based on the model while the segmental curves are the reported infection rates.

example, in Sichuan Province 20 counties had attained transmission control status and 16 had attained transmission interruption by 1985. By 2001, 21 counties had attained transmission control and 25 counties had attained transmission interruption (Liang et al., 2006). However, in the endemic counties such as Xichang, the infection level in 2000 reached as high as an average prevalence of 29% (Seto et al., 2011) (Table 1).

In the endemic counties such as Xichang, to control the infection rate in humans be less than 1% is still a challenge. From Fig. 4, we can see that we need first to decrease the transmission coefficient from snails to humans (less than 2.2×10^{-4}). We also need to control the population of snails by eliminating more snails (more than 7%). Of

course, chemotherapy is necessary and the recovery rate should be more than 70%.

The situation in Guangdong Province is much more better than in Yunnan and Sichuan provinces. It was the first province where schistosomiasis was eradicated successfully as an endemic area in China in 1985. However, there are still reported infection of schistosomiasis in recent years (see Fig. 5). Since Guangdong has a large number of immigrants from other provinces including endemic provinces, it continues to be the subject of surveillance, focusing on snail habitats and infected snails, coupled with a strengthening of surveys aiming at the identification of the sources of infection, both on local residents and immigrants.

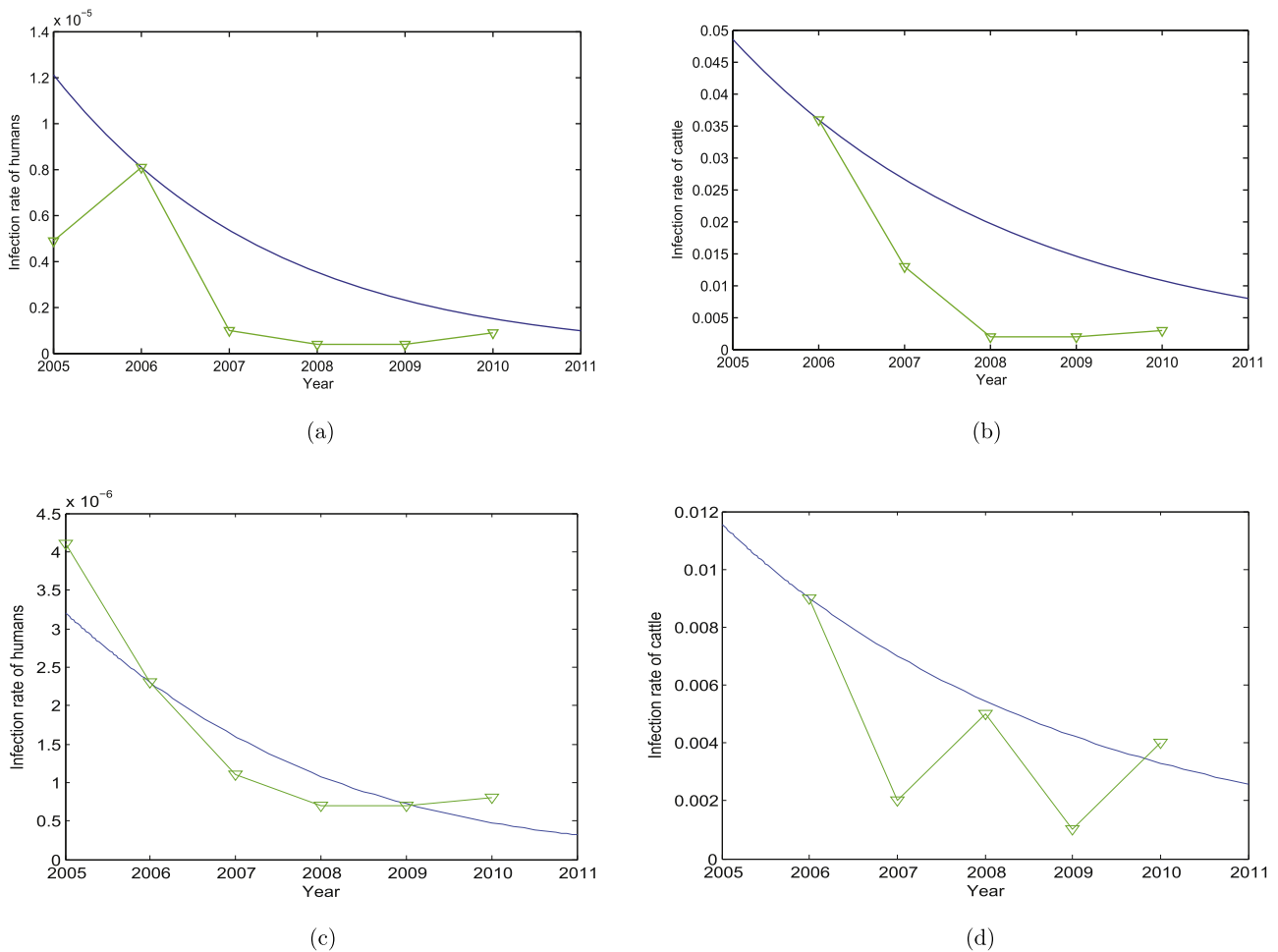


Fig. 3. Simulation of the infection rates of humans and cattle from 2002 to 2010 in (a, b) Yunnan Province and (c, d) Sichuan Province. The smooth solid curves represent the simulated infection rates based on the model while the segmental lines are the reported infection rates.

5. Plain regions with waterway networks

This strata locates in the delta of the Yangze River, including Shanghai, part of Jiangsu, and Zhejiang provinces. Economically these provinces are well developed, and are declared to have eliminated schistosomiasis. Since animal reservoirs are of little important there, the situations in these regions are different from the other two types of regions.

The migration of large amount of people from rural endemic areas to these areas makes contribution to the newly reported infections. On the other hand, travelers from these areas to the endemic regions usually lack resistance to schistosomiasis and pay less attention to prevention from being infected with schistosomiasis. Thus, there are still reported infections in Shanghai, Zhejiang, and Jiangsu recently (see Fig. 6). An investigation shows that 138 out of 2931 mobile people were positive in serum indirect hemagglutination (IHA) test (4.71%) (Zhou et al., 2007). It makes the disease surveillance a difficult and tough task provided that snails exist somewhere and sometimes in the plain regions with waterway networks.

6. Discussion

At the present stage of schistosomiasis control, we are challenged with reinfection, infection in migrant population, urban schistosomiasis and the impact of water conservation projects. It is still far away from the elimination of *S. japonica* in China,

although the transmission rate is decreasing. Therefore, traditional strategies in controlling schistosomiasis including chemotherapy, health education, livestock chemotherapy, and snail control in risk areas need to be continued. In addition, different control and prevention measures should be emphasized for different regions. For the serious endemic areas in the marshland and lakes regions, the aim is to control the transmission of schistosomiasis first. For Yunnan and Sichuan provinces in the mountainous and hilly regions, the elimination of schistosomiasis is challenge, and attention should be paid to other animals such as dogs. For the rest areas which has been controlled or eliminated but has the potential risk for schistosomiasis transmission, such as Guangdong, Shanghai, and other areas in the plain regions with waterway networks, surveillance for both human and animals is necessary.

Another problem is that traveling causes new infections of other species of schistosomiasis. For example, a gradual increase in the cases infected with *S. haematobium* or *S. mansoni* is reported in those returning to China after the China-aided projects in Africa and labor services export to Africa (Wang et al., 2013). Once these infections are imported to regions where the snail intermediate hosts of African schistosomiasis are present, there is a high possibility of transmission of African schistosomiasis into China. In fact, since the 1970s, the snail intermediate hosts of *S. mansoni* have been found in Hongkong and Shenzhen in China, and high-density *Biomphalaria straminea* habitats have been identified in many rivers of Shenzhen recently (Wang et al., 2013). This cannot be ignored. Many outbreaks of acute schistosomiasis have been documented

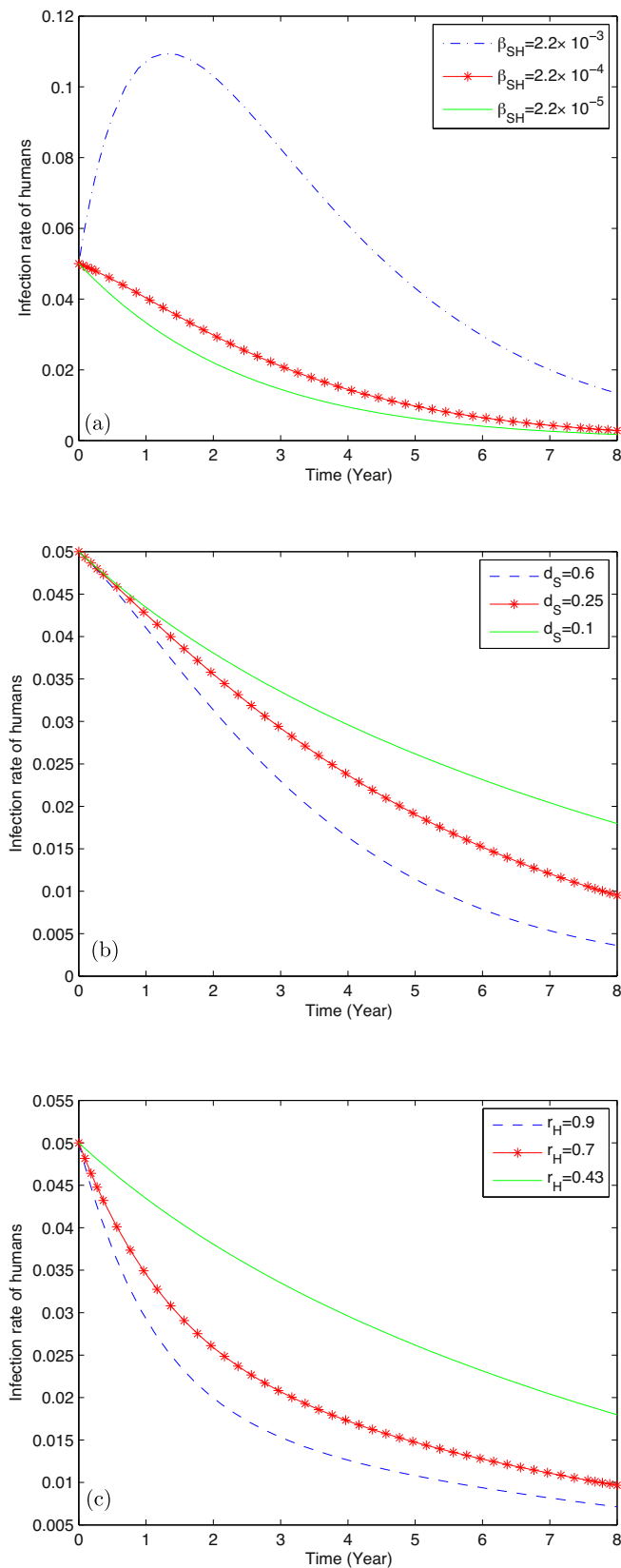


Fig. 4. Simulations on possible measures to reduce the infection rate in humans less than 1% in Xichang, Sichuan Province. (a) Decrease the transmission coefficient from snails to humans (less than 2.2×10^{-4}); (b) Reduce the population of snails by eliminating more snails (more than 7%); (c) Increase the human recovery rate (more than 70%).

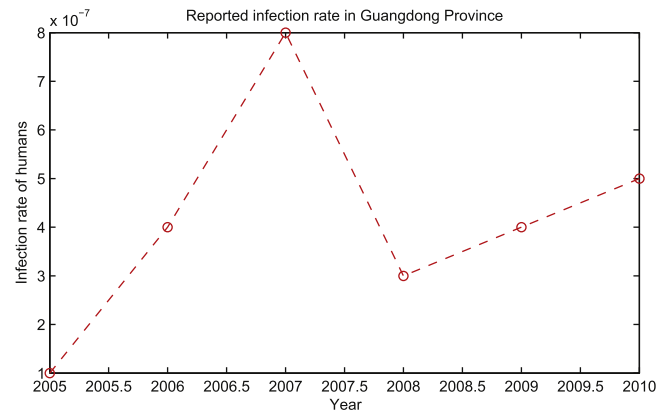


Fig. 5. The reported infection rate of humans in Guangdong Province.

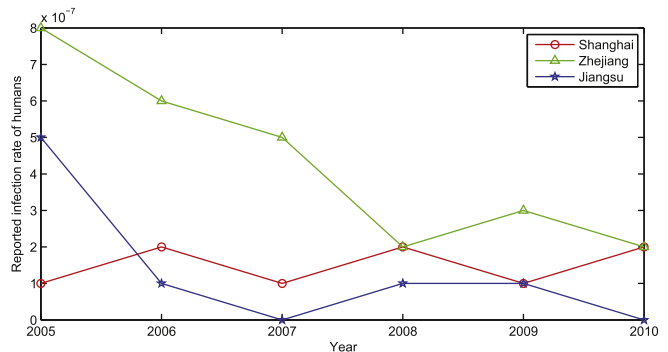


Fig. 6. The reported infection rates of humans in Shanghai, Zhejiang and Jiangsu provinces.

among travelers. One case is that the outbreaks associated with river rafting in the Omo and Mui rivers in Ethiopia are cases seen among returned travelers (CDC, 1982; Schwartz et al., 2005). Schistosomiasis used to be thought of as a solely tropical disease but is now of increasing importance to practitioners in non-endemic regions. More effective and comprehensive control and prevention measures are needed to combat the disease.

References

- Centers for Disease Control (CDC), 1982. Centers for Disease Control (CDC), Cercarial dermatitis among bathers in California; katayama syndrome among travelers to Ethiopia. *MMWR Morb. Mortal. Wkly. Rep.* 31, 435–438.
- Chen, M., Feng, Z., 1999. Schistosomiasis control in China. *Parasitol. Int.* 48, 11–19.
- Chen, Z., Zou, L., Shen, D., Zhang, W., Ruan, S., 2010. Mathematical modelling and control of schistosomiasis in Hubei Province, China. *Acta Trop.* 115, 119–125.
- Collins, C., Xu, J., Tang, S., 2012. Schistosomiasis control and the health system in PR China. *Infect. Dis. Poverty* 1, <http://dx.doi.org/10.1186/2049-9957-1-8>.
- Diekmann, O., Heesterbeek, J.A.P., Metz, J.A.J., 1990. On the definition and the computation of the basic reproduction ratio R_0 in models for infectious diseases in heterogeneous populations. *J. Math. Biol.* 28, 365–382.
- Diekmann, O., Heesterbeek, J.A.P., Roberts, M.G., 2010. The construction of next generation matrices for compartmental epidemic models. *J. Royal Soc. Interface* 7, 873–885.
- Liang, S., Yang, C., Zhong, B., Qiu, D., 2006. Re-emerging schistosomiasis in hilly and mountainous areas of Sichuan, China. *Bull. WHO* 84, 139–144.
- Liang, S., Seto, E., Remais, J., et al., 2007. Environmental effects on parasitic disease transmission exemplified by schistosomiasis in western China. *Proc. Natl. Acad. Sci. U. S. A.* 104, 7110–7115.
- Mao, S., Shao, B., 1982. Schistosomiasis control in the people's Republic of China. *Am. J. Trop. Med. Hyg.* 31, 92–99.
- McManus, D., Gray, D., Li, Y., Feng, A., Williams, G., et al., 2010. Schistosomiasis in the People's Republic of China: the era of the Three Gorges Dam. *Clin. Microbiol. Rev.* 23, 442–466.
- National Institute of Parasitic Diseases, Chinese Center for Diseases Control and Prevention, Atlas of Schistosomiasis Transmission in China, <http://www.ipd.org.cn/schisto/newreader.htm>

- Office of Endemic Diseases Control, Ministry of Health, National Criteria of the People's Republic of China, 1996. *Criteria for Control and Elimination of Schistosomiasis in China*. China Publishing House for Criteria, Beijing.
- Ross, A., Remigio, Olveda, Acosta, L., Harn, D., Chy, D., Li, Y., Gray, D., Gordon, C., McManus, D., Williams, G., 2013. Road to the elimination of schistosomiasis from Asia: the journey is far from over. *Microbes Infect.* 15 (13), 858–865.
- Schwartz, E., Kozarsky, P., Wilson, M., Cetron, M., 2005. Schistosome infection among river rafters on Omo River, Ethiopia. *J. Travel Med.* 12, 3–8.
- Seto, E.Y.W., Remais, J.V., Carton, E.J., et al., 2011. Toward sustainable and comprehensive control of schistosomiasis in China: lessons from Sichuan. *PLoS Negl. Trop. Dis.* 5 (10), e1372, <http://dx.doi.org/10.1371/journal.pntd.0001372>.
2010. *Sichuan Health Yearbook 2010*. Sichuan Yearbook Press, Chengdu.
- The Carter Center, *Schistosomiasis Control Program*. Retrieved March 2014.
- van den Driessche, P., Watmough, J., 2002. Reproduction numbers and sub-threshold endemic equilibria for compartmental models of disease transmission. *Math. Biosci.* 180, 29–48.
- Wang, L., Utzinger, J., Zhou, X., 2008. Schistosomiasis control: experiences and lessons from China. *Lancet* 372, 1793–1795.
- Wang, W., Liang, Y., Hong, Q., Dai, J., 2013. African schistosomiasis in mainland China: risk of transmission and countermeasures to tackle the risk. *Parasites Vectors* 6, 249.
- WHO Representative Office China, Schistosomiasis in China, <http://www.wpro.who.int/china/mediacentre/factsheets/schistosomiasis/en/index.html>
- WHO, Schistosomiasis, Fact sheet No. 115. Updated February 2014. <http://www.who.int/mediacentre/factsheets/fs115/en/>
- Zhang, J., Jin, Z., Sun, G., Zhou, T., Ruan, S., 2011. Analysis of rabies in China: transmission dynamics and control. *PLoS ONE* 6 (7), e20891, <http://dx.doi.org/10.1371/journal.pone.0020891>.
- Zhou, X., Cai, L., Sheng, H., et al., 2007. Potential risks for transmission of schistosomiasis caused by mobile population in Shanghai. *Zhongguo Ji Sheng Chong Xue Yu Ji Sheng Chong Bing Za Zhi* 25 (3), 180–184 (in Chinese).