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Mapping and prediction of schistosomiasis in Nigeria using compiled survey data and Bayesian geospatial modelling

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Abstract. Schistosomiasis prevalence data for Nigeria were extracted from peer-reviewed journals and reports, geo-referenced and collated in a nationwide geographical information system database for the generation of point prevalence maps. This exercise revealed that the disease is endemic in 35 of the country's 36 states, including the federal capital territory of Abuja, and found in 462 unique locations out of 833 different survey locations. *Schistosoma haematobium*, the predominant species in Nigeria, was found in 368 locations (79.8%) covering 31 states, *S. mansoni* in 78 (16.7%) locations in 22 states and *S. intercalatum* in 17 (3.7%) locations in two states. *S. haematobium* and *S. mansoni* were found to be co-endemic in 22 states, while co-occurrence of all three species was only seen in one state (Rivers). The average prevalence for each species at each survey location varied between 0.5% and 100% for *S. haematobium*, 0.2% to 87% for *S. mansoni* and 1% to 10% for *S. intercalatum*. The estimated prevalence of *S. haematobium*, based on Bayesian geospatial predictive modelling with a set of bioclimatic variables, ranged from 0.2% to 75% with a mean prevalence of 23% for the country as a whole (95% confidence interval (CI): 22.8-23.1%). The model suggests that the mean temperature, annual precipitation and soil acidity significantly influence the spatial distribution. Prevalence estimates, adjusted for school-aged children in 2010, showed that the prevalence is <10% in most states with a few reaching as high as 50%. It was estimated that 11.3 million children require praziquantel annually (95% CI: 10.3-12.2 million).

Keywords: schistosomiasis, prevalence, geo-referencing, geographical information system, risk mapping, Bayesian geospatial modelling, control, Nigeria.

Introduction

More than 200 million people are thought to be infected with *Schistosoma* spp., with more than 95% of all infections concentrated in Africa (Steinmann et al., 2006; Utzinger et al., 2009). Due to the requirement of an intermediate snail host, this trematode parasite thrives in areas characterised by poor sanitation and hygiene, poverty and general neglect, where rivers,

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lakes and irrigation schemes facilitate its continued transmission (WHO, 2002; Gryseels et al., 2006; Hotez and Kamath, 2009; Stothard et al., 2009; Utzinger et al., 2011).

Schistosomiasis has been classified as a neglected tropical disease (NTD), although an estimated 779 million people in the world are at risk for it according to relatively recent surveys (Steinmann et al., 2006; Hotez et al., 2007a). Three species (*S. mansoni*, *S. haematobium* and *S. intercalatum*) are endemic in Nigeria, which led to the formation of a national schistosomiasis control programme in the late 1980s. However, due to lack of political will and inadequate funding for control activities, the burden of schistosomiasis did not decline. Estimates in the mid-1990s suggested that more than 100 million people were at risk for this disease and that 25.8 million people were actually infected (Chitsulo et al., 2000). More recently, the latter figure was updated to 29 million infections (Steinmann et al., 2006; Moné et al., 2010), which corresponds to 14% of the global number of *Schistosoma* infections and puts Nigeria at the top of the list of endemic countries. To date, concerted efforts to control schistosomiasis in Nigeria have failed, not only due to the reasons given above, but also because reliable data regarding its geographical distribution are lacking. The paucity of empirical schistosomiasis estimates and endemic foci within states and local government areas (LGAs), the units usually used for health interventions, have proved a major impediment for the national control programme. Attempts to provide risk estimates at these units remain sporadic, but some information is available, e.g. from the state of Niger (Mafe et al., 2000) and more recently from the state of Ogun (Ekpo et al., 2008).

Several sub-Saharan African countries have received support from United Nations (UN) and non-governmental organizations (NGOs) to control schistosomiasis along with other NTDs (Hotez et al., 2007b). Nigeria, however, has only received limited international support due to absence of governmental commitment and reliable empirical data. Given the large population of the country and the high frequency of NTDs, including schistosomiasis, this situation will only change when the current neglect is translated into proactive action (Hotez et al., 2012). The ongoing global move to control and eventually eliminate the NTDs (IPPPH, 2009; BMGF, 2010; Utzinger, 2012; WHO, 2012; Rollinson et al., 2013) will likely result in many African nations receiving support to implement national control programmes. Data compiled by the "Global Neglected Tropical Diseases" (GNTD) database (Hürlimann et al., 2011), supplemented with local geo-referenced survey data, will be helpful in this context. The work presented here was undertaken to help move the Nigerian schistosomiasis control programme forward by updating maps on the geographical distribution of the disease.

Methods

Literature review

A comprehensive literature review related to schistosomiasis survey data in Nigeria, using PubMed and other readily available bibliographic databases, was conducted under the umbrella of the EU-funded CONTRAST project (Kristensen, 2008). Details of how the GNTD database was established, including standard protocols for data extraction of relevant literature, have been presented elsewhere (Hürlimann et al., 2011). Additional specific searches were performed based on references from the retrieved publications. Websites of international organization, such as the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), were also consulted for schistosomiasis survey data and the Federal Ministry of Health, State Ministries of Health, NGOs, universities and local research institutions in Nigeria were contacted. Relevant data, including the number of those examined, age groups surveyed, *Schistosoma* species, sex ratio, diagnostic method, study approach and study location, were extracted and collated in a standardised database.

Geo-referencing of identified survey data

Data compiled in the GNTD database, supplemented with recent surveys and reports obtained from the aforementioned sources were analysed. For a detailed description of the various data sources, the data extraction process, the database system and internal quality checks, the reader is invited to consult recently published papers, e.g. Hürlimann et al. (2011) Schur et al. (2013) and Stensgaard et al. (2013). Studies lacking information about the geographical coordinates of survey locations were retrospectively geo-referenced using a variety of sources, such as GEOnet Names Servers (http://earth-info.nga.mil/gns/html/index.html) and Google maps (http://maps.google.com). If this was not possible, the reported locations were visited for geo-referencing

using a hand-held global positioning system (GPS) receiver (Garmin Etrex, Garmin Corporation, USA). The analyses presented here are restricted to school children of the 5 to 14 years age group and non-hospital records.

Population data

Population data at the 1 km^2 spatial resolution in Nigeria for 2010 were obtained from the AfriPop population database (http://www.clas.ufl.edu/users/atatem/index_files/Nigeria.htm). The total population count for 2010 was 150,511,635 persons. The number of school-aged children in Nigeria in 2010 was computed to be 40,337,118, which represents 26.8% of the total population count based on information in the international database of the United States Census Bureau (http://www.census.gov/population/ international/data/idb/region.php).

Mapping and Bayesian geospatial modelling of S. haematobium *presence*

Climatic and environmental data, going back to the 1950s, were obtained from the WorldClim-Global Climatic Data source (http://worldclim.org/bioclim); the Earth Resources Observation (EROS) centre (http://eros.usgs.gov), and the International Soil Reference and Information Centre (ISRIC) (http://www.isric.org).

With regard to geospatial modelling, we first carried out bivariate logistic regressions to determine the relationship between the risk of *S. haematobium* infection and the potential climatic and environmental variables. Next, Bayesian geostatistical logistic regression models with location-specfic random effects were fitted to identify the most significant predictors using advanced variable selection procedures (Schur et al., 2013). Bayesian geostatistical models, fitted by Markov chain Monte Carlo (MCMC) simulation methods (Diggle et al., 1998) were employed to estimate infection risk of *S. haematobium* at unobserved locations via joint Bayesian kriging. A grid of prediction locations with a spatial resolution of 5 x 5 km was used, resulting in 30,051 pixels.

School-aged population infected with Schistosoma

The total population data grid map with 1 x 1 km spatial resolution was rescaled to a 5 x 5 km resolution grid using the geographical information system (GIS) software ArcMap version 9.2 (ESRI, Redlands, CA, USA) to match the spatial resolution of the geostatistical *S. haematobium* risk estimates for Nigeria. Population counts were linked to the percentage of school-aged children within each predicted pixel level. The estimated number of infected school-aged children with *S. haematobium* infection was calculated by combining the median predictive posterior distribution of the infection prevalence predicted at the pixel level with the population size of that age group within that pixel. The median predictive posterior distribution of the number of infected school-aged children per state was estimated by summing up the pixel-samples within each state and calculating summary statistics. The calculation was carried out as follows: assuming that the pixel value of the population data grid at location $x=a$, then the estimated school-aged population y at location x is 26.8 (the percentage share of the population accepted to consist of children) divided by 100 multiplied by a. Therefore the number of infected school-aged population is the summed values of $y_1, y_2, ..., y_n$, where the predicted *S. haematobium* pixel value is greater than zero.

Data aggregation by state and praziquantel treatment requirement

The national schistosomiasis control programme in Nigeria is implemented by the State Ministries of Health and NGOs under the supervision of the Federal Ministry of Health. Shape files containing geographical information by state administrative boundaries were linked in ArcMap with *S. haematobium* risk estimates and school-aged populations to estimate the number of infected children at the pixel-level. Population-adjusted prevalence estimates at the state level were calculated by summing all infected school-aged children at the pixel-level and dividing by the total school-aged population by state.

Praziquantel, the drug used for treatment of schistosomiasis, is usually administered as a single oral dose of 40 mg/kg (WHO, 2006; Doenhoff et al., 2008). The drug requirements were computed using the estimated number of infected school-aged children and multiplying by the estimated number of praziquantel tablets needed per child. Based on guidelines put forth by WHO (2006), the average school-aged child requires three tablets used as a single treatment every year in moderate endemicity settings (prevalence of 10-50%). The treatment needs were calculated for each state for the year 2010 following the same approach as recently presented by Schur et al. (2012).

Results

Temporal analysis of schistosomiasis survey data in Nigeria

An overview of the points in time when schistosomiasis surveys were conducted in Nigeria is given in Fig. 1. The first surveys pertaining to schistosomiasis were carried out in Nigeria before its independence in 1960. Later on, particularly between 1986 and 1990, a considerable number of surveys were done as the government had a growing interest in disease control at that time. This resulted in the establishment of the first national schistosomiasis control programme in 1988 (Federal Ministry of Health, 1997). However, the failure of the control programme to implement large-scale control activities led to a decrease of surveys between 1992 and 2003. The spike in reported surveys in 2004 may be due to particular activities that year by different NGOs, most importantly the Carter Center (http://www.cartercenter.org/index.html) (Eigege et al., 2008; Njepuome et al., 2009). Since 2006, the number of surveys has increased steadily as the prospect of new initiatives to control schistosomiasis as part of packages targeting additional, multiple NTDs (e.g. onchocerciasis, lymphatic filariasis and soil-transmitted helminthiasis) became reality.

Geographical distribution of schistosomiasis in Nigeria

Schistosomiasis is endemic in all but one of the 36 states of Nigeria. The Akwa Ibom State in the southern part of the country is the only state where, to date, no endemic foci of either *S. haematobium* or *S. mansoni* has been reported. Our empirical data reveal that *S. haematobium* is the predominant species in the country, accounting for 79.8% of all reported cases, while the rate of *S. mansoni* reached 16.7% and that of *S. intercalatum* 3.7%. Fig. 2 shows the map of Nigeria depicting its states and Abuja. Fig. 3 shows the distribution of all georeferenced survey locations in Nigeria with *Schistosoma* infections. *S. haematobium* and *S. mansoni* are both endemic in northern and southern Nigeria, while *S. intercalatum* has only been reported from the states of Bayelsa and Rivers in the Niger delta. In the 22 states where *S. mansoni* exists, *S. haematobium* is co-endemic, but co-distribution of all three *Schistosoma* species (i.e. *S. haematobium*, *S. mansoni* and *S. intercalatum*) has only been reported from the state of Rivers.

S. haematobium is the most prevalent of the three species among school-aged children and it often exceeds the high-endemicity threshold of 50% prevalence. Although this infection is comparatively more frequent in the South, it is also widespred in the rest of the country in contrast to *S. mansoni* infections, which are clearly more common in the northern half of the country. There are also differences with respect to intensity of disease as can be seen in Figs. 4-6, which show the geographical distribution of the three schistosome species in Nigeria, according to the WHO (2002) classification of schistosomiasis rates of prevalence (i.e. 0.1-9.9%, low prevalence; 10.0-49.9%, moderate prevalence; and ≥50%, high prevalence).

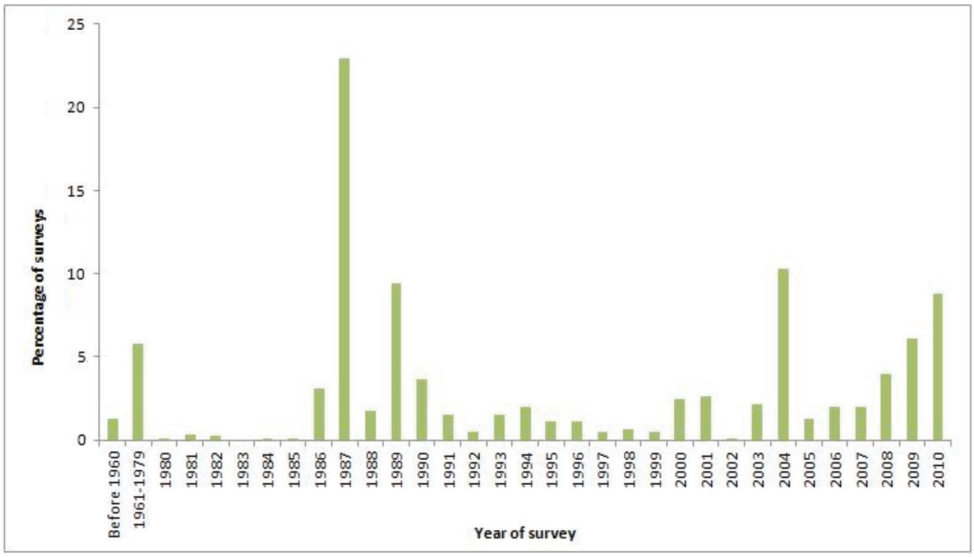

Fig. 1. Time-period of included georeferenced schistosomiasis prevalence surveys in Nigeria.

Fig. 2. Map of Nigeria showing the 36 states and the federal capital territory (FCT) of Abuja.

S. haematobium *risk maps*

The geostatistical model for *S. haematobium* suggests that the annual mean temperature, annual precipitation, precipitation seasonality and soil acidity are associated with *S. haematobium* risk in Nigeria. The parameter estimates included in Table 1 indicate that these variables were significant covariates in the final model, as their values from 25% SD to 75% SD includes zero.

The spatial distribution of *S. haematobium* risk throughout the country is shown in Fig. 7. Areas of high infection risk (>50%) were predicted for locations around the Niger and Benue rivers, as well as locations near the Lake Chad basin. Moreover, high risk areas were identified in the south-western and north-western parts of Nigeria. The map of the prediction error for *S. haematobium* shows that areas of relatively high uncertainty (75% quintile) are concentrated in areas of high infection risk, whereas areas of low uncertainty (25% quintile) are mainly found in low-risk areas. Aggregated prevalence levels for each state are shown in Fig. 8A. States with a moderate infection risk are Sokoto, Kebbi, Kwara, Niger, Zamfara and Kogi. Additionally, states along Benue River (Benue, Taraba, Nasarawa, FCT and Adamawa) and in the Lake Chad basin area (Bornu and Yobe) showed moderate infection prevalence. Other inland areas of moderate risk for *S. haematobium* include the

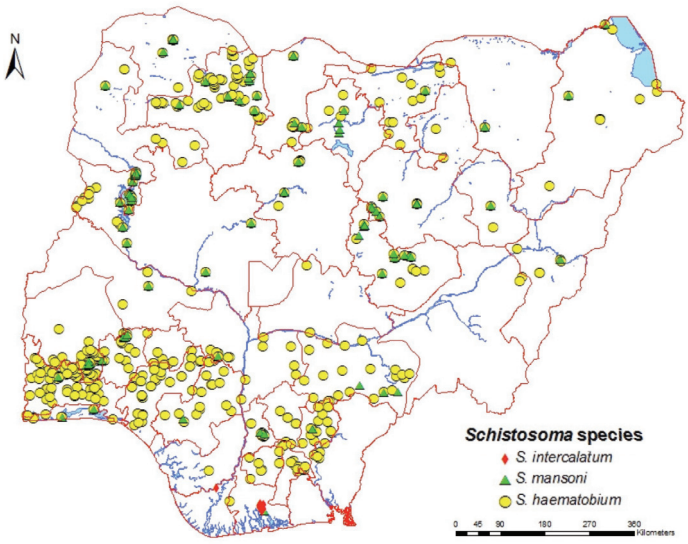

Fig. 3. Geographical distribution of reported schistosomiasis cases in Nigeria, stratified by the three existing *Schistosoma* species.

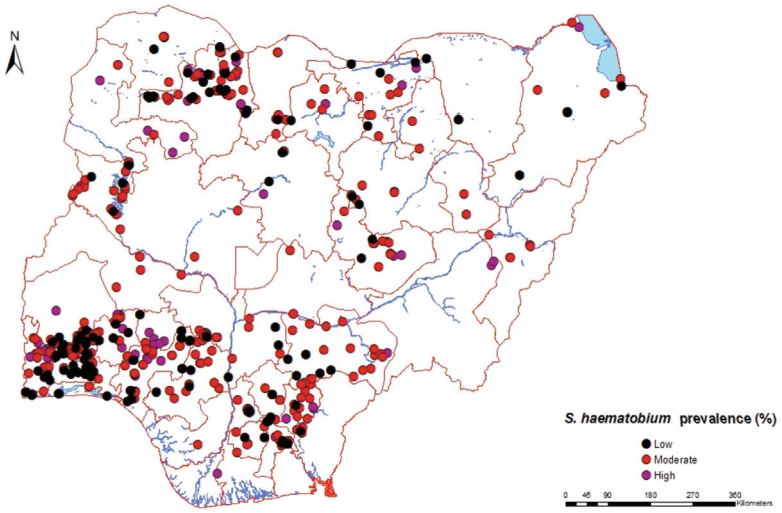

Fig. 4. Observed prevalence of *S. haematobium* in Nigeria including 368 georeferenced survey locations.

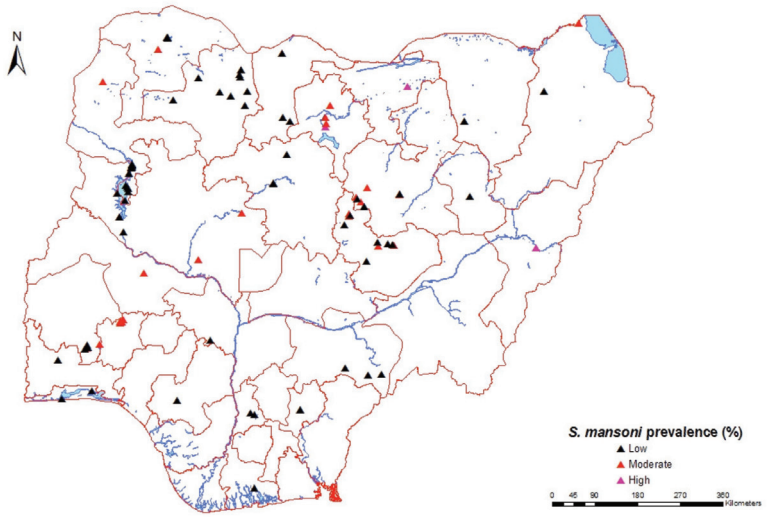

Fig. 5. Observed prevalence of *S. mansoni* in Nigeria including 78 georeferenced survey locations.

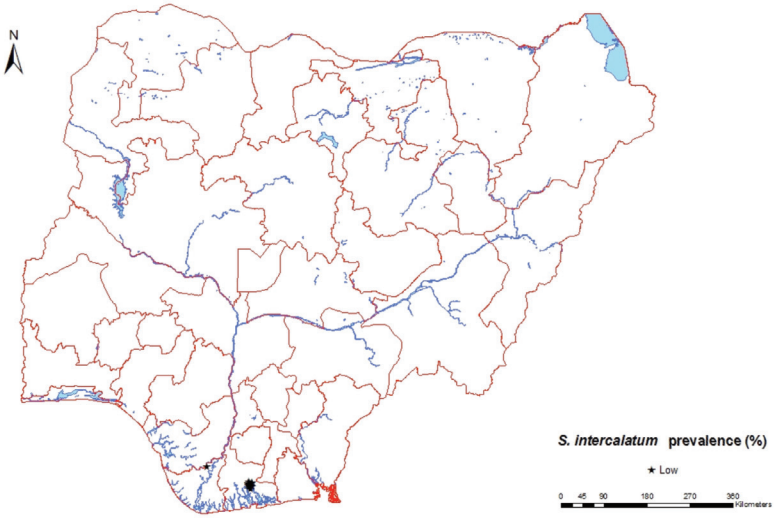

Fig. 6. Observed prevalence of *S. intercalatum* in Nigeria including 17 georeferenced survey locations.

Table 1. Model parameter estimates for *S. haematobium* in Nigeria using Bayesian regression.

Variable	Mean	SD	25% SD	Median	75% SD
Annual mean temperature	0.459	0.336	0.148	0.382	1.675
Annual precipitation	-1.071	0.420	-1.641	-1.129	0.064
Precipitation seasonality	-0.596	0.589	-1.100	-0.715	1.698
Soil acidity	0.533	0.297	-0.341	0.581	0.951

SD, standard deviation

states Ogun, Oyo and Osun in the south-western part of the country. Areas of low risk (<10%) were found in the southern part of Nigeria (i.e. the states of Delta, Edo, Enugu, Anambra and Ebonyi) and in the northern part (i.e. Plateau, Gombe, Bauchi, Kaduna and Katsina). There are, however, also low-risk states in the Niger delta, e.g. Rivers, Imo, Abia, Akwa Ibom, Bayelsa and the southern parts of Cross River. The map reveals that most of the states in Nigeria are characterised by either low or moderate risk with no state considered to be at high risk. Still, high-risk communities with prevalence in excess of 50% were found in several states (Fig. 8B).

School-aged population infected and treatment requirements

State-specific estimates of the number of school-aged children infected with *Schistosoma*, and hence requiring praziquantel treatment as of 2010 are shown in Table 2. The results suggest that the total number of infected school-aged children in Nigeria is 11.3 million (95% confidence interval (CI): 10.3-12.2 million). The state of Anamabra in southern Nigeria was found to have the highest number of infected school-aged children, while the Enugu state in the

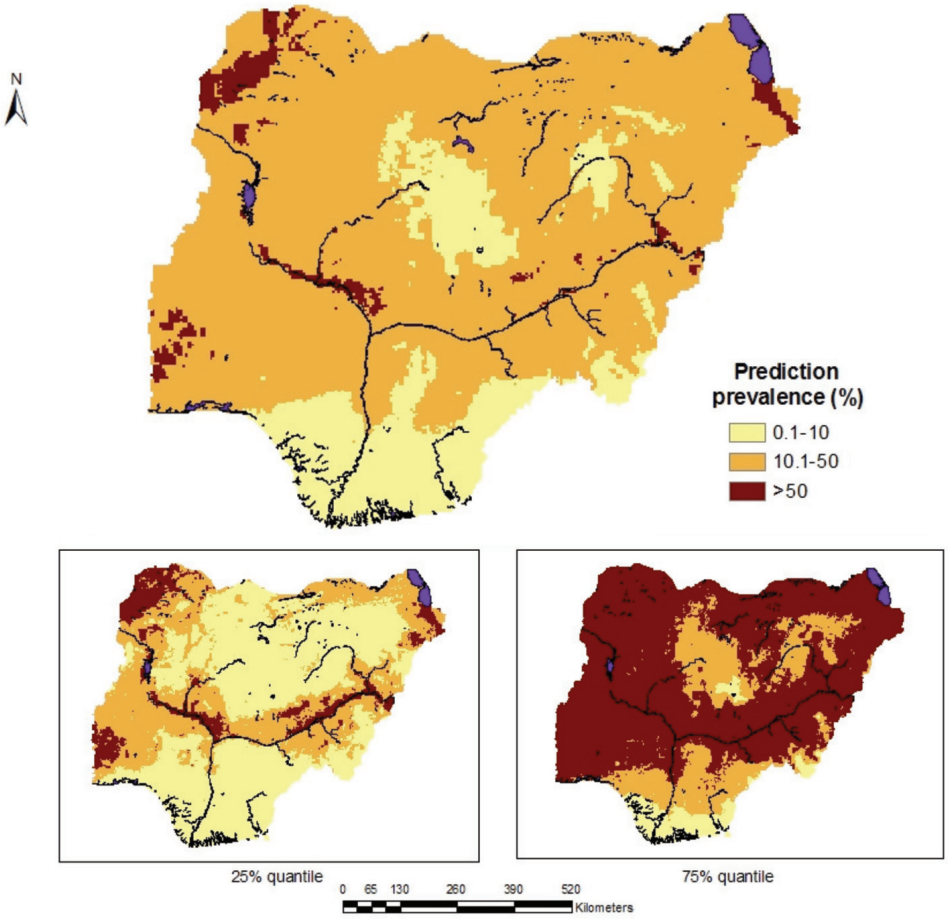

Fig. 7. The predicted median posterior distribution of infection risk of *S. haematobium* in Nigeria based on Bayesian geostatistics and predicted error maps.

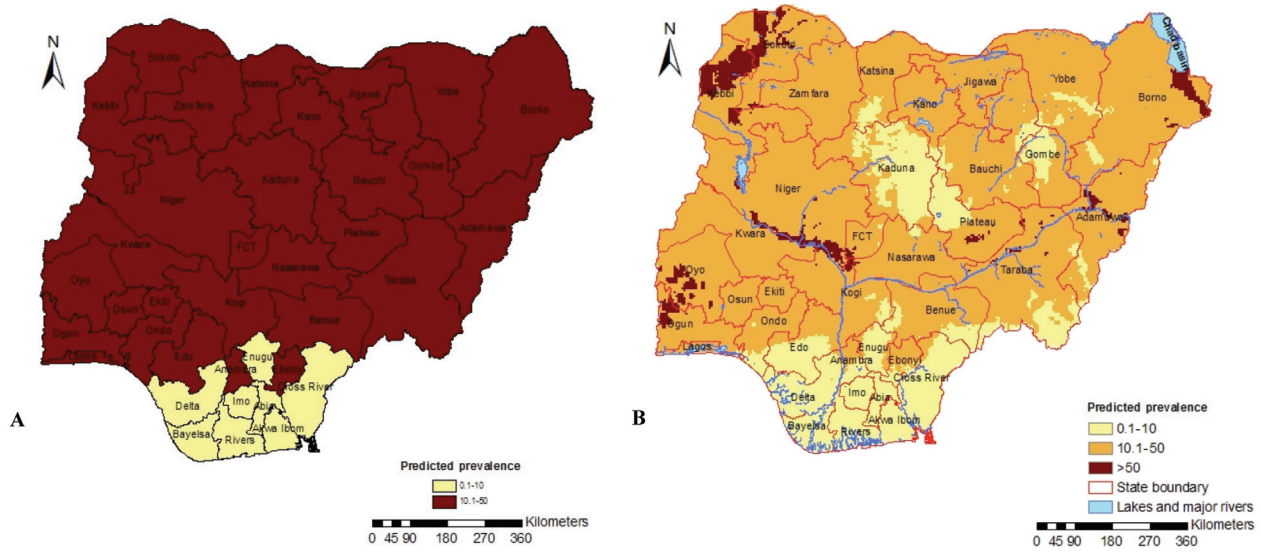

Fig. 8. Prevalence estimates of *S. haematobium* for the 36 states in Nigeria including the federal capital territory (FCT) of Abuja. Prevalences (based on the 2002 WHO classification) are shown at the state level (A) and the pixel level (B).

same region had the lowest. The number of praziquantel tablets required for treating the predicted number of school-aged children was estimated at 34 million tablets for 2010.

Discussion

The paucity of detailed information on schistosomiasis distribution in Nigeria hampers the implementation of the national control programme. Risk maps were produced to facilitate the targeting of schistosomiasis control activities, planning of future surveys and surveillance. The first detailed hard-copy maps of the global distribution of schistosomiasis were published a quarter century ago (Doumenge et al., 1987). With the advent of desktop GIS and mapping software, the application of GIS for creating digital disease maps became feasible and these proved extremely useful for the planning, control and surveillance of human helminth infections (Brooker and Michael, 2000; Brooker et al., 2000, 2009, 2010; Simoonga et al., 2009). However, with the exception of a single state, Ogun (Ekpo et al., 2008) and despite several surveys pertaining to the distribution of schistosomiasis and the intermediate host snails in Nigeria, the first ones dating back to the 1930s (Ramsay, 1934; Cowper 1963, 1973; WHO, 1985), the compilation of these records into a comprehensive GIS-based overview did not exist before the current study.

In 2010, a project known as the "Global Atlas of Helminth Infections" (GAHI; http://www.thiswormyworld.org) started to offer digital maps on the spatial distribution of helminth infection in sub-Saharan Africa, including Nigeria. However, only maps of the observed prevalence at compiled survey locations are available (Brooker et al., 2010) and the underlying survey data are not provided for in-depth analyses. In 2011, the open-access GNTD database containing georeferenced schistosomiasis prevalence data was launched to fill this gap. This database allows extraction of compiled prevalence data from various published and unpublished sources for many different countries (Hürlimann et al., 2011), which stimulated spatially explicit analyses, such as risk mapping, studies of the distribution of intermediate host snails and estimates of treatment needs for the school-aged population (Schur et al., 2011, 2012, 2013; Stensgaard et al., 2013). Employing this rich source of schistosomiasis survey data, the geographical distributions of the three human *Schistosoma* species that occur in Nigeria have been mapped. High-risk areas have been identified allowing prioritization of areas warranting control interventions. The data also permit temporal analyses, which should assist the planning of future surveys. The current priority would be to focus on areas where data are particularly sparse so that cost-effectiveness of mapping and subsequent control interventions can be enhanced.

Table 2. The numbers of school-aged children infected with *S. haematobium* and the praziquantel (PZQ) treatment requirements in 2010 shown by state.

S/N	State	Population	School-aged children[a]	Numbers infected	95% CI	Prevalence[b]	PZQ tablets required
1	Abia	3,088,489	827,715	217,860	93,415-342,301	28.9	653,580
2	Adamawa	3,345,139	896,497	264,130	194,336-333,924	27.9	792,390
3	Akwa Ibom	4,079,860	1,093,403	268,540	143-088-393,992	24.9	805,620
4	Anambra	4,554,555	1,220,621	419,070	268,378-569,762	37.5	1,257,210
5	Bauchi	4,904,861	1,314,503	377,820	195,112-560,528	26.4	1,133,460
6	Bayelsa	1,764,882	472,989	140,330	793,312-201,387	29.3	420,990
7	Benue	4,489,165	1,203,096	327,020	234,170-419,870	25.2	981,060
8	Bornu	4,458,940	1,194,996	320,720	214,734-426,706	25.6	962,160
9	Cross River	3,059,240	819,876	181,730	124,771-238,689	22.5	545,190
10	Delta	4,367,659	1,170,533	408,840	256,895-560,785	36.5	1,226,520
11	Ebonyi	2,301,621	616,834	113,330	84,650-142,009	17.8	339,990
12	Edo	3,498,159	937,507	245,390	158,146-332,634	28.8	736,170
13	Ekiti	2,580,707	691,630	252,000	110,248-393,752	37.3	756,000
14	Enugu	3,461,328	927,636	132,180	83,934-180,426	15.4	396,540
15	Abuja*	1,490,699	399,507	114,410	62,293-166,527	32.9	343,230
16	Gombe	2,504,758	671,275	157,520	103,704-211,336	21.5	472,560
17	Imo	4,125,237	1,105,563	362,510	197,502-527,519	34.5	1,087,530
18	Jigawa	4,638,479	1,243,112	397,130	192,366-601,894	30.4	1,191,390
19	Kaduna	6,529,746	1,749,972	405,680	319,280-492,080	22.3	1,217,040
20	Kano	10,215,494	2,737,752	979,360	588,134-137,059	34.1	2,938,080
21	Katsina	6,186,868	1,658,081	607,710	382,804-832,616	34.3	1,823,130
22	Kebbi	3,442,422	922,569	287,040	199,605-374,475	28.3	861,120
23	Kogi	3,521,364	943,726	307,490	145,307-469,673	31.6	922,470
24	Kwara	2,558,692	685,729	250,590	140,882-360,298	36.7	751,770
25	Lagos	10,518,608	2,818,987	605,610	196,764-1,014,456	30.5	1,816,830
26	Nasarawa	1,966,300	526,968	135,250	108,667-161,833	24.6	405,750
27	Niger	4,187,613	1,122,280	304,400	237,572-371,228	25.7	913,200
28	Ogun	4,120,568	1,104,312	256,540	161,192-351,886	26.0	769,620
29	Ondo	3,708,369	993,843	265,080	162,334-367,826	27.4	795,240
30	Osun	3,761,319	1,008,034	317,570	157,996-476,004	33.7	952,710
31	Oyo	6,139,127	1,645,286	375,570	253,224-497,916	24.6	1,126,710
32	Plateau	3,400,482	911,329	214,350	180,740-247,960	22.6	643,050
33	Rivers	5,316,003	1,424,689	409,620	117,376-701,864	29.6	1,228,860
34	Sokoto	3,954,209	1,059,728	282,900	168,807-396,993	25.4	848,700
35	Taraba	2,385,772	639,387	182,660	137,065-228,255	26.7	547,980
36	Yobe	2,475,468	663,425	143,130	95,624-190,636	20.1	429,390
37	Zamfara	3,409,431	913,728	238,660	152,239-325,081	23.8	715,980
	Total	150,511,635	40,337,118	11,270,720	10,339,510-12,198,830	27.9	33,812,160

[a]Computation based on 26.8% U.S. Census Bureau international database estimate; [b]adjusted to school-aged population; *The federal capital territory of Abuja is considered equivalent of a state

The data used in the current analyses were extracted from peer-reviewed publications and a variety of reports, and hence differ with regard to survey dates, the diagnostic method used and the populations surveyed. To minimise bias, we restricted our analysis to surveys focussing on school-aged children (5-14 years), who constitute the target group for preventive chemotherapy in schistosomiasis control programmes (WHO, 2002, 2006). We present the first smooth empirical risk map for *S. haematobium* across Nigeria at a spatial resolution of 5 x 5 km. Previous mapping efforts using remotely sensed climatic variables have been based on data from the Moderate-Resolution Imaging Spectroradiometer (MODIS) satellites data

archives (http://wist.echo.nasa.gov) (Schur et al., 2011, 2013). We used readily available BioClim data dating back to the 1950s and employed advanced variable selection methods.

In the current analysis, we estimated the number of school-aged children infected with *S. haematobium* to be 11.3 million, which corresponds to 34 million praziquantel tablets for their treatment. The estimates might be slightly higher if the other two *Schistosoma* species (i.e. *S. mansoni* and *S. intercalatum*) were considered as well (Schur et al., 2012). Giving the average annual population growth rate for Nigeria to be 2.5%, the required number of praziquantel tablets might increase every year by a percentage close to that ot the growth rate. As several international donors have shown interest in supplying the drug for free, only the cost for distribution and other logistic requirements need to be considered to calculate the cost-effectiveness of this preventive chemotherapy strategy. Nevertheless, the provision of data such as presented here will enable the national control programme to leverage evidence-based information for sourcing of funds. As more geostatistical model-based analysis from the GNTD database will become available for Nigeria and elsewhere, it is our hope that control of schistosomiasis in Nigeria and indeed Africa will be accelerated, as reliable risk estimates at high spatial resolution will reduce the cost of parasitological surveys.

Schistosomiasis is a focal disease depending entirely on freshwater systems harbouring the intermediate host snails. Moreover, human activities (e.g. bathing, washing and fishing) promote contacts with infested water, since excreted parasite eggs must reach freshwater sources, hatch and penetrate a suitable snail intermediate host (Lengeler et al., 2002; Brooker et al., 2009; Utzinger et al., 2011). Therefore, any reduction in the prevalence of infection in areas without chemotherapeutic intervention can only be due to improvement in any or all of the following: water supply and sanitation and/or health education and awareness and avoidance of transmission sites. It is noteworthy that these preventive control measures are still often neglected in Nigeria. Indeed, effective control measures have been demonstrated in very limited areas such as in Plateau and Nasarawa states in north-central Nigeria (Hopkins et al., 2002; Njepuome et al., 2009). Thus the endemic foci documented in this analysis are still relevant for control. Therefore, stakeholders interested in schistosomiasis control might find the data, provided maps and endemic foci useful for their operational purposes.

Conclusion

Based on data compiled from the GNTD database supplemented with local data for the creation of point prevalence maps, we performed model-based Bayesian geostatistical estimation of schistosomiasis infection prevalence for unobserved locations and computed the number of infected school-aged children and praziquantel treatment requirement for Nigeria. This should accelerate control activities and help attract resources to implement a sustainable control programme capable of reducing the burden of schistosomiasis in Nigeria.

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