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Human schistosomiasis in Benin: Countrywide evidence of *Schistosoma haematobium* predominance

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ABSTRACT

Background: A national mapping of human schistosomiasis was conducted in Benin to provide the baseline epidemiological data required to implement the national strategy for schistosomiasis control and elimination to achieve the WHO's goal of reaching at least 75% of school-age children in endemic areas by 2020.

Methods: Parasitological surveys were conducted from 2013 to 2015, among 19,250 children aged 8–14 years randomly sampled in 385 units (schools/villages) across all districts. Urine and stool samples were examined using parasite-egg filtration for urine samples and the Kato-Katz technique for stool specimens.

Results: Human schistosome eggs from two major species (*S. haematobium* and *S. mansoni*) were detected in the surveyed population with variable prevalence and parasite intensity. Urinary schistosomiasis due to *S. haematobium* was widely distributed and detected in 76/77 districts with a national average prevalence of 17.56% (95 °CI:16.80%– 18.32%), compared to *S. mansoni* detected in 28/77 districts with a national prevalence of 2.45% (95 °CI:2.14%–2.76%). The combined national prevalence of schistosomiasis, defined by infections with either or both schistosome species was 19.78% (95% CI:18.90% –20.49%), and was detected in 76/77 districts. Based on our findings, 31 districts were classified as low-risk ($>0\%$ and $<10\%$); 37 as moderate-risk ($\geq 10\%$ and $<50\%$); and 8 as high-risk ($\geq 50\%$) of schistosome infection. No infection was detected in Kpomassè district in this study. In several districts where the two species were endemic with prevalence $\geq 10\%$, *S. haematobium* was the most prevalent schistosome species. Boys were relatively more infected than girls (18.29% v 16.82%, $p = 0.007$). Of note, heavy infections with *S. haematobium* (> 50 eggs/10 mL) were detected in several districts of Atacora, Donga, Borgou, Collines, Ouémé and Atlantique departments.

Conclusions: The schistosomiasis mapping reported here clearly present a nationwide view of the epidemiological pattern of *Schistosoma* infections and the baseline data for implementing an effective control strategy by preventive chemotherapy (PCT). Although PCT might not be required in 32/77 districts, a yearly and bi-annual deworming is needed in 2 and 43 districts, respectively. If no environmental change occurs, and no mass treatment is delivered, prevalence is likely to remain stable for many years owing to poor hygiene and sanitation.

1. Background

Schistosomiasis is still the most widespread Neglected Tropical Diseases (NTD) in the world and is considered a poverty-related disease. This infection is particularly abundant among people living in deprived communities with poor and limited access to safe water, sanitary

Abbreviations: NCPCD, national control program of communicable diseases; NTD, neglected tropical diseases; PCT, preventive chemotherapy; PTA, parents and teachers associations; SAC, school age children; PSAC, pre-school-age children; SSA, Sub-Saharan Africa; STH, soil transmitted helminths; USAID, United States Agency for International Development; WHO, World Health Organization; WCBA, women of child-bearing age; WSSA, West Sub-Saharan Africa

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facilities or inadequate health facilities like many sub-Saharan Africa (SSA) countries (Hotez and Kamath, 2009; WHO, 2018). However, infections were also reported in developed countries, such as the Corsica region in France (Holtfreter et al., 2014; Boissier et al., 2015; Ramalli et al., 2018). Schistosomiasis is a water-associated vector-borne disease caused by parasitic blood fluke, known as schistosome with at least 280 million people affected worldwide (Chitsulo et al., 2004; WHO, 2018). Fifty per cent of endemic countries are in Africa and it is estimated that around 85% and 90% of the people at risk live in SSA (Chitsulo et al., 2000; WHO, 2011), making schistosomiasis the most prevalent neglected tropical disease in SSA. As schistosomiasis, most of the populations affected with Soil Transmitted Helminths (STH) are in SSA (Hotez et al., 2006; WHO, 2006; Stothard et al., 2017), and the control of these NTDs has become a priority for many governments with the support of donors and funding agencies following the World Health Assembly resolution in 2001 (WHA 2001).

In Benin, the misconception that schistosomiasis is not a disease made the population reluctant to seek treatment even in presence of explicit symptoms such as haematuria (Sady et al., 2015; Inobaya et al., 2018). For most people in rural areas in Benin, schistosomiasis was a sign of puberty for boys rather than a disease (Boko et al., 2016). The control of Schistosomiasis using preventive chemotherapy (PCT) has been integrated progressively. Instead of sporadic treatment of school age children in the villages, the National Control Program of Communicable Diseases (NCPCD) has implemented PCT in all districts with confirmed cases in accordance with WHO's guidelines with the support of RTI-INTERNATIONAL ENVISION. The national mapping study of the NTD infections (Schistosomiasis and STH)was carried out over three-year. This manuscript describes the national mapping of human schistosomiasis over the 77 districts in Benin, as the results of the STH mapping have been recently published (Ibikounlé et al., 2018).

2. Materials and methods

2.1. Study area

The study area was previously described in (Ibikounlé et al., 2018). The republic of Benin is divided into 12 departments (political subdivisions), which are further divided into 77 districts in total. The districts are divided into 545 sub-districts and into 3755 villages. Each sub-district has at least one unit of health and each village has at least one public school. All the 77 districts were considered in this study. In 2015, the total population was estimated at 10,008,749 inhabitants with 29.7% of the population being school-age children (8 ± 14-year-old) (INSAE and ICF, 2015). Rainfall intensifies from the south to the north of the country. In the northern departments (Atacora, Donga, Borgou and Alibori), the annual rainfall varies between 900 mm and 1200 mm with numerous lakes and rivers feeding the country. In the southern departments (Collines, Zou, Atlantic, Littoral, Mono, Couffo Plateau and Ouémé), the annual rainfall varies from 800 mm to 1200 mm (INSAE and ICF, 2015). The geographical location of each surveyed school, including altitude and universal transverse mercator coordinates are provided in S1 Table.

2.2. Study design

This study was conducted from 2013 to 2015 in the 77 districts of Benin (Table 1). In each district, five primary schools were selected as previously described (Ibikounlé et al., 2018). Briefly, schools were identified based on their proximity to a river or waterbodies where snails were suspected to be present. From each selected school, 50 children (25 girls and 25 boys) aged between 8 and 14 years were randomly enrolled in each school. We selected this age group not only for convenience but also as children are generally more active at this age, more likely to go swimming and more exposed to schistosomiasis. Additionally, WHO guidelines (WHO, 2011) are based on prevalence in School-age children. Two containers (one for urine and the second for stool) were distributed to each participant by a team of laboratory technicians and the samples were collected within an hour between 10:00 and 12:00 am. In each site the samples were conditioned separately in two refrigerated coolers (one ice cooler for urine and one for stools) and immediately transported to the laboratory of district health centre to be screened using appropriate methods.

2.3. Detection of schistosome eggs in urine and stool samples

The urine samples collected from the school-children were measured and assessed for schistosomiasis infection. Urine samples were homogenized to ensure adequate dispersal of eggs, and 10 mL of the urine were immediately filtered through a Nucleopore ® filter with 13 µm size pore. The filters were examined by microscopy after adding 5% Lugol solution to detect the presence of different species of schistosome eggs. Intensity of infection was quantified as number of eggs per 10 mL of urine (eggs/10 mL). The intensity of schistosome infections were graded as negative (0), light (1–49 eggs) and heavy (≥50 eggs) (WHO, 2011).

The stool samples were analyzed using the Kato-Katz method (Katz et al., 1972). Briefly, 41.7 mg of stool is filtered through a nylon mesh and covered with cellophane previously soaked in 50% green-malachite (Katz et al., 1972; WHO, 1996). The slides were observed under microscope by two technicians and their results were validated by a supervisor. *S. mansoni* eggs were counted 24 h later. The intensity of the infection was estimated as number of eggs per gram (EPG) of stool for the designated parasite and classified as negative (0 egg), light (1–99 eggs), moderate (100–399 eggs) or heavy (≥400 eggs) (WHO, 2011).

For quality control purpose, 10% of the urine samples were screened again by the supervisor and 10% of the feces slides in each district were examined again by an independent team of senior biologists and parasitologists.

2.4. Statistical analysis

Data were double entered in Microsoft Excel 2008 (Redmond, Washington, USA). Range and consistency checks were conducted for all non-string variables. Descriptive statistics and prevalence estimates were determined using Epi-Info 7 (CDC, Atlanta, USA). The 95% confidence intervals of each prevalence were calculated by considering the cluster effect according Bennett et al. (1991). The multiple comparison test chi square proportions were used to compare the prevalence of schistosomiasis between districts and departments. The Fisher exact method of maximum likelihood and calculation of confidence intervals was used to determine the gender odd ratio in each district. A Z-test was used to compare the prevalence values between districts and gender. Comparisons with a P value < 0.05 were considered significant. Geographical positions of studied schools were used to plot the sites and to produce maps using GIS software (ArcGIS ESRI Inc., Version 10.4, California, USA).

2.5. Ethical considerations

The study was approved by the Comité National d'Ethique pour la Recherche en Santé (CNERS) under the reference #009/CNERS-MS from the Ministry of Health in Benin. As previously described in (Ibikounlé et al., 2018), informed consent was obtained from parents, or from the head teacher of each school. When neither the parents nor the head teachers are available, the chief of the village or the parents and teachers association (PTA) provided the consent to proceed. In some districts where PTA exist, the head of the PTA and the head teachers received detailed explanation about the study. Individual parents were informed by the PTA and consents were secured orally. The PTA then provided a formal written approval on behalf of schoolchildren and parents. In cases where the legal representative was

Table 1
Prevalence and intensity of *S. haematobium* infection in Beninese schoolchildren (N: schoolchildren examined per department; (%): overall prevalence in the department; a: districts mapped in 2013; b: districts mapped in 2014 and c: districts mapped in 2015).

Department	District	Infected/ Examined	Prevalence [95% CI]	p-value	Intensity of Infection	
					Light n (%)	Heavy n (%)
ATACORA	COBLI[b]	14/250	5.60 [1.57;9.63]	p < 0.001	11 (78.57)	3 (21.43)
	BOUKOUMBE[b]	50/250	20.00 [12.99;27.01]		28 (56.00)	22 (44.00)
	MATERI[b]	7/250	2.80 [0.00;5.69]		2 (28.57)	5 (71.43)
	KOUANDE[b]	28/250	11.20 [5.67;16.73]		25 (89.29)	3 (10.71)
	TOUKOUNTOUNA[b]	2/250	0.80 [0.00;2.36]		1 (50.00)	1 (50.00)
	TANGUIETA[b]	2/250	0.80 [0.00;2.36]		1 (50.00)	1 (50.00)
	NATITINGOU[a]	3/250	1.20 [0.00;3.11]		3 (100.00)	0 (0.00)
	KEROU[a]	20/250	8.00 [3.24;12.76]		20 (100.00)	0 (0.00)
	PEHUNCO[a]	107/250	42.80 [34.13;51.47]		98 (91.58)	9 (8.41)
		233/2,250	10.36 [8.58;12.14]		189 (81.12)	44 (18.88)
DONGA	BASSILA[c]	69/250	27.60 [19.76;35.44]	p < 0.001	49 (71.01)	20 (28.99)
	DJOUGOU[c]	23/250	9.20 [4.13;14.27]		21 (91.30)	2 (8.70)
	COPARGO[a]	135/250	54.00 [45.26;62.74]		89 (65.92)	46 (34.07)
	OUAKE[a]	144/250	57.60 [48.94;66.26]		98 (68.05)	46 (31.94)
		371/1000	37.10 [32.84;41.33]		257 (69.27)	114 (30.73)
BORGOU	NIKKI[c]	79/250	31.60 [23.45;39.75]	p < 0.001	60 (75.95)	19 (24.05)
	PÈRÈRÈ[c]	41/250	16.40 [9.91;22.89]		36 (87.80)	5 (12.20)
	TCHAOUROU[b]	141/250	56.40 [47.71;65.09]		82 (58.16)	59 (41.84)
	PARAKOU[b]	56/250	22.40 [15.09;29.71]		47 (83.93)	9 (16.07)
	SINENDE[b]	91/250	36.40 [27.97;44.83]		82 (90.11)	9 (9.89)
	BEMBEREKE[a]	227/250	90.80 [85.73;95.87]		111 (48.89)	116 (51.10)
	N'DALI[a]	152/250	60.80 [52.24;69.36]		78 (51.31)	74 (48.68)
	KALALE[a]	50/250	20.00 [12.99;27.01]		41 (82)	9 (18)
		837/2000	41.85 [38.79;44.91]		537 (64.16)	300 (35.84)
ALIBORI	BANIKOARA[b]	63/250	25.20 [17.59;32.81]	p < 0.001	40 (63.49)	23 (36.51)
	GOGOUNOU[b]	16/250	6.40 [2.11;10.69]		15 (93.75)	1 (6.25)
	MALANVILLE[b]	80/250	32.00 [23.82;40.18]		80 (100)	0 (0.00)
	KARIMAMA[b]	23/250	9.20 [4.13;14.27]		23 (100)	0 (0.00)
	SEGBANA[b]	5/250	2.00 [0.00;4.45]		2 (40.00)	3 (60.00)
	KANDI[b]	58/250	23.20 [15.80;30.60]		43 (74.14)	15 (25.86)
		245/1,500	16.33 [13.69;18.98]		203 (82.86)	42 (17.14)
COLLINES	DASSA-ZOUMÈ[c]	33/250	13.20 [7.27;19.13]	p < 0.001	27 (81.82)	6 (18.18)
	OUÈSSÈ[c]	51/250	20.40 [13.34;27.46]		29 (56.86)	22 (43.14)
	SAVÈ[c]	26/250	10.40 [5.05;15.75]		22 (84.62)	4 (15.38)
	BANTE[b]	46/250	18.40 [11.61;25.19]		30 (65.22)	16 (34.78)
	GLAZOUE[b]	16/250	6.40 [2.11;10.69]		15 (93.75)	1 (6.25)
	SAVALOU[b]	50/250	20.00 [12.99;27.01]		12 (24.00)	38 (76.00)
		222/1,500	14.80 [12.26;17.34]		135 (60.81)	87 (39.19)
ZOU	ABOMEY[c]	8/250	3.20 [0.11;6.29]	p < 0.001	8 (100.00)	0 (0.00)
	AGBANGNIZOUN[c]	20/250	8.00 [3.24;12.76]		20 (100.00)	0 (0.00)
	BOHICON[c]	1/250	0.40 [0.00;1.51]		1 (100.00)	0 (0.00)
	COVÈ[c]	7/250	2.80 [0.00;5.69]		7 (100.00)	0 (0.00)
	DJIDJA[c]	37/250	14.80 [8.57 ;21.03]		32 (86.49)	5 (13.51)
	OUINHI[c]	35/250	14.00 [7.92;20.08]		33 (94.29)	2 (5.71)
	ZAKPOTA[c]	80/250	32.00 [23.82;40.18]		68 (85.00)	12 (15.00)
	ZOGBODOMEY[c]	64/250	25.60 [17.95;33.25]		63 (98.44)	1 (1.56)
	ZAGNANADO[c]	35/250	14.00 [7.92;20.08]		17 (48.57)	18 (51.43)
		287/2,250	12.75 [10.81;14.70]		249 (86.76)	38 (13.24)
OUEME	ADJARRA[c]	2/250	0.80 [0.00;2.36]	p < 0.001	2 (100)	0 (0.00)
	ADJOHOUN[c]	6/250	2.40 [0.00;5.08]		5 (83.33)	1 (16.67)
	AGUÉGUÉ[c]	164/250	65.60 [57.27;73.93]		153 (93.29)	11 (6.71)
	AKPRO-MISSÉRÉTÉ[c]	8/250	3.20 [0.11;6.29]		7 (87.50)	1 (12.50)
	AVRANKOU[c]	2/250	0.80 [0.00;2.36]		2 (100.00)	0 (0.00)
	BONOU[c]	8/250	3.20 [0.11;6.38]		4 (50.00)	4 (50.00)
	DANGBO[c]	143/250	57.20 [48.53;65.87]		98 (68.53)	45 (31.47)
	PORTO-NOVO[c]	7/250	2.80 [0.00;5.69]		5 (71.43)	2 (28.57)
	SÈMÈ-KPODJI[c]	10/250	4.00 [0.56;7.44]		8 (80.00)	2 (20.00)
		350/2,250	15.46 [9.27;12.95]		284 (81.14)	66 (18.86)
PLATEAU	ADJA OUERE[c]	80/250	32.00 [23.82;40.18]	p < 0.001	70 (87.50)	10 (12.50)
	IFANGNI[c]	14/250	5.60 [1.57;9.63]		13 (92.86)	1 (7.14)
	POBE[c]	72/250	28.80 [20.86;36.74]		52 (72.22)	20 (27.78)
	KETOU[c]	45/250	18.00 [11.26;24.74]		19 (42.22)	26 (57.78)
	SAKÉTÉ[c]	4/250	1.60 [0.00;3.80]		2 (50.00)	2 (50.00)
		215/1,250	17.20 [14.02;19.90]		156 (72.56)	59 (27.44)

(*continued on next page*)

Table 1 (*continued*)

Department	District	Infected/ Examined	Prevalence [95% CI]	p-value	Intensity of Infection	
					Light n (%)	Heavy n (%)
ATLANTIQUE	ABOMEY-CALAVI[c]	1/250	0.40 [0.00;1.51]	p < 0.001	1 (100.00)	0 (0.00)
	ALLADA[c]	2/250	0.80 [0.00;2.36]		2 (100.00)	0 (0.00)
	KPOMASSE[c]	0/250	0.00 [0.00;0.00]		0 (0.00)	0 (0.00)
	OUIDAH[c]	32/250	12.80 [51.00;68.20]		4 (12.50)	28 (87.50)
	SÔ-AVA[c]	149/250	59.60 [53.52;65.68]		112 (75.17)	37 (24.83)
	TOFFO[c]	63/250	25.20 [17.59;32.81]		58 (92.06)	5 (7.94)
	TORI-BOSSITO[c]	28/250	11.20 [5.67;16.73]		28 (100.00)	0(0.00)
	ZE[c]	67/250	26.80 [19.04;34.56]		52 (77.61)	15 (22.39)
		342/2,000	17.10 [14.77;19.43]		257 (75.15)	85 (24.85)
LITTORAL	COTONOU[c]	5/250	2.00 [0.00;4.45]	N = 250	2 (40.00)	3 (60.00)
COUFFO	APLAHOUE[b]	47/250	18.80 [11.95;25.65]	p < 0.001	47 (100)	0 (0.00)
	DJAKOTOMEY[b]	21/250	8.40 [3.54;13.26]		21 (100)	0 (0.00)
	DOGBO[b]	8/250	3.20 [0.11;6.29]		8 (100)	0 (0.00)
	KLOUEKAME[b]	62/250	24.80 [17.23;32.37]		50 (80.65)	12 (19.35)
	LALO[b]	48/250	19.20 [12.30;26.10]		35 (72.92)	13 (27.08)
	TOVIKLIN[b]	11/250	4.40 [0.80;8.00]		11 (100)	0 (0.00)
		197/1,500	13.13 [10.72;15.55]		172 (87.31)	25 (12.69)
MONO	ATHIEME[b]	14/250	5.60 [1.57;9.63]	p < 0.001	13 (92.86)	1 (7.14)
	BOPA[b]	2/250	0.80 [0.00;2.36]		1 (50.00)	1 (50.00)
	COME[b]	3/250	1.20 [0.00;3.11]		3 (100)	0 (0.00)
	GRAND POPO[b]	9/250	3.60 [0.33;6.87]		9 (100)	0 (0.00)
	HOUEYOGBE[b]	30/250	12.00 [76.30;17.70]		19 (63.33)	11 (36.67)
	LOKOSSA[b]	20/250	8.00 [3.24;12.76]		20 (100)	0 (0.00)
		78/1,500	5.20 [3.61;6.79]		65 (83.33)	13 (16.67
National prevalence		3380/19,250	17.56 [16.80;18.32]		2501 (73.99%)	879 (20.01%)

unable to read and write, a detailed verbal explanation of the form was given so that informed consent was obtained. Two copies of the written consent form were signed and dated. The person giving the consent kept one copy and the second copy was returned to the NCPCD. During the sampling, all schoolchildren from whom no consent statement was received were replaced by other volunteers according to inclusion criteria. Participants detected with high intensity of infection or any other intestinal parasite infections were directed to healthcare centres for appropriate treatment before the school-based PCT, organized the following year.

3. Results

Screening of the 19,250 samples collected from schoolchildren in 385 schools revealed that two major species were widely distributed in Benin. *S. haematobium* and *S. mansoni* parasites were detected in schistosomiasis-exposed populations across the country. The average national prevalence was 17.60% and 2.45% for *S. haematobium* and *S. mansoni*, respectively.

3.1. Large distribution of light S. haematobium infections in Beninese schoolchildren

The median prevalence of *S. haematobium* across the 77 surveyed districts was 11.2% with interquartile range (IQR) of 3.2%–25.2% (Supplemental Table 2). *S. haematobium* infection was absent in only 2 districts in Benin (Table1 and Fig. 1). In the other 75 districts, *S. haematobium* eggs were detected in 3380 children with district prevalence ranging from 0.4% to 90.8%. Of the 77 districts surveyed, eight (Copargo, Ouaké, Tchaourou, Bembéréké, N'dali, Aguégué, Dangbo and Sô-Ava) were considered as high risk for *S. haematobium* transmission (prevalence above 50.0%). The highest prevalence of *S. haematobium* was observed in the district of Bembéréké, located in the northern region of the country. In this district, 227 out of 250 screened schoolchildren were infected including 116 children detected with heavy infection. Remarkably, 3 (Tchaourou, Bembéréké, N'dali) out of the 8 districts with high *S. haematobium* transmission are neighbor districts and located in the same department (Borgou). This observation highlighted the high infectious rate of exposed individuals living in these specific areas of the department of Borgou. In this department, the prevalence of *S. haematobium* ranged from 16.4% to 90.8%. A relatively low *S. haematobium* transmission (prevalence below 10%) was observed in 36 out of 77 districts, including 24 districts where the prevalence was below 5%. The lowest prevalence of *S. haematobium* was found in Bohicon and Abomey-Calavi districts, where only one schoolchild was infected. Finally, transmission of *S. haematobium* was considered moderate (prevalence between 10%–49.9%) in 33 districts. In most of the surveyed districts the urinary schistosomiasis infestation was light.

3.2. Prevalence of S. mansoni infection

The detection of schistosome eggs in the stool samples showed that schoolchildren in several districts were infected by *S. mansoni*. However, schistosomiasis infection with *S. mansoni* was less prevalent as compared to *S. haematobium*. The median prevalence of *S. mansoni* across the country was 0% (IQR, 0–1.2). Indeed, no *S. mansoni* eggs were detected in 49/77 (63.6%) districts (Table 2 and Fig. 2). In 28 other districts the prevalence of *S. mansoni* ranged from 0.4% to 46%. Of these 28 districts, the prevalence of *S. mansoni* was less than 10% in 23 (82.1%) districts, including six districts (Kouandé, Parakou, Malanville, Bonou, Pobè and Aplahoué) where *S. mansoni* infection was detected in only one schoolchild. The district of Tanguiéta from the department of Atacora was the most exposed to *S. mansoni* infection with a prevalence of 46%. Two other districts from the same department were found as the second (Cobli) and third (Boukoumbé) most exposed to *S. mansoni* infection with a prevalence of 40.4% and 18.4%, respectively. In this department, *S. mansoni* infection was detected in 6 out 9 districts, highlighting the relatively high rate of *S. mansoni*

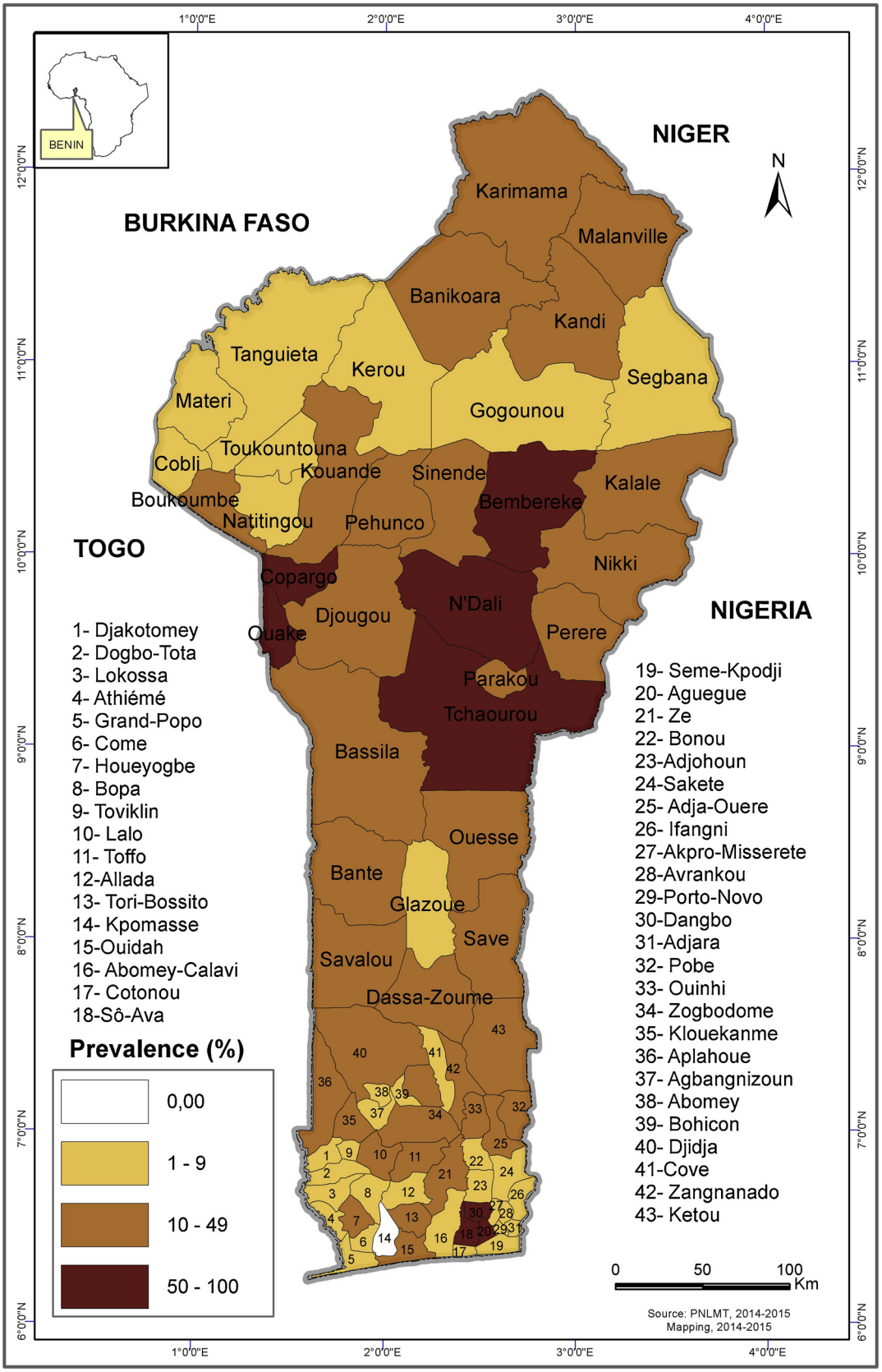

Fig. 1. *Schistosoma haematobium* distribution.

infection in this region of the country compared to other districts and departments. The districts of N'dali (department of Borgou) and Lokossa (department of Couffo) are the other two areas where the prevalence of *S. mansoni* was higher than 10% (15% for N'dali and 14% for Lokossa).

Table 2
Prevalence and intensity of *S. mansoni* infection in Benin schoolchildren (N: schoolchildren examined per department; (%): overall prevalence in the department; a: districts mapped in 2013; b: districts mapped in 2014 and c: districts mapped in 2015).

Departments	Districts	Infecte/Examined	Prevalence [95° IC]	p-value	Intensity of Infection		
					Light, n (%)	Moderate, n (%)	Heavy, n (%)
ATACORA	COBLI[b]	101/ 250	40.40 [31.80;49.00]	P < 0.001	94 (93.07)	6 (5.94)	1 (0.99)
	BOUKOUMBE[b]	46/250	18.40 [11.61;25.19]		19 (41.30)	18 (39.13)	9 (19.57)
	MATERI[b]	16/250	6.40 [2.11;10.690]		8 (50.00)	7 (43.75)	1 (6.25)
	KOUANDE[b]	1/250	0.40 [0.00 ;1.57]		1 (100)	0	0
	TOUKOUNTOUNA[b]	0/250	0.00 [0.00;0.00]		0	0	0
	TANGUIETA[b]	115/250	46.00 [37.26;54.74]		31 (26.96)	37 (32.17)	47 (40.87)
	NATITINGOU[a]	0/250	0.00 [0.0;0.0]		0	0	0
	KEROU[a]	0/250	0.00 [0.0;0.0]		0	0	0
	PEHUNCO[a]	3/250	1.20 [0.00;3.11]		3 (100.00)	0	0
		282/2,250	12.53 [10.60;14.47]		156 (55.32)	68 (24.11)	58 (20.57)
DONGA	BASSILA[c]	0/250	0.00 [0.0;0.0]	P < 0.01	0	0	0
	DJOUGOU[c]	0/250	0.00 [0.0;0.0]		0	0	0
	COPARGO[a]	0/250	0.00 [0.0;0.0]		0	0	0
	OUAKE[a]	4/250	1.33 [0.00; 3.80]		4 (100.00)	0	0
		4/1,000	0.40 [0.1;0.95]		4 (100)	0	0
BORGOU	NIKKI[c]	0/250	0.00 [0.0;0.0]	P < 0.001	0	0	0
	PERERE[c]	8/250	3.20 [0.11;6.29]		8 (100.00)	0	0
	TCHAOUROU[b]	20/250	8.00 [0.11;6.29]		2 (10.00)	14 (70.00)	4 (20.00)
	PARAKOU[b]	1/250	0.40 [0.00;1.51]		1 (100.00)	0	0
	SINENDE[b]	10 /250	4.00 [0.56;7.44]		9 (90.00)	1 (10.00)	0
	BEMBEREKE[a]	0/250	0.00 [0.0;0.0]		0	0	0
	N'DALI[a]	37/250	15.00 [18.57;21.03]		17 (45.95)	13 (35.13)	7 (18.92)
	KALALE[a]	3/250	1.20 [0.00;3.11]		3 (100.00)	0	0
		79/2,000	3.95 [2.45;4.75]		40 (50.63)	28 (35.44)	11 (13.92)
ALIBORI	BANIKOARA[b]	0/250	0.00 [0.0;0.0]	p = 0.001	0	0	0
	GOGOUNOU[b]	0/250	0.00 [0.0;0.0]		0	0	0
	MALANVILLE[b]	1/250	0.40 [0.00;3.11]		1 (100)	0	0
	KARIMAMA[b]	0/250	0.00 [0.0;0.0]		0	0	0
	SEGBANA[b]	5/250	2.00 [0.00;4.45]		2 (40.00)	3 (60.00)	0
	KANDI[b]	0/250	0.00 [0.0;0.0]		0	0	0
		6/1,500	0.40 [0.1;0.85]		3 (50.0)	3 (50.0)	0
COLLINES	DASSA-ZOUME[c]	0/250	0.00 [0.0;0.0]	–	0	0	0
	OUESSE[c]	0/250	0.00 [0.0;0.0]		0	0	0
	SAVÈ[c]	0/250	0.00 [0.0;0.0]		0	0	0
	BANTE[b]	0/250	0.00 [0.0;0.0]		0	0	0
	GLAZOUE[b]	0/250	0.00 [0.0;0.0]		0	0	0
	SAVALOU[b]	0/250	0.00 [0.0;0.0]		0	0	0
		0/1,500	0		0	0	0
ZOU	ABOMEY[c]	0/250	0.00 [0.0;0.0]	–	0	0	0
	AGBANGNIZOUN[c]	0/250	0.00 [0.0;0.0]		0	0	0
	BOHICON[c]	0/250	0.00 [0.0;0.0]		0	0	0
	COVÈ[c]	0/250	0.00 [0.0;0.0]		0	0	0
	DJIDJA[c]	0/250	0.00 [0.0;0.0]		0	0	0
	OUINHI[c]	0/250	0.00 [0.0;0.0]		0	0	0
	ZAKPOTA[c]	0/250	0.00 [0.0;0.0]		0	0	0
	ZOGBODOMEY[c]	0/250	0.00 [0.0;0.0]		0	0	0
	ZAGNANADO[c]	0/250	0.00 [0.0;0.0]		0	0	0
		0/2,250	0		0	0	0
OUEME	ADJARRA[c]	0/250	0.00 [0.0;0.0]	–	0	0	0
	ADJOHOUN[c]	0/250	0.00 [0.0;0.0]		0	0	0
	AGUEGUE[c]	0/250	0.00 [0.0;0.0]		0	0	0
	AKPRO-MISSERETE[c]	0/250	0.00 [0.0;0.0]		0	0	0
	AVRANKOU[c]	0/250	0.00 [0.0;0.0]		0	0	0
	BONOU[c]	1/250	0.40 [0.00;1.51]		0	1 (100.00)	0
	DANGBO[c]	0/250	0.00 [0.0;0.0]		0	0	0
	PORTO-NOVO[c]	0/250	0.00 [0.0;0.0]		0	0	0
	SEME-KPODJI[c]	4/250	1.60 [0.00;3.80]		4 (100.00)	0	0
		5/2,250	0.22 [0.1;0.50]		4 (80.0)	1 (20.0)	0
PLATEAU	ADJA OUERE[c]	0/250	0.00 [0.0;0.0]	–	0	0	0
	IFANGNI[c]	0/250	0.00 [0.0;0.0]		0	0	0
	POBE[c]	1/250	0.40 [0.00;1.51]		0	1 (100.00)	0
	KETOU[c]	0/250	0.00 [0.0;0.0]		0	0	0
	SAKÉTÉ[c]	0/250	0.00 [0.0;0.0]		0	0	0
		1/1,250	0.08 [0.1;0.30]		0	1 (100)	0

(*continued on next page*)

Table 2 (*continued*)

Departments	Districts	Infecte/Examined	Prevalence [95° IC]	p-value	Intensity of Infection		
					Light, n (%)	Moderate, n (%)	Heavy, n (%)
ATLANTIQUE	ABOMEY-CALAVI[c]	0/250	0.00 [0.0;0.0]	p < 0.001	0	0	0
	ALLADA[c]	0/250	0.00 [0.0;0.0]		0	0	0
	KPOMASSE[c]	0/250	0.00 [0.0;0.0]		0	0	0
	OUIDAH[c]	17/250	6.80 [2.39;11.21]		15 (88.24)	1 (5.88)	1 (5.88)
	SÔ-AVA[c]	0/250	0.00 [0.0;0.0]		0	0	0
	TOFFO[c]	6/250	2.40 [0.00;5.08]		4 (66.67)	1 (16.67)	1 (16.67)
	TORI-BOSSITO[c]	8/250	3.20 [0.11;6.29]		8 (100.00)	0	0
	ZE[c]	8/250	3.20 [011;6.29]		7 (87.50)	1 (12.50)	0
		39/2,000	1.95 [1.09;2.81]		34 (87.18)	3 (7.69)	2 (5.13)
LITTORAL	COTONOU[c]	0/250	0.00 [0.0;0.0]		0	0	0
COUFFO	APLAHOUE[b]	1/250	0.40 [0.00;1.51]	p < 0.001	1 (100)	0	0
	DJAKOTOMEY[b]	10 /250	4.00 [0.56;7.44]		8 (80.00)	2 (20.00)	0
	DOGBO[b]	0/250	0.00 [0.0;0.0]		0	0	0
	KLOUEKAME[b]	1/250	0.40 [0.00;1.51]		1 (100)	0	0
	LALO[b]	0/250	0.00 [0.0;0.0]		0	0	0
	TOVIKLIN[b]	0/250	0.00 [0.0;0.0]		0	0	0
		12/1,500	0.80 [0.16;1.44]		10 (83.33)	2 (16.67)	0
MONO	ATHIEME[b]	0/250	0.00 [0.0;0.0]	p < 0.001	0	0	0
	BOPA[b]	4/250	1.60 [0.00;3.80]		4 (100)	0	0
	COME[b]	3 /250	1.20 [0.00;3.11]		3 (100)	0	0
	GRAND POPO[b]	0/250	0.00 [0.0;0.0]		0	0	0
	HOUEYOGBE[b]	0/250	0.00 [0.0;0.0]		0	0	0
	LOKOSSA[b]	37/250	14.80 [8.57;21.03]		22 (59.46)	14 (37.84)	1 (2.70)
		44/1,500	2.93 [1.73;4.14]		29 (65.91)	14 (31.82)	1 (2.27)
National prevalence		472/19,250	2.45 [2.14;2.76]		280 (59.32%)	120 (25.42%)	72 (15.25%)

3.3. Schistosomiasis infection in Benin

A combined prevalence of *S. haematobium* and *S. mansoni* in Benin, as defined by the average prevalence infections with either or both schistosome species, and the proportion of mixed infection was analyzed and reported in Table 3 and Fig. 3. The national prevalence of *S. haematobium* was significantly higher than *S. mansoni* (Mann-Whitney test, P < 0.001) (Fig. 4). Considering infections with both species, the median schistosomiasis prevalence across the country was 14% (IQR, 3.8–29.2), whereas the mean prevalence was 19.79%. No schistosomiasis infection was detected among the surveyed schoolchildren in the districts of Kpomassè (department of Atlantic). The geographic distribution of the districts with high schistosomiasis transmission (> 50% prevalence) based on the combined prevalence, overlapped the high *S. haematobium* transmission. The highest schistosomiasis-exposed district was Bembéréké (90.8% *S. haematobium* and 0% *S. mansoni*). Furthermore, 37 (48%) districts were spotted as moderate for schistosomiasis transmission, of which 4 districts (Cobli, Tanguiéta, Djakotomey and Lokossa) had low *S. haematobium* transmission. Overall, schistosomiasis transmission was considered low in 32 districts distributed all over the country. At the department level, the schistosomiasis transmission patterns were considered low and moderate (prevalence range, 2–37), with the lowest departments being Littoral (2%) and Mono (8%) (Table 3 and Fig. 1). As particular note, in 10 out of the 12 departments in Benin, the prevalence of schistosomiasis was relatively high (above 10%).

Many schoolchildren were detected with both urinary and intestinal schistosomiasis infection (Table 3). However, the prevalence of this co-infection *S. haematobium* and *S. mansoni* rarely exceeded 5%. The highest prevalence of co-infection was observed in the district of Cobli, where 14 (5.6%) schoolchildren were infected with both species.

3.4. Gender difference in schistosomiasis transmission pattern in Benin

The relationship between schistosomiasis infections and the gender per department are presented in Table 4. Countrywide, boys appeared to be more infected than girls (p = 0.007). However, in 9/12 departments, there was no gender-related difference in the prevalence of schistosomiasis infections. In the department of Alibori, Collines and Couffo, the risk of *S. haematobium* infection was greater in boys than in girls (Table 4).

4. Discussion

The results of this mapping study indicated the presence of schistosomiasis infections in almost every district of the 12 departments in Benin and showed a high heterogeneity level of *S. haematobium* and *S. mansoni* prevalence across the country. Inter and intra-specific prevalence of schistosomiasis infections and schistosome parasite intensities were observed across the districts and appeared to be influenced by gender. In the departments of Atacora, Donga, Borgou, Zou, Ouémé, Plateau, Atlantique, Littoral and Mono, boys and girls are similarly affected (p > 0.05). However, in the other 3 departments of the country (Alibori, Collines and Couffo), schistosomiasis infections were greater in boys (p < 0.05).

4.1. Schistosomiasis prevalence in Benin

Prior to the current study, schistosomiasis data were obtained through surveys which included few clusters of villages, and the sampling was not powered to reflect the national epidemiology of the disease. In the southern part of the country, Chippaux et al. (1990) has previously reported prevalence of 23.0% and 13.4% for urinary and intestinal schistosomiasis, respectively in Toho-Todougba (district of Ouidah). Garba et al. (2000) indicated 19.7% and 3.9% prevalence of *S. haematobium* and *S. mansoni* in Adjarala (district of Aplahoué). In 2009, studies conducted by Ibikounlé et al. (2009) in the southern Benin reported prevalence values of 100% and 0% in Sô-Tchanhoué (district of Sô-Ava), and 11.4% and 28.6% in Toho-Todougba (district of Ouidah) for *S. haematobium* and *S. mansoni* infections, respectively. In the northern areas, Ibikounlé et al. (2014a; 2014b) has previously described prevalence values of 48.44% and 0% in the district of Nikki, 45.24% and 4.11% in the district of Pérérê, and 29.40% and 0% in the district of Péhunco for *S. haematobium* and *S. mansoni*, respectively. Compared to these reports, in many sites/districts there was a remarkable decrease in the prevalence of schistosomiasis varying from

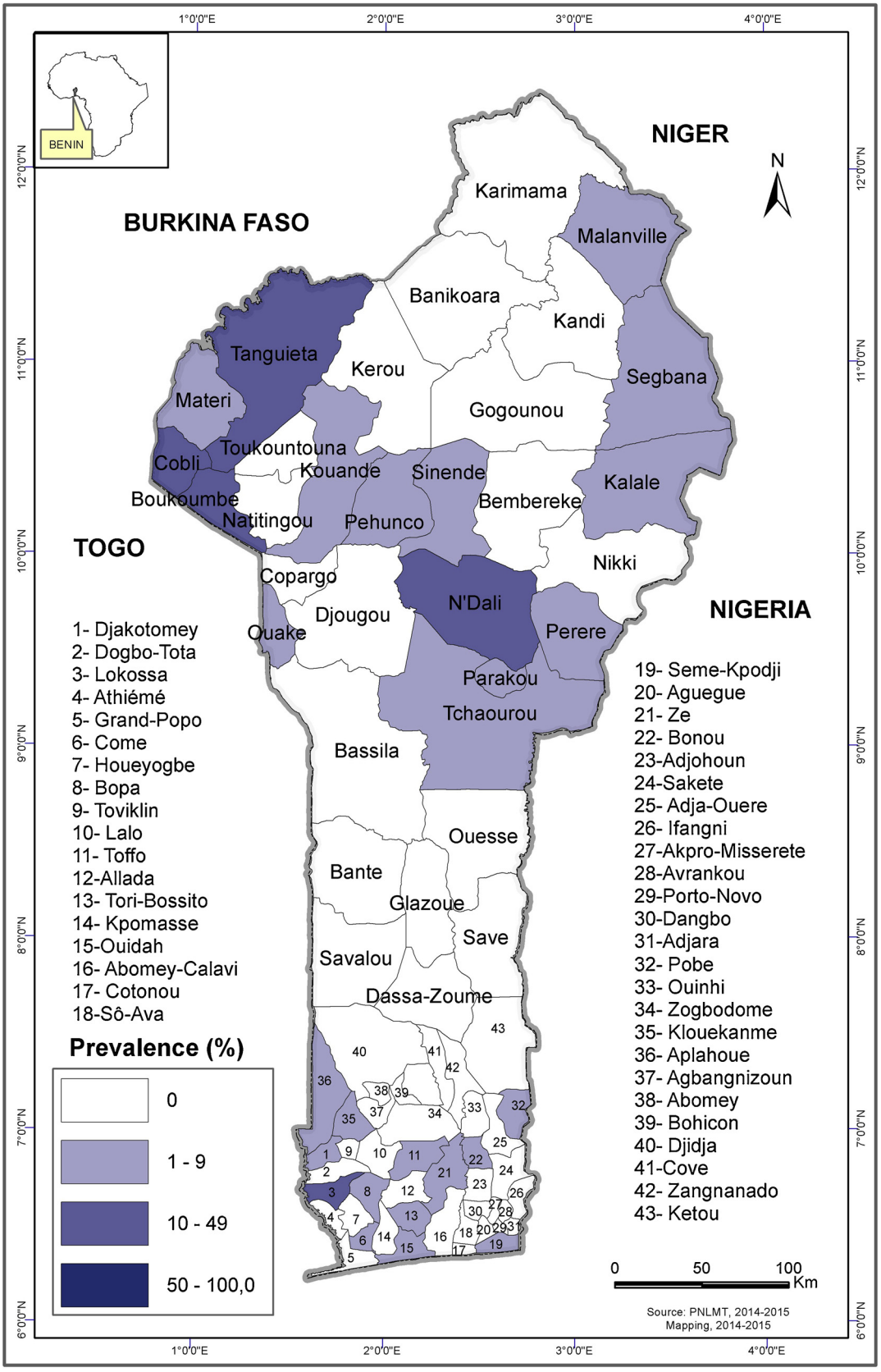

Fig. 2. *Schistosoma mansoni* distribution.

Table 3
Combined prevalence of schistosomiasis infection in Beninese schoolchildren (N: schoolchildren examined per department; (%): overall combined prevalence in the department; a: districts mapped in 2013; b: districts mapped in 2014 and c: districts mapped in 2015).

Department	Districts	Infected/ Examined	Prevalence [95° IC]	p-value	PCT strategy
ATACORA	COBLI	101/250	40.40 [31.80;49.00]	p < 0.001	1PCT/2Years for SAC
	BOUKOUMBE	92/250	36.80 [28.35;45.25]		1PCT/2Years for SAC
	MATERI	23/250	9.20 [4.13;14.27]		No PCT
	KOUANDE	28/250	11.20 [5.67;16.73]		1PCT/Year for SAC
	TOUKOUNTOUNA	2/250	0.80 [0.00;2.36]		No PCT
	TANGUIETA	116/250	46.40 [37.66;55.14]		1PCT/Year for SAC
	NATITINGOU	3/250	1.20 [0.00;3.11]		No PCT
	KEROU	20/250	8.00 [3.24;12.76]		No PCT
	PEHUNCO	107/250	42.80 [34.13;51.47]		1PCT/2Years for SAC
		492/2,250	21.87 [19.45;2428]		
DONGA	BASSILA	69/250	27.60 [19.76;35.44]	p < 0.001	1PCT/2Years for SAC
	DJOUGOU	23/250	9.20 [4.13;14.27]		No PCT
	COPARGO	135/250	54.00 [45.26;62.74]		1PCT/Year for SAC
	OUAKE	143/250	57.20 [48.53;65.87]		1PCT/Year for SAC
		370/1,000	37.00 [32.77;41.23]		
BORGOU	NIKKI	79/250	31.60 [23.45;39.75]	p < 0.001	1PCT/2Years for SAC
	PERERE	49/250	19.60 [12.64;26.56]		1PCT/2Years for SAC
	TCHAOUROU	160/250	64.00 [55.59;72.41]		1PCT/Year for SAC
	PARAKOU	56/250	22.40 [15.09;29.71]		1PCT/2Years for SAC
	SINENDE	100/250	40.00 [31.41;48.59]		1PCT/2Years for SAC
	BEMBEREKE	227/250	90.80 [85.73;95.87]		1PCT/Year for SAC
	N'DALI	158/250	63.20 [54.75;71.65]		1PCT/Year for SAC
	KALALE	50/250	20.00 [12.99;27.01]		1PCT/2Year for SAC
		879/2,000	43.95 [40.87;47.03]		
ALIBORI	BANIKOARA	63/250	25.20 [17.59;32.81]	p < 0.001)	1PCT/2Years for SAC
	GOGOUNOU	16/250	6.40 [2.11;10.69]		1PCT/3Years for SAC
	MALANVILLE	79/250	31.60 [23.45;39.75]		1PCT/2Years for SAC
	KARIMAMA	23/250	9.20 [4.13;14.27]		No PCT
	SEGBANA	10/250	4.00 [0.56;7.44]		No PCT
	KANDI	58/250	23.20 [15.80;30.60]		1PCT/2Year for SAC
		249/1,500	16.60 [13.94;19.26]		
COLLINES	DASSA-ZOUME	33/250	13.20 [7.27;19.13]	p < 0.001	1PCT/2Year for SAC
	OUESSE	51/250	20.40 [5.05;15.75]		1PCT/2Year for SAC
	SAVÈ	26/250	10.40 [6.61;14.18]		1PCT/2Year for SAC
	BANTE	46/250	18.40 [11.61;25.19]		1PCT/2Year for SAC
	GLAZOUE	16/250	6.40 [2.11;10.69]		No PCT
	SAVALOU	50/250	20.00 [12.99;27.01]		1PCT/2Year for SAC
		222/1,500	14.80 [12.26;17.34]		
ZOU	ABOMEY	8/250	3.20 [0.11;6.29]	p < 0.001	No PCT
	AGBANGNIZOUN	20/250	8.00 [3.24;12.76]		No PCT
	BOHICON	1/250	0.40 [0.00;1.51]		No PCT
	COVÈ	7/250	2.80 [0.00.5.69]		No PCT
	DJIDJA	37/250	14.80 [8.57;21.03]		1PCT/2Years for SAC
	OUINHI	35/250	14.00 [7.90.20.08]		1PCT/2Year for SAC
	ZAKPOTA	85/250	34.00 [25.70;42.30]		1PCT/2Year for SAC
	ZOGBODOMEY	73/250	29.20 [21.23;37.17]		1PCT/2Year for SAC
	ZAGNANADO	35/250	14.00 [7.92.20.08]		1PCT/2Years for SAC
		301/2,250	13.38 [11.39;15.37]		
OUEME	ADJARRA	0/250	0.00 [0.0;0.0]	p < 0.001	No PCT
	ADJOHOUN	6/250	2.40 [0.00;5.08]		No PCT
	AGUEGUE	164/250	65.60 [57.27;73.93]		1PCT/Year for SAC
	AKPRO-MISSERETE	8/250	3.20 [0.11;5.6.29]		No PCT
	AVRANKOU	2/250	0.80 [0.00;2.36]		No PCT
	BONOU	9/250	3.60 [0.33;6.87]		No PCT
	DANGBO	143/250	57.20 [48.53;65.87]		1PCT/Year for SAC
	PORTO-NOVO	7/250	2.80 [0.00;5.69]		No PCT
	SEME-KPODJI	14/250	5.60 [1.57;9.63]		No PCT
		353/2,250	16.44 [13.56;17.81]		
PLATEAU	ADJA OUERE	80/250	32.00 [23.82;40.18]	p < 0.001	1PCT/2Year for SAC
	IFANGNI	14/250	5.60 [1.57;9.63]		No PCT
	POBE	73/250	29.20 [21.23;37.17]		1PCT/2Year for SAC
	KETOU	45/250	18.00 [11.26;24.74]		1PCT/2Year for SAC
	SAKÉTÉ	4/250	1.60 [0.00;3.80]		No PCT
		216/1250	17.28 [14.32;20.24]		

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Table 3 (*continued*)

Department	Districts	Infected/ Examined	Prevalence [95° IC]	p-value	PCT strategy
ATLANTIQUE	ABOMEY-CALAVI	1/250	0.40 [0.00;1.51]	p < 0.001	No PCT
	ALLADA	2/250	0.80 [0.00;2.36]		No PCT
	KPOMASSE	0/250	0.00 [0.0;0.0]		No PCT
	OUIDAH	49/250	19.60 [12.64;26.56]		1PCT/2Years for SAC
	SÔ-AVA	149/250	59.60 [51.00;68.20]		1PCT/Year for SAC
	TOFFO	67/250	26.80 [19.04;34.56]		PCT/2Year for SAC
	TORI-BOSSITO	34/250	13.60 [7.59;19.61]		1PCT/2Year for SAC
	ZE	74/250	29.60 [21.60;37.6]		1PCT/2Year for SAC
		376/2000	18.80 [16.38;21.22]		
LITTORAL	COTONOU	5/250	2.00 [0.00;4.45]		No PCT
COUFFO	APLAHOUE	48/250	19.20 [12.30;26.10]	p < 0.001	1PCT/2Year for SAC
	DJAKOTOMEY	31/250	12.40 [6.62;18.18]		2PCT/2Year for SAC
	DOGBO	8/250	3.20 [0.11;6.29]		No PCT
	KLOUEKAME	62/250	24.80 [17.23;32.37]		1PCT/2Year for SAC
	LALO	48/250	19.20 [12.30;26.10]		1PCT/2Year for SAC
	TOVIKLIN	11/250	4.40 [0.80;8.00]		No PCT
		208/1,500	13.87 [11.39;16.34]		
MONO	ATHIEME	14/250	5.60 [1.57;9.63]	p < 0.001	1PCT/3Years for SAC
	BOPA	5/250	2.00 [0.00;4.45]		No PCT
	COME	6/250	2.40 [0.00;5.08]		No PCT
	GRAND POPO	9/250	3.60 [10.33.6.87]		No PCT
	HOUEYOGBE	30/250	12.00 [6.30;17.70]		1PCT/2Years for SAC
	LOKOSSA	56/250	22.40 [15.09;29.71]		1PCT/2Year for SAC
		120/1,500	8.00 [6.06;9.94]		
National prevalence		3,791/19,250	19.69 [18.90;20.49]		

100% to 59.60%, 48.44% to 31.60% and 45.24% to 16.40% respectively in Sô-Ava, Nikki and Pérérè districts. This decline in the infestation rate might be linked to the awareness of the population and the mass treatment of praziquantel campaigns organized in the municipalities. Meanwhile, the high rates of infestation in some departments could be explained by the fact that the majority of people living in these areas are in permanent contact with water bodies, regardless of the season. In this study, one district (Kpomassè) had no detected schistosomiasis infection during this survey. Although this observation is encouraging for the NTDs elimination, it is possible that the low sensitivity of the Kato-Katz method used in this survey might permitted the missing of submicroscopic schistosomiasis infections. Further studies using new generation diagnosis techniques such a point-of-care circulating cathodic antigen (POC−CCA), real-time polymerase chain reaction (real-time PCR), quantitative PCR (qPCR) and PCR-ELISA (Assaré et al., 2018; Clarke et al., 2018; Fuss et al., 2018; Senra et al., 2018) would provide better estimations of schistosomiasis infections in these low-endemicity settings.

4.2. Gender and schistosomiasis transmission

Our data suggest that boys might be more exposed to schistosomiasis infections compared to girls. However, this gender difference in schistosomiasis infection was statistically significant in only 3 out 12 departments (Alibori, Atacora and Couffo). The predominance of schistosomiasis infection in young boys living in these departments, could be explained by a greater mobility of this age group and their regular contact with water bodies lodging the freshwater snails through recreational activities. In the other hand, it is difficult to draw a countrywide gender-influenced difference in schistosomiasis infections, since in 9/12 (75%) departments the infection risk seemed similar for both boys and girls.

4.3. Limitations

Our study has few limitations. Firstly, our data were not suitable to conduct an analysis to establish associations between the prevalence of schistosomiasis infection and contact with potentially infected open water sources. Secondly, the prevalence of *Schistosoma* in other targeted populations such as adult populations and particularly in pregnant women and pre-school-age children (PSAC) and women of childbearing age (WCBA) has not been investigated. Such information would be useful to advise on schistosomiasis control, but they are not required for PCT control strategy according to WHO guidelines. Data shown in this report are therefore sufficient to justify treatment in these two additional population groups as well (WHO, 2006). Thirdly, only one sample was analyzed for each participant and may underestimate the reported prevalence. This is due to limited financial and human resources and the large number of samples to be processed, as the study was conducted on national scale. The daily variation in the detection of *Schistosoma* eggs (Tarafder et al., 2010), which may influence the prevalence estimates reported in this study, could not be considered. However, the selection of the study site (close to water bodies) could partially compensate for the single stool sample analysis. Fourthly, the burden of schistosomiasis infections on the Beninese population has not been addressed in the current study. Many studies conducted in Benin showed that helminth infections have many impacts on people living in the endemic areas like pregnant women and children (Mireku et al., 2015, 2018). Helminth infections have also been associated with poor cognitive development, gross motor outcomes in infants, maternal anemia in pregnant women (Van der Werf et al., 2003; Mpairwe et al., 2014; Ouédraogo et al., 2012; Mireku et al., 2015, 2018; Zida et al., 2016; Chalotte et al., 2017). According to recent reports, schistosomiasis could also be responsible for appendicitis and Gastric fundus splenosis with hemangioma masquerading as a gastrointestinal stromal tumor in patients (Bazongo et al., 2017; Guan et al., 2018).. PCT for schistosomiasis should be tailored to prevent sequelae and disabling consequences in these populations at risk. The schistosomiasis infections may cause not only maternal anemia but also affect infants' hemoglobin levels, their growth, their susceptibility to helminth infections, their cognitive development, their selective attention, their socioeconomic status, their physical fitness and their immunological responses to vaccination (Malhotra et al., 2015; Gall et al., 2017; Welch et al., 2017). In addition, *Schistosoma* co-infections with several pathogens like STH are frequent in many populations and represent further challenges both in the developing better diagnosis tools, and in controlling and eliminating many poverty-related infectious diseases.

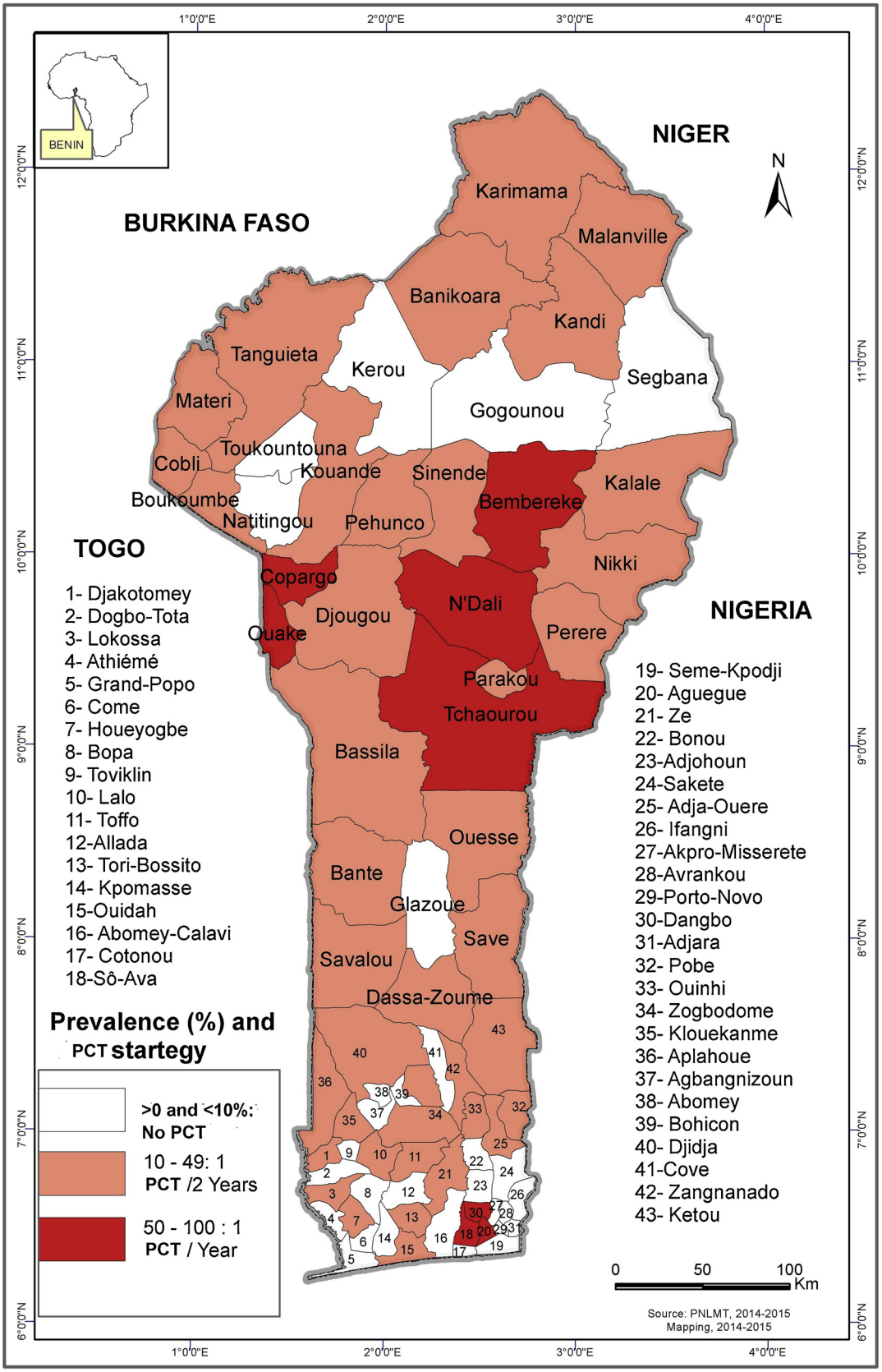

Fig. 3. Combined schistosomiasis distribution and PCT strategy.

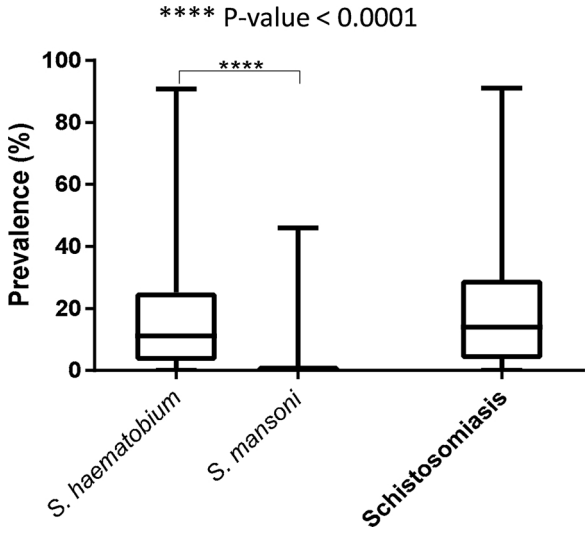

Fig. 4. Comparative analysis of national *S. haematobium* and *S. mansoni* prevalence.

Table 4
Relationship between gender and the prevalence of schistosomiasis.

Departments	Prevalence /sex		Z value	p value
	Girls	Boys		
Atacora (9)	9.51	11.20	−1.32	0.118
Donga (4)	38.80	35.40	−1.11	0.265
Borgou (8)	40.60	43.70	−1.40	0.160
Alibori (6)	**13.86**	**18.80**	**−2.59**	**0.010**
Collines (6)	**12.80**	**16.80**	**−2.18**	**0.029**
Zou (9)	13.51	11.82	1.20	0.228
Ouémé (9)	15.55	15.37	0.12	0.907
Plateau (5)	15.68	18.72	−1.43	0.154
Atlantique (8)	17.00	17.20	−1.12	0.905
Littoral (1)	1.60	2.40	−0.45	0.651
Couffo (6)	**10.40**	**15.75**	**−3.07**	**0.002**
Mono (6)	4.8	5.60	−0.70	0.485
National Prevalence	**16.82**	**18.29**	**−2.69**	**0.007**

5. Conclusion

The epidemiological data transmitted to the NPCDC of the Ministry of Health should allow the choice of strategy to control schistosomiasis infections in Benin. The current epidemiological data provided the initial state of endemicity for schistosomiasis and indicated districts in Benin that required PCT. These findings will support the NPCDC of the Ministry of Health to effectively implement the Strategic Plan for the elimination of NTD for the achievement of the Millennium Development Goals by 2020.

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Competing interests

The authors have declared that no competing interests exist

Author summary

Several countries in the African continent like Benin are recognized as endemic for schistosomiasis. From 2013–2015, the National Control Program for Communicable Diseases of Ministry of Health has conducted a national mapping of human schistosomiasis using Kato-Katz and urine filtration methods to assess the baseline epidemiological scale to all the 77 districts of Benin. The data generated would help to design and implement a control program by mass preventive chemotherapy (PCT) with praziquantel. The results of our surveys demonstrated that in 45 districts the combined prevalence of schistosomiasis infection was above 10% and therefore requiring PCT. *S. haematobium* was the most prevalent schistosome species compared to *S. mansoni* and boys were more infected than girls.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.actatropica.2019.01.004.

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