

TRSTMH

A pilot study using wearable global position system (GPS) data loggers to compare water contact levels: Schistosoma haematobium infection in pre-school-aged children (PSAC) and their mothers at Barombi Kotto, Cameroon

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1 **A pilot study using wearable global position system (GPS) dataloggers to compare water**
2 **contact levels: *Schistosoma haematobium* infection in pre-school-aged children (PSAC)**
3 **and their mothers at Barombi Kotto, Cameroon**

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14

15 **Abstract**

16 Barombi Kotto, Cameroon serves as a reference location for assessing intervention strategies
17 against *Schistosoma haematobium*. As part of a pilot study, the whole community was treated
18 with praziquantel, inclusive of pre-school-aged children (PSAC) and their mothers. One year
19 later egg-patent infections were reassessed and water contact patterns of 12 pairs of PSAC
20 and their mother were measured with global position system (GPS) dataloggers. A substantial
21 reduction in general infection prevalence, from 44.8% to 11.7 %, was observed but certain
22 PSAC and mothers continued to have egg-patent infections. Analysis of GPS data
23 demonstrated similar water contact levels between child and mother groups, although
24 certain individuals were numerical outliers. This study shows the potential of GPS dataloggers
25 to clarify the at-risk status of PSAC and mothers.

26

27 **Keywords**

28 Urogenital schistosomiasis, i-gotU, paediatric schistosomiasis, female genital
29 schistosomiasis, praziquantel

30 **Introduction**

31 Urogenital schistosomiasis is an important waterborne disease, caused by infection with the
32 blood fluke *Schistosoma haematobium*, and common in many parts of sub-Saharan Africa (1).
33 In Cameroon, for example, there is a national control programme active in the distribution of
34 praziquantel (PZQ) to school-aged children (SAC) (2, 3). However, in the move towards local
35 interruption of schistosome transmission, the programme is developing new tactics of control
36 (4) and has benefited from recent bilateral support from China in snail control and
37 environmental surveillance (5), as well as from UK to expand access of interventions (6).

38 Overlooked for too long, expanding access of PZQ to pre-school-aged children (PSAC)
39 and their mothers is attracting increasing attention (7, 8). It has been shown elsewhere that
40 these groups can be patently infected (9-12) and alongside SAC, may contribute towards
41 schistosome transmission but their water contact(s) is rarely measured and hence the role of
42 PSAC in sustaining local transmission remains speculative (13, 14). As a pilot investigation of
43 expanded access to praziquantel treatment, in June 2016 Campbell *et al.* undertook a detailed
44 cross-sectional epidemiological and malacological survey at Barombi Kotto, Cameroon (15).
45 Barombi Kotto is well-known crater lake and is of significant international interest as a
46 longstanding focus of urogenital schistosomiasis (16-18). Before treating all community
47 members with PZQ, Campbell *et al.* noted that a quarter of PSAC had egg-patent infections.
48 Furthermore, adult women had raised signs and symptoms of female genital schistosomiasis
49 (FGS), the latter is of growing international concern (13, 19). Environmental water contact is
50 very common across the community, for example, bathing, washing and other domestic
51 chores are typically performed on the immediate shoreline of the island while potable water
52 is collected in plastic containers from a local stream which is only accessible by canoe (15).
53 The level of environmental water contact, however, on the immediate lake shoreline of both
54 PSAC and their mothers remained to be determined and compared.

55 To shed fresh light on the at-risk status of PSAC and their mothers, using wearable
56 global position system (GPS) dataloggers, we attempted to measure and compare the water
57 contact patterns of PSAC and their mothers (20, 21). Furthermore, we hoped to pinpoint
58 water contact sites, measuring putative immersion times, on the Barombi Kotto crater lake
59 shoreline as baseline information for future interventions.

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Methods & Materials

Study location and parasitological examination

This parasitological resurvey and GPS study was conducted in June 2017 in the community on the central island of Barombi Kotto crater lake, where some 375 people are permanent residents. Study protocols were approved by the Liverpool School of Tropical Medicine Research Ethics Committee and the Cameroon National Ethical Committee of Research for Human Health. Participation involved obtaining written informed consent from mothers and their PSAC before deployment of the GPS datalogger. A total of 179 individuals (20 PSAC, 55 SAC and 104 adults) underwent a parasitological reinspection where each provided a 10ml urine sample which was filtered and stained with Lugol's iodine to visualise *S. haematobium* eggs by microscopy as described previously (15). All participants found infected with schistosomiasis were offered and observed to take praziquantel treatment (40 mg/kg)

Water exposure assessment

A subset of 12 mothers and PSAC pairs were randomly selected, then 6 pairs were assigned into two groups to wear the GPS dataloggers (i-gotU-120, Mobile Action, UK; dimension 44.5 x 28.5 x 13 mm, weight 20 g) over a 48-hour period on two occasions. The dataloggers were worn on the arm or wrist using a custom made elastic strap (20). The dataloggers were configured to record GPS location and velocity at 1 minute intervals during waking hours (05:00-21:00). Analysis of GPS data was conducted in QGIS (22) and filtered per the velocity filtering method (23). A zone was developed around the lakeshore of the island, 10m into the lake and 5m into the shore, a conservative assessment of the positional accuracy of the i-gotU-120 dataloggers based on previous observations (24). A water contact event was defined as a GPS location recording within a defined lakeshore geospatial buffer zone around the island circumference: a conservative assessment of the positional accuracy of the i-gotU dataloggers (24). As the GPS loggers recorded location at 1 minute intervals, each water contact event is analogous to 1 minute spent in the geospatial buffer zone and could be tallied and compared between individuals and groups.

94 **Statistical analysis**

95 Statistical analysis was performed using the R statistical software (25). Prevalence of
96 schistosomiasis was calculated with 95% binomial confidence intervals (95% CIs) with
97 correction for samples of $n < 30$. The track logs of each GPS unit were plotted and overlaid
98 against a base map of Barombi Kotto shoreline to identify travel patterns on and off the island.

99

100 **Results and Discussion**

101

102 *<please insert table 1 here>*

103

104 The characteristics of the study population and infection status is shown in Table 1. In June
105 2017, the overall prevalence of egg-patent infection was 11.7 % (95% CI 7.0 - 17.0) with only
106 1 infection of heavy intensity encountered albeit in a PSAC. The epidemiological survey
107 undertaken by Campbell *et al.* one year previously observed a much higher egg-patent
108 prevalence of 40.1% (24.6% in PSAC, 51.3% in SAC and 44.9% in adults). The overall reduction
109 across all demographic groups, see Table 1, is most likely due to the community-wide PZQ
110 treatment.

111

112 *<please insert Figure 1 here>*

113

114 Twelve PSAC and mother pairs were randomly selected and assigned into two groups
115 of 6 pairs, to wear the GPS dataloggers on two locations. In total, there were 3 individuals
116 with egg-patent infections (2 mothers and 1 PSAC) and their intensities of egg-patent
117 infections against the sampled population is shown in Figure 1A. The water contact levels of
118 the 12 mother and child pairs for the 48 hour period is shown in Figure 1B. This documents a
119 high level of water contact events (reaching up to 166 water contact events in 24 hours) in
120 both mothers and PSAC on the Barombi Kotto shoreline. As data points were recorded at 1
121 minute intervals, the number of water contact events can be interpreted as the time spent in
122 water contact which would likely positively correlate with actual bodily immersion or skin
123 contact with lake shore water.

124 The average number of water contact events in 24 hours were 27.4 [95% CIs: -1.3,
125 56.1] for mothers and 14.1 [95% CIs: 8.5 ,19.7] for PSAC, with no significant difference

126 between the two groups, Figure 1B. These findings have important implications in that water
127 contact levels of PSAC should not to be overlooked and follow similar levels to that observed
128 in Uganda (20). In Uganda PSAC were observed to spend on average half an hour on the
129 shoreline of Lake Albert and were clearly shown to be an at-risk vulnerable group not only to
130 first infection but also re-infection (10), as evidenced here in Barombi Kotto. Our study shows
131 the potential of GPS data logging technology to clarify their at-risk status which should assist
132 in better infection surveillance and control of urogenital schistosomiasis in general as well as
133 for regular access to treatment with the soon to be deployed paediatric PZQ formulation (12).

134 Upon more detailed inspection of individual water contact patterns, whilst our GPS
135 sample of two infected mothers (“M1”, “M2”) and one infected PSAC (“X4”) was too small to
136 determine a precise relationship between water exposure and infection status, two of these
137 individuals were clear numerical outliers in terms of their water contact(s) (4.6, 166.1, and
138 31.8 for “M1”, “M2” and “X4”, respectively). The latter two lying far outside the confidence
139 intervals for PSAC and mother averages. This demonstrates the importance of individual
140 variation in exposure and likely environmental contamination, Figure 1B. Indeed, it is very
141 plausible that the water contact behaviours of “M2” and “X4” could classify them as ‘raised-
142 spreaders’ who should be specifically targeted for increased frequency of treatment(s)
143 alongside behavioural change interventions. It remains to be seen if these individuals play
144 more pivotal roles than others in facilitating and sustaining local transmission of
145 schistosomes.

146 Another interesting facet revealed by the GPS dataloggers is the similar geospatial
147 pattern of water contact between the two groups which illustrate that PSAC frequently
148 accompany their mothers to the same locations, Figure C. This is also consistent with other
149 studies using questionnaires (13, 21). Furthermore, observed water contacts were largely co-
150 clustered on the South-West lakeshore of the island, notably an area where activities of the
151 3 infected cases were concentrated. Micro-spatial heterogeneity of schistosome transmission
152 has been described elsewhere (26, 27) and is further evidenced here, Figure 1D. In the future
153 context of interruption of schistosome transmission (14, 27), as a cost-effective measure, it
154 would be sensible to apply focal molluscicides at this location rather than elsewhere, to have
155 highest impact upon removal of infected snail hosts.

156 Our findings document that GPS dataloggers are an accepted method of measuring
157 water exposure in PSAC and their mothers and directly compare environmental risk of

158 schistosomiasis exposure. We suggest that in future the water contact levels of these two
159 demographic groups should further investigated. The wearable GPS technology is also of
160 value to identify putative transmission foci for spatial targeting of interventions.

161 **Authors Contributions**

162 JRS and MS conceived the study; GM, MS, LATT and JRS designed the study protocol; GM
163 carried out the field work; GM and MS carried out the analysis and interpretation of these
164 data. GM and JRS drafted the manuscript with LATT and MS critically revising. All authors read
165 and approved the final manuscript.

166

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174 fieldwork in Cameroon, as well as, the local community and field team volunteers at Barombi
175 Kotto.

176

177 **Competing interests**

178 None declared

179

180 **Ethical approval**

181 The study was approved by the Liverpool School of Tropical Medicine and the Cameroon
182 National Ethical Committee of Research for Human Health.

183

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272

273 **Figure Legend**

274 Figure 1. **A.** The *S. haematobium* egg count frequency for the 21 individuals found positive
 275 at the time of community resurvey; **B.** Plot of water contact events over 24 hour period for
 276 mothers (n=12) and PSAC (n=12), the black lines denote average with 95% CIs others for
 277 mothers [27.4 (-1.3, 56.1)] and PSAC [14.1 (8.6, 19.7)] since our sample size was < 30 instead
 278 of using the formula of 1.96*Standard error, 2.201*standard error (11 degrees of freedom)
 279 was used. No significant difference was found between water contact events for mother
 280 and children groups ($P = 0.34$, *paired t-test*) evidencing similar water contact levels; **C.** GPS
 281 co-ordinates of individuals over a 48-hour period stratified by *S. haematobium* infection
 282 status and age with different colours representing individuals: (i) not infected PSAC (n=11);
 283 (ii) infected PSAC (n=1); (iii) uninfected mothers (n=10); and (iv) infected mothers (n=2). The

284 *S. haematobium* infected mothers (M1 and M2) and child (X4) from the GPS study are
285 identified in plots A and B.
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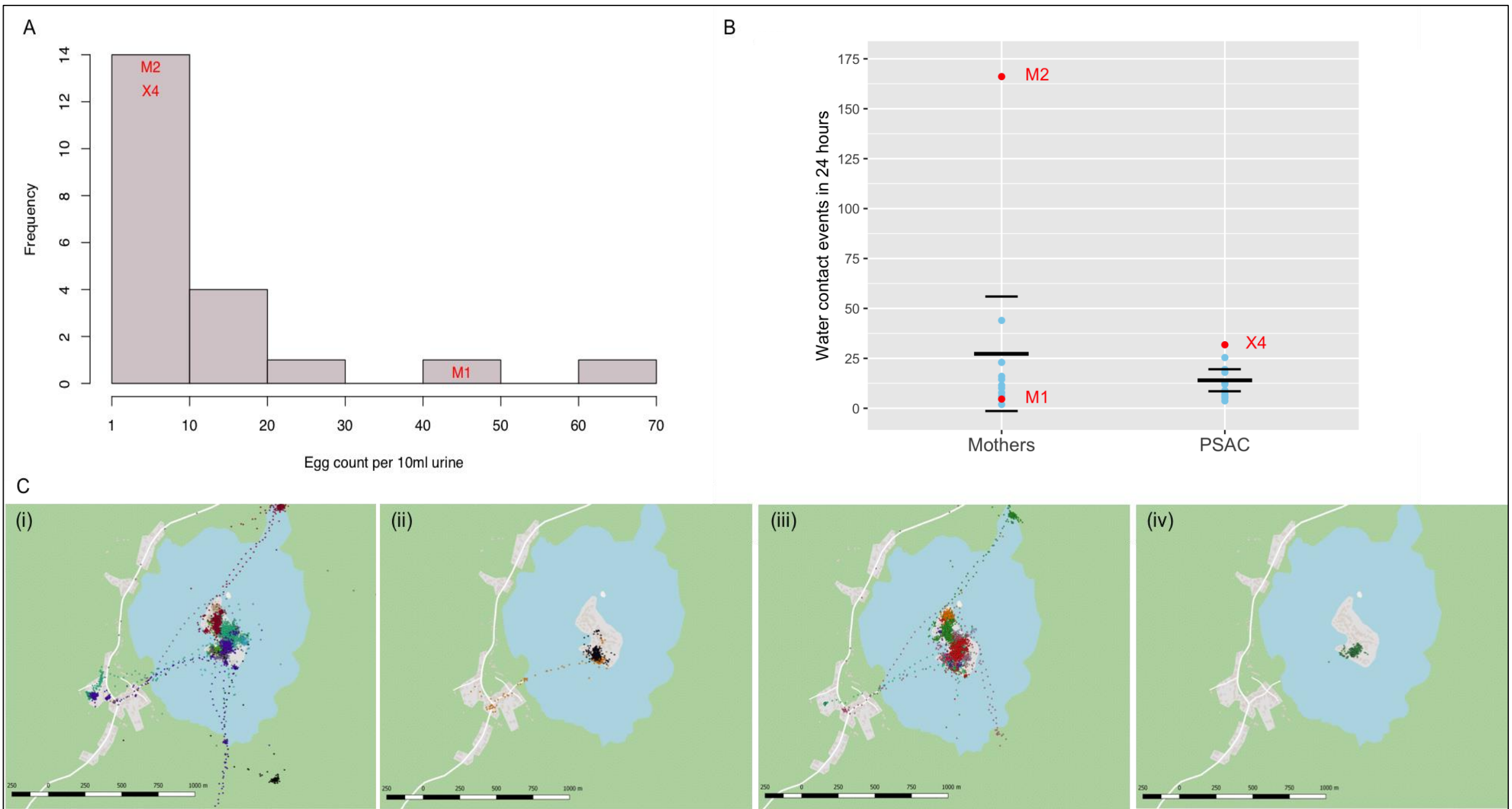


Table 1. Characteristics of individuals enrolled in community-wide parasitological survey ($n = 179$) and subset of mother and PSAC pairs in GPS water-exposure study ($n = 24$).

Characteristic	Total	PSAC	SAC	Adults	P-value ^b
Community baseline demographics					
Number of individuals	180	21	55	104	
Female, n (%)	102 (57.3)	11 (52.4)	32 (60.4)	59 (56.7)	0.808
Age, mean(range) (years)	26.0 (1-84)	3.48 (1-6)	11.51 (7-16)	38.15 (17-84)	<0.001
Community parasitology					
<i>S. haematobium</i> positive, n (%)	22 (12.2)	2 (9.5)	7 (12.7)	13 (12.5)	0.922
[95% CI]	[7.8, 17.9]	[1.2, 30.4] ^c	[5.3, 24.5]	[6.8, 20.4]	
Infection intensity, n (%)					
No eggs	158 (87.8)	19 (90.5)	48 (87.3)	91 (87.5)	0.073
1-50 eggs/10ml	21 (11.7)	1 (4.8)	7 (12.7)	13 (12.5)	
>50 eggs/10ml	1 (0.6)	1 (4.8)	0 (0.0)	0 (0.0)	
Mother and PSAC pair baseline demographics					
Number of individuals	24	12		12	
Female, n (%)	20(83.3%)	8 (66.6)		12 (100.0)	0.1
Age, mean (range) (years)	16.23 (0.5-52)	2.62 (0.5-6)		29.83 (20-52)	<0.001
Mother and PSAC pair parasitology					
<i>S. haematobium</i> positive, n (%)	3 (12.5)	1 (8.3)		2 (16.7)	1
[95% CI]	[2.7, 32.4]	[0.2, 38.5]		[2.1, 48.4]	

^a Determined by filtration and microscopy egg-detection in 10ml urine sample.

^b P value is the difference between groups by Fisher exact test or Student's t test.

^cLightly infected PSAC was from GPS study ("X4") and the heavily infected PSAC was from the community cohort (male, aged 4 years).

Thank you for considering our manuscript and allowing us to respond to the referees. Please find our comments/amendments below.

Reviewer #1:

This manuscript illustrates the use of GPS data loggers to measure rates of contact with water bodies among pre-school age children and their mothers in a Cameroonian community where schistosomiasis is endemic. This is a useful method for quantifying potential exposure to schistosomes and it should certainly be adopted more widely to better understand exposure among different demographic groups and to better understand individual exposure heterogeneity. This makes the pilot study interesting, primarily from a methodological standpoint. However, because this is a pilot with a small sample size (24 individuals) and no comparator groups, the results are fundamentally fairly limited in scope and some of the interpretation of the data and subsequent conclusions are overstated. The paper needs to better reflect that this is an illustrative pilot of how GPS dataloggers can be used to quantify contact patterns with water bodies (likely related of exposure to schistosomes) and temper some of the excessively strong conclusions.

Thank you for the comments we have toned down excessively strong conclusions with modifications throughout and drawn attention to the novelty of the GPS methodology.

Specific comments are below:

1) Abstract, line 24, "In future, PSAC and mothers should be included in both surveillance and control interventions for urogenital schistosomiasis in general." This strong conclusion is not reflective of the data generated from this pilot study. Only the water contact patterns of 12 PSAC and 12 mothers were measured, with no comparator groups from other population demographics. It is not surprising that "...certain individuals had substantive water contact" (line 23). The most appropriate demographic group(s) for surveillance and targeting for the control or elimination of schistosomiasis depends on the relative contact patterns and contributions to transmission among demographic groups. For example, it is quite conceivable that school-age children (SAC) have greater potential exposure (water contact) to schistosomes than PSAC or mothers - in which case they may be the best target group for surveillance (and control). There is a perfectly reasonable debate on whether targeting only SAC is sufficient to control or eliminate schistosomiasis but, in the absence of comparator demographic groups, the data presented here do not provide substantive evidence either way. It cannot be concluded that because water contacts are identified among PSAC and mothers they should necessarily be targeted above other demographic groups for surveillance and control.

In this study we did not have comparator groups across major demographical groups but in a previous study in East Africa we did (see Seto et al. Patterns of intestinal schistosomiasis among mothers and young children from Lake Albert, Uganda: water contact and social networks inferred from wearable global positioning system dataloggers. Geospatial Health 2012;7(1):1-13). In this study we recorded levels for PSAS, SAC, Mothers and Adult Men and also showed that the water contact levels of PSAC and SAC were similar but at different times of the day. More broadly although there is about twofold less water contact per day at Barombi Kotto

(Cameroon) than in Bugoigo (Uganda), the relative level of water contact in PSAC to mothers shows that they are similar as well (i.e. no significant difference). We have modified the text to discuss this point a bit more.

2) Materials & Methods, line 70, "6 pairs were assigned into two groups to wear GPS dataloggers...". The rationale for dividing the PSAC-mother pairs into two groups is not very clear. Could the Authors give some more detail on this?

This was due to limited number of data loggers (only 13 working loggers in the field due to technical issues with computer-iGOTU interface). We therefore had to use them in 2 rotations, each time using 12 individuals/loggers, which was sufficient to get a snap shot but of course if we had more loggers or greater time in the field we would have collected additional information..

3) Results and Discussion, line 117, "They should be routinely included in disease surveillance and considered for regular treatment with the soon to be deployed paediatric PZQ formulation (12)." This interpretation is beyond the scope of the presented data. The rationale for interventions to target SAC (and omit PSAC and adults) is not based on a presumption that PSAC are unexposed to infection. Rather, it is because SAC tend to harbor the bulk of the parasite population and thus contribute the most to transmission (it is also logistically efficient to reach them through the schools infrastructure). The idea is that the wider population will be protected from infection by the disproportionate reductions in transmission that are achieved by targeting SAC and thus, ultimately, that the disease will be controlled (or eliminated) without requiring community-wide. Whether this approach is best suited to meet current control and elimination goals is actively debated, and there are certainly strong arguments that PSAC and adults should be included in treatment programmes. But the water contact data presented here do not particularly support this argument, especially since only 1/20 PSAC was found to be infected. Again, just because PSAC and mothers are contacting water bodies does not necessarily mean that they are particularly important drivers of transmission or have a higher risk of infection than other demographic groups. To make this conclusion, one would need contact data from the wider population.

Agreed, we have toned down this but called for further studies in other countries to quantify these levels and also assess roles in transmission. This is perhaps more important in locations that are striving for elimination and any infected case that contaminates the environment should be managed.

4) Results and Discussion, line 121, "these individuals are clear outliers in their level of water contact (4.6, 166.1, and 31.8 for "M1", "M2", and "X1" [sic], respectively)." Looking at the box and whisker plot in Figure 1, panel B, it is clear that only M2 is an obvious outlier. It is perhaps also worth the Authors commenting on the low egg count in individual M2 despite the high contact with water. I assume that the quoted "X1" individual is a typographical error and the Authors mean "X4" (as identified in Figure 1)?

We have redrawn this part of the figure with a new plot.

1. Yes typo – should be "X4"

2. Outliers –M1 and X4 both are outside the 95% confidence intervals for the mean water contact for mothers and PSAC, respectively. However, the current box and whisker plot show quantiles – and only M1 is an outlier of the 75% quantiles – the revised plot depicts the mean and 95% Cis, with M1 and X4 shown as outliers.

5) Results and Discussion, line 131, "Another interesting facet revealed by the GPS dataloggers is the similar geospatial pattern of water contact between the two groups which illustrate that PSAC frequently accompany their mothers to the same locations..." Would the Authors not expect that PSAC would frequently accompany their mothers to the same locations? This result seems more confirmatory of a priori expectations than anything else.

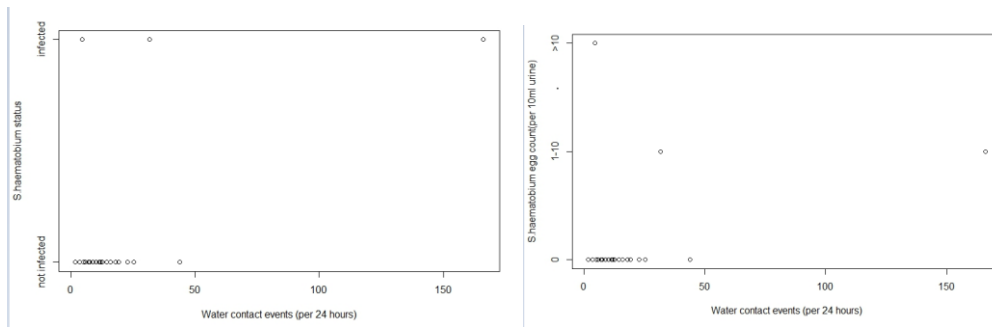
It depends on the mother child pair and likely the location and the chore/tasks they are doing. For example, it is not uncommon for children from different guardians to intermingle such that the exact spatial relationship between pairs is 'scrambled'. It does not appear to be so in this instance so is worth a comment.

6) Results and Discussion, line 137, "as a cost-effective measure, it would be sensible to apply focal molluscicides at this location rather than elsewhere, to have highest impact upon removal of infected snail hosts". This is an interesting idea, but again, I feel that this statement should be phrased in a more circumspect manner. Whether such an approach would be cost-effective would depend on a number of factors, including the cost of identifying likely sites of exposure prior to treatment (compared to a more blanket mollusciciding approach) and the infection level of snails in these locations compared to other locations (that are perhaps more frequented by other demographic groups).

We have amended the text and we simply wished to raise the importance of these data with speculation for better targeting of control in future. With the China-Africa initiative, focal mollusciciding is being promoted. It would be a good idea to help synergise these efforts to maximise their impact on the ground.

7) It would be interesting for the Authors to present the water contact data plotted against the parasitological data to explore any relationship. I appreciate that the small sample size will make strong statistical associations unlikely, but the information would still be of interest to the reader.

We have conducted plots as suggested (see below) but the relationship is not so clear hence we prefer to use the revised Figure B plot. The LHS plot is binary plot of infection with water contact, then the RHS plot is intensity of infection with water contact. As the referee suggests if we have more infected cases (6-10 perhaps) it might have made the relationship a bit clearer.



Reviewer #2:

This is an interesting paper.

The importance of including PSAC and their mothers in control efforts seems clear.

Also the use of the datalogger seems an asset, although some issues need clarification.

Some more info on the epidemiology would be useful. Are they waterpumps and pit latrines on the island or on the shore? Are people aware of the risk of contracting schisto, i.e. has health education been given? What do people do for a living? Figure C seems to suggest that people cross the lake to and from the island. Is crossing the lake to the shore a daily activity and for what purpose? Do they wade through the water or, this being a crater lake, is it too deep and do they use boats? How is this counted in terms of exposure?

Thank you for these insights, these are good questions and we have put some background information in the discussion to give a better local insight into the participant activities.

The section on water exposure measurement does not read well.

It would be good if you could explain the accuracy of the measurement better as the number of watercontacts seems very high; on average 27 in 24 hours (in fact between 05:00 and 21:00). How do you know if people are on the beach/shore along the shoreline, or actually in the water? What is the actual time spent during these watercontacts (give range for example); and to what activities do they correspond (for PASC more obvious - playing probably- than for the mothers).

Referring methods we have changed.

A zone was developed around the lakeshore of the island, 10m into the lake and 5m into the shore, a conservative assessment of the positional accuracy of the i-gotU-120 data loggers based on previous observations (24). A water contact event was defined as a GPS location recording within a defined lakeshore geospatial buffer zone around the island circumference: a conservative assessment of the positional accuracy of the i-gotU data loggers (24). As the GPS loggers recorded location at 1 minute intervals, each water contact

event is analogous to 1 minute spent in the geospatial buffer zone and could be tallied and compared between individuals and groups.

1 **A pilot study using wearable global position system (GPS) data loggers to compare water**
2 **contact levels-patterns: *Schistosoma haematobium* infection in pre-school-aged children**
3 **(PSAC) and their mothers at Barombi Kotto, Cameroon**

4
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14
15 **Abstract**

16 Barombi Kotto, Cameroon serves as a reference location for assessing intervention strategies
17 against *Schistosoma haematobium*. As part of a pilot study, the whole community was treated
18 with praziquantel, inclusive of pre-school-aged children (PSAC) and their mothers. One year
19 later egg-patent infections were reassessed and water contact patterns of 12 pairs of PSAC
20 and their mother were measured with global position system (GPS) dataloggers. A substantial
21 reduction in general infection prevalence, from 44.8% to 11.7 %, was observed but certain
22 PSAC and mothers continued to have egg-patent infections. Analysis of GPS data
23 demonstrated similar water contact levels between child and mother groups, although
24 certain individuals were numerical outliers. This study shows the potential of GPS dataloggers
25 to clarify the at-risk status of PSAC and mothers.

26 ~~Barombi Kotto, Cameroon serves as a reference location for assessing intervention strategies~~
27 ~~against *Schistosoma haematobium*. As part of a pilot study, the whole community was treated~~
28 ~~with praziquantel, inclusive of pre-school-aged children (PSAC) and their mothers. One year~~
29 ~~later egg-patent infections were reassessed and water contact patterns of 12 pairs of PSAC~~
30 ~~and their mother were measured with wearable global position system (GPS) dataloggers.~~
31 ~~The cross-sectional resurvey revealed a substantial reduction in general prevalence, from~~
32 ~~44.8% to 11.7 %, but PSAC continued to be infected. Analysis of GPS data demonstrated the~~

33 ~~similar at risk status of child and mother groups, with certain individuals having substantive~~
34 ~~water contact. In future, PSAC and mothers should be included in both surveillance and~~
35 ~~control interventions for urogenital schistosomiasis in general.~~

36

37 **Keywords**

38 Urogenital schistosomiasis, ~~i-gotU, environmental epidemiology~~, paediatric schistosomiasis,
39 female genital schistosomiasis, praziquantel

40 **Introduction**

41 Urogenital schistosomiasis is an important waterborne disease, caused by infection with the
42 blood fluke *Schistosoma haematobium*, and common in many parts of sub-Saharan Africa (1).
43 In Cameroon, for example, there is a national control programme active in the distribution of
44 praziquantel (PZQ) to school-aged children (SAC) (2, 3). However, in the move towards local
45 interruption of schistosome transmission, the programme is developing new tactics of control
46 (4) and has benefited from recent bilateral support from China in snail control and
47 environmental surveillance (5), as well as from UK to expand access of interventions (6).

48 Overlooked for too long, expanding access of PZQ to pre-school-aged children (PSAC)
49 and their mothers is attracting increasing attention (7, 8). It has been shown elsewhere that
50 these groups can be patently infected (9-12) and alongside SAC, may contribute towards
51 schistosome transmission ~~but-but~~ their water contact(s) is rarely measured and hence the
52 role of PSAC in sustaining local transmission remains speculative (13, 14). As a pilot
53 investigation of expanded access to praziquantel treatment, in June 2016 Campbell *et al.*
54 undertook a detailed cross-sectional epidemiological and malacological survey at Barombi
55 Kotto, Cameroon (15). Barombi Kotto is well-known crater lake and is of significant
56 international interest as a longstanding focus of urogenital schistosomiasis (16-18). Before
57 treating all community members with PZQ, Campbell *et al.* noted that a quarter of PSAC had
58 egg-patent infections. ~~Furthermore, and~~ adult women had raised signs and symptoms of
59 female genital schistosomiasis (FGS), the latter is of growing international concern (13, 19).
60 Environmental water contact is very common across the community, for example, bathing,
61 washing and other domestic chores are typically performed on the immediate shoreline of
62 the island while potable water is collected from a local stream which is only accessible by
63 canoe (15). The water contact levels of both PSAC and their mothers, however, remained to
64 be determined and compared.

65 To shed fresh light on the at-risk status of PSAC and their mothers, using wearable
66 global position system (GPS) data loggers, we attempted to measure and compare the water
67 contact patterns of PSAC and their mothers (20, 21). Furthermore, we hoped to pinpoint
68 water contact sites, ~~and~~ measuring putative immersion times, on the Barombi Kotto crater
69 lake shoreline as baseline information for future interventions.

70

71

72 **Methods & Materials**

73 **Study location and parasitological examination**

74 This parasitological resurvey and GPS study was conducted in June 2017 in the community on
75 the central island of Barombi Kotto crater lake, where some 375 people are permanent
76 residents. Study protocols were approved by the Liverpool School of Tropical Medicine
77 Research Ethics Committee and the Cameroon National Ethical Committee of Research for
78 Human Health. Participation involved obtaining written informed consent from mothers and
79 their PSAC before deployment of the GPS datalogger. A total of 179 individuals (20 PSAC, 55
80 SAC and 104 adults) underwent a parasitological reinspection where each provided a 10ml
81 urine sample which was filtered and stained with Lugol's iodine to visualise *S. haematobium*
82 eggs by microscopy as described previously (15). All participants found infected with
83 schistosomiasis were offered and observed to take praziquantel treatment (40 mg/kg)

84

85 **Water exposure assessment**

86 A subset of 12 mothers and PSAC pairs were randomly selected, then 6 pairs were assigned
87 into two groups to wear the GPS dataloggers (i-gotUGOTU-120, Mobile Action, UK; dimension
88 44.5 x 28.5 x 13 mm, weight 20 g) over a 48-hour period on two occasions. The dataloggers
89 were worn on the arm or wrist using a custom made elastic strap (20). The dataloggers were
90 configured to record GPS location and velocity at 1_-minute intervals during waking hours
91 (05:00-21:00). Analysis of GPS data was conducted in QGIS (22) and filtered per the velocity
92 filtering method (23). ~~A zone was developed around the lakeshore of the island, 10m into the~~
93 ~~lake and 5m into the shore, a conservative assessment of the positional accuracy of the i-~~
94 ~~GOTU-120 data loggers based on previous observations (24). To quantify water contact~~
95 ~~events a cumulative total was calculated based on the 1 minute interval recording, for~~
96 ~~example, each water contact event is analogous to 1 minute spent in the geospatial buffer~~
97 ~~zone. A zone was developed around the lakeshore of the island, 10m into the lake and 5m~~
98 ~~into the shore, a conservative assessment of the positional accuracy of the i-gotU-120 data~~
99 ~~loggers based on previous observations (24). A water contact event was defined as a GPS~~
100 ~~location recording within a defined lakeshore geospatial buffer zone around the island~~
101 ~~circumference: a conservative assessment of the positional accuracy of the i-gotU data~~
102 ~~loggers (24). As the GPS loggers recorded location at 1 minute intervals, each water contact~~

103 event is analogous to 1 minute spent in the geospatial buffer zone and could be tallied and
104 compared between individuals and groups.

106 **Statistical analysis**

107 Statistical analysis was performed using the R statistical software (25). Prevalence of
108 schistosomiasis was calculated with 95% binomial confidence intervals (95% CIs) with
109 correction for samples of n < 30. The track logs of each GPS unit were plotted and overlaid
110 against a base map of Barombi Kotto shoreline to identify travel patterns on and off the island.

112 **Results and Discussion**

114 *<please insert table 1 here>*

116 The characteristics of the study population and infection status is shown in Table 1. In June
117 2017, the overall prevalence of egg-patent infection was 11.7 % (95% CI 7.0 - 17.0) with only
118 1 infection of heavy intensity encountered albeit in a PSAC. The epidemiological survey
119 undertaken by Campbell *et al.* one year previously observed a much higher egg-patent
120 prevalence of 40.1% (24.6% in PSAC, 51.3% in SAC and 44.9 in adults). The overall reduction
121 across all demographic groups, see Table 1, is most likely due to the community-wide PZQ
122 treatment.

124 *<please insert Figure 1 here>*

126 Twelve PSAC and mother pairs were randomly selected and assigned into two groups
127 of 6 pairs, to wear the GPS dataloggers on two locations. In total, there were 3 individuals
128 with egg-patent infections (2 mothers and 1 PSAC) and their intensities of egg-patent
129 infections against the sampled population is shown in Figure 1A. The water contact levels of
130 the 12 mother and child pairs for the 48 hour period is shown in Figure 1B. This documents a
131 high level of water contact events (reaching up to 166 water contact events in 24 hours) in
132 both mothers and PSAC on the Barombi Kotto shoreline. As data points were recorded at
133 one minute intervals, the number of water contact events can be interpreted as the time

134 spent in water contact which would likely positively correlate with actual bodily immersion or
135 skin contact with lake shore water.

136 The average number of water contact events in 24 hours were 27.4 [95% CIs: ~~-1.83,~~
137 ~~526.91~~] for mothers and 14.1 [95% CIs: ~~89.25~~, ~~19.47~~] for PSAC, with no significant difference
138 between the two groups, Figure 1B. These findings have important implications in that water
139 contact levels of PSAC ~~are-should~~ not to be overlooked and follow similar levels to that
140 observed in Uganda (20). ~~In Uganda PSAC were observed to spend on average half an hour~~
141 ~~on the shoreline of Lake Albert and were clearly shown to be making them a provenan~~ at-risk
142 vulnerable group ~~not only~~ to first infection ~~but also and~~ in this instance, ~~as evidenced here in~~
143 ~~Barombi Kotto~~, re-infection (10). ~~Our study shows the potential of GPS data logging~~
144 ~~technology to clarify their at-risk status which should assist in better infection surveillance~~
145 ~~and control of urogenital schistosomiasis in general as well as~~ ~~They should be routinely~~
146 ~~included in disease surveillance and considered~~ for regular ~~access to~~ treatment with the soon
147 to be deployed paediatric PZQ formulation (12).

148
149 Upon more detailed inspection of individual water contact patterns, whilst our GPS
150 sample of two infected mothers ("M1", "M2") and one infected PSAC ("X4") was too small to
151 determine a precise relationship between water exposure and infection status, these
152 individuals ~~we~~ are clear ~~numerical~~ outliers in their level of water contact (4.6, 166.1, and 31.8
153 for "M1", "M2" and "X4", respectively). The the latter two lying far outside the confidence
154 intervals for PSAC and mother averages, and demonstrates the importance of individual
155 variation in exposure and likely contamination, Figure 1B. Indeed, it is very plausible that the
156 water contact behaviours of "M2" and "X4" ~~could might~~ classify them as 'raised-spreaders'
157 who should be specifically targeted for increased frequency of treatment(s) ~~alongside and~~
158 behavioural change interventions. ~~It remains to be seen, especially~~ if these individuals ~~y~~ play
159 more pivotal roles than others in facilitating ~~and sustaining~~ local transmission ~~of~~
160 ~~schistosomes~~.

161 Another interesting facet revealed by the GPS dataloggers is the similar geospatial
162 pattern of water contact between the two groups which illustrate that PSAC frequently
163 accompany their mothers to the same locations, Figure C. This is also consistent with other
164 studies using questionnaires (13, 21). Furthermore, observed water contacts were largely co-
165 clustered on the South-West lakeshore of the island, notably an area where activities of the

166 3 infected cases were concentrated. Micro-spatial heterogeneity of schistosome transmission
167 has been described elsewhere (26, 27) and is further evidenced here, Figure 1D. In the future
168 context of interruption of schistosome transmission (14, 27), as a cost-effective measure, it
169 would be sensible to apply focal molluscicides at this location rather than elsewhere, to have
170 highest impact upon removal of infected snail hosts.

171 Our findings document that GPS dataloggers are an accepted method of measuring
172 water exposure in PSAC and their mothers and directly compare environmental risk of
173 schistosomiasis exposure. We suggest that in future the water contact levels of these two
174 demographic groups should ~~be integrated into control strategies for elimination in Cameroon~~
175 ~~and elsewhere~~ further investigated. The wearable GPS technology is also of value to identify
176 putative transmission foci for spatial targeting of interventions.

177

178 **Authors Contributions**

179 JRS and MS conceived the study; GM, MS, LATT and JRS designed the study protocol; GM
180 carried out the field work; GM and MS carried out the analysis and interpretation of these
181 data. GM and JRS drafted the manuscript with LATT and MS critically revising. All authors read
182 and approved the final manuscript.

183

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191 fieldwork in Cameroon, as well as, the local community and field team volunteers at Barombi
192 Kotto.

193

194 **Competing interests**

195 None declared

196

197 **Ethical approval**

198 The study was approved by the Liverpool School of Tropical Medicine and the Cameroon
199 National Ethical Committee of Research for Human Health.

200

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289

290 **Figure Legend**

291 Figure 1. **A.** The *S. haematobium* egg count frequency for the 21 individuals found positive
292 at the time of community resurvey; **B.** Plot of water contact events over 24 hour period for
293 mothers (n=12) and PSAC (n=12), the black lines denote average with 95% CIs others for
294 mothers [27.4 (-1.3, 56.1)] and PSAC [14.1 (8.6, 19.7)] since our sample size was < 30 instead
295 of using the formula of 1.96*Standard error 2.201*standard error (11 degrees of freedom)
296 was used. Box and whisker plot of the number of water contact events in 24 hours, for
297 mothers (n=12) and PSAC (n=12). No significant difference was found between water
298 contact events for mother and children groups ($P = 0.34$, *paired t-test*) evidencing similar
299 water contact levels; **C.** GPS co-ordinates of individuals over a 48-hour period stratified by *S.*
300 *haematobium* infection status and age with different colours representing individuals: (i)
301 not infected PSAC (n=11); (ii) infected PSAC (n=1); (iii) uninfected mothers (n=10); and (iv)
302 infected mothers (n=2). The *S. haematobium* infected mothers (M1 and M2) and child (X4)
303 from the GPS study are identified in plots A and B.
304

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**Department of Parasitology
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4/3/2018

Dear Jonathan,

Please accept my best wishes, and I trust all is well with the RSTM&H journals.

You may be aware I used to be the Honorary Scientific Secretary of the RSTM&H and have taken an active interest in both journals for many years and have published there since 1995.

Most recently we were delighted with our report in the *Transactions*, see Al-Shehri (2016) (RSTM&H) in 2016 and I now have a short paper of sufficient interest to the readership which I would like you to consider.

Our paper is entitled “**Using global position system (GPS) data loggers to compare water contact patterns: *Schistosoma haematobium* infection in pre-school-aged children (PSAC) and their mothers at Barambi Kotto, Cameroon**”. The work has international value as it looks at two neglected groups in schistosomiasis control – pre-school-aged children and their mothers – as well as implements a novel approach using GPS dataloggers.

The first author Grace Macklin is a hardworking PhD student; she also presented her findings at last year’s RIP meeting. After December, I have worked with Grace and the author team to shape her findings into a solid manuscript.

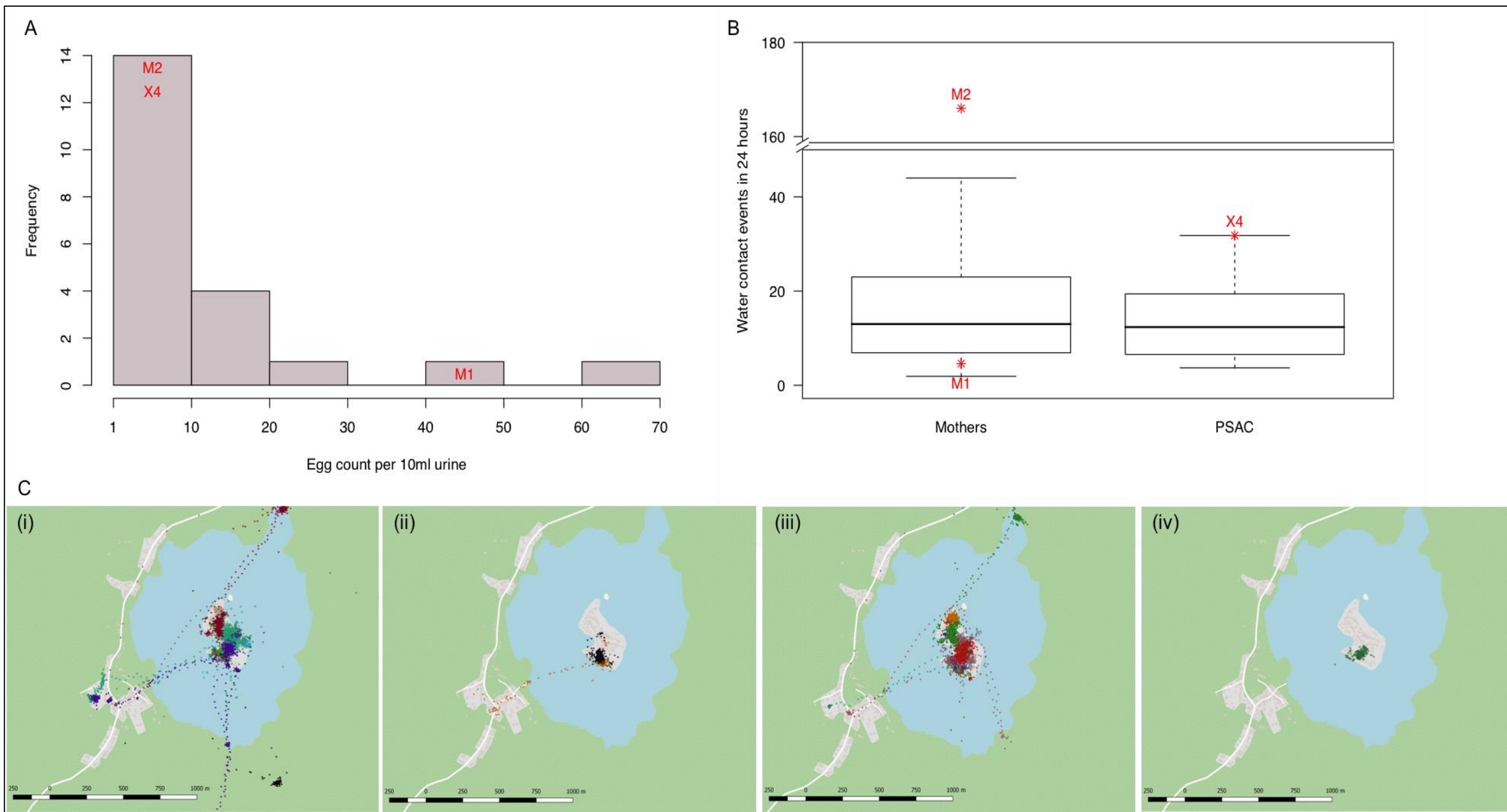
Our manuscript should attract attention not only from those in schistosomiasis control (and paediatric praziquantel initiative) but also has a broader appeal those interested in geospatial epidemiology. The latter has much further application in recording at-risk status of individuals where there is a strong spatial location of transmission.

I look forward to hearing for you and our work has a favourable appraisal. I would recommend the following referees: Professor Clive Shiff (JHSPH); Professor Joanne Webster (RVC); Dr Amadou Garba (WHO); Dr Mark Booth (University of Newcastle).

A handwritten signature in blue ink, appearing to read 'Russell Stothard', enclosed in a light blue rectangular box.

Professor J.R. Stothard

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1 **Using global position system (GPS) data loggers to compare water contact patterns:**
2 ***Schistosoma haematobium* infection in pre-school-aged children (PSAC) and their mothers**
3 **at Barombi Kotto, Cameroon**

4
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14

15 **Abstract**

16 Barombi Kotto, Cameroon serves as a reference location for assessing intervention strategies
17 against *Schistosoma haematobium*. As part of a pilot study, the whole community was treated
18 with praziquantel, inclusive of pre-school-aged children (PSAC) and their mothers. One year
19 later egg-patent infections were reassessed and water contact patterns of 12 pairs of PSAC
20 and their mother were measured with wearable global position system (GPS) dataloggers.
21 The cross-sectional resurvey revealed a substantial reduction in general prevalence, from
22 44.8% to 11.7 %, but PSAC continued to be infected. Analysis of GPS data demonstrated the
23 similar at-risk status of child and mother groups, with certain individuals having substantive
24 water contact. In future, PSAC and mothers should be included in both surveillance and
25 control interventions for urogenital schistosomiasis in general.

26

27 **Keywords**

28 Urogenital schistosomiasis, environmental epidemiology, paediatric schistosomiasis, female
29 genital schistosomiasis, praziquantel

30 **Introduction**

31 Urogenital schistosomiasis is an important waterborne disease, caused by infection with the
32 blood fluke *Schistosoma haematobium*, and common in many parts of sub-Saharan Africa (1).
33 In Cameroon, for example, there is a national control programme active in the distribution of
34 praziquantel (PZQ) to school-aged children (SAC) (2, 3). However, in the move towards local
35 interruption of schistosome transmission, the programme is developing new tactics of control
36 (4) and has benefited from recent bilateral support from China in snail control and
37 environmental surveillance (5) as well as from UK to expand access of interventions (6).

38 Overlooked for too long, expanding access of PZQ to pre-school-aged children (PSAC)
39 and their mothers is attracting increasing attention (7, 8). It has been shown elsewhere that
40 these groups can be patent infected (9-12) and alongside SAC, may contribute towards
41 schistosome transmission but their water contact(s) is rarely measured (13, 14). As a pilot
42 investigation of expanded access to praziquantel treatment, in June 2016 Campbell *et al.*
43 undertook a detailed cross-sectional epidemiological and malacological survey at Barombi
44 Kotto, Cameroon (15). Barombi Kotto is well-known crater lake and is of significant
45 international interest as a longstanding focus of urogenital schistosomiasis (16-18). Before
46 treating all community members with PZQ, Campbell *et al.* noted that a quarter of PSAC had
47 egg-patent infections and adult women had raised signs and symptoms of female genital
48 schistosomiasis (FGS), the latter is of growing international concern (13, 19). The water
49 contact levels of PSAC and their mothers, however, remained to be determined.

50 To shed fresh light on the at-risk status of PSAC and their mothers, using wearable
51 global position system (GPS) data loggers, we attempted to measure the water contact
52 patterns of PSAC and their mothers (20, 21). Furthermore, we hoped to pinpoint water
53 contact sites and measure putative immersion times on the Barombi Kotto crater lake
54 shoreline as baseline information for future interventions.

55

56 **Methods & Materials**

57 **Study location and parasitological examination**

58 This parasitological resurvey and GPS study was conducted in June 2017 in the community on
59 the central island of Barombi Kotto crater lake, where some 375 people are permanent
60 residents. Study protocols were approved by the Liverpool School of Tropical Medicine
61 Research Ethics Committee and the Cameroon National Ethical Committee of Research for

62 Human Health. Participation involved obtaining written informed consent from mothers and
63 their PSAC before deployment of the GPS datalogger. A total of 179 individuals (20 PSAC, 55
64 SAC and 104 adults) underwent a parasitological reinspection where each provided a 10ml
65 urine sample which was filtered and stained with Lugol's iodine to visualise *S. haematobium*
66 eggs by microscopy as described previously (15). All participants found infected with
67 schistosomiasis were offered and observed to take praziquantel treatment (40 mg/kg)

68

69 **Water exposure assessment**

70 A subset of 12 mothers and PSAC pairs were randomly selected, then 6 pairs were assigned
71 into two groups to wear the GPS dataloggers (i-GOTU-120, Mobile Action, UK; dimension 44.5
72 x 28.5 x 13 mm, weight 20 g) over a 48-hour period on two occasions. The dataloggers were
73 worn on the arm or wrist using a custom made elastic strap (20). The dataloggers were
74 configured to record GPS location and velocity at 1 minute intervals during waking hours
75 (05:00-21:00). Analysis of GPS data was conducted in QGIS (22) and filtered per the velocity
76 filtering method (23). A zone was developed around the lakeshore of the island, 10m into the
77 lake and 5m into the shore, a conservative assessment of the positional accuracy of the i-
78 GOTU-120 data loggers based on previous observations (24). To quantify water contact
79 events a cumulative total was calculated based on the 1 minute interval recording, for
80 example, each water contact event is analogous to 1 minute spent in the geospatial buffer
81 zone.

82

83 **Statistical analysis**

84 Statistical analysis was performed using the R statistical software (25). Prevalence of
85 schistosomiasis was calculated with 95% binomial confidence intervals. The track logs of each
86 GPS unit were plotted and overlaid against a base map of Barombi Kotto shoreline.

87

88 **Results and Discussion**

89

90 *<please insert table 1 here>*

91

92 The characteristics of the study population and infection status is shown in Table 1. In June
93 2017, the overall prevalence of egg-patent infection was 11.7 % (95% CI 7.0 - 17.0) with only

94 1 infection of heavy intensity encountered albeit in a PSAC. The epidemiological survey
95 undertaken by Campbell *et al.* one year previously observed a much higher egg-patent
96 prevalence of 40.1% (24.6% in PSAC, 51.3% in SAC and 44.9 in adults). The overall reduction
97 across all demographic groups, see Table 1, is most likely due to the community-wide PZQ
98 treatment.

99

100 **<please insert Figure 1 here>**

101

102 Twelve PSAC and mother pairs were randomly selected and assigned into two groups
103 of 6 pairs, to wear the GPS dataloggers on two locations. In total, there were 3 individuals
104 with egg-patent infections (2 mothers and 1 PSAC) and their intensities of egg-patent
105 infections against the sampled population is shown in Figure 1A. The water contact levels of
106 the 12 mother and child pairs for the 48 hour period is shown in Figure 1B. This documents a
107 high level of water contact events (reaching up to 166 water contact events in 24 hours) in
108 both mothers and PSAC on the Barombi Kotto shoreline. As data points were recorded at one
109 minute intervals, the number of water contact events can be interpreted as the time spent in
110 water contact which would likely positively correlate with actual bodily immersion or skin
111 contact with lake shore water.

112 The average number of water contact events in 24 hours were 27.4 [95% CIs: 1.8, 52.9]
113 for mothers and 14.1 [95% CIs: 9.2 ,19.1] for PSAC, with no significant difference between the
114 two groups, Figure 1B. These findings have important implications in that water contact levels
115 of PSAC are not to be overlooked and follow similar levels to that observed in Uganda (20)
116 making them a proven at-risk vulnerable group to infection and in this instance re-infection
117 (10). They should be routinely included in disease surveillance and considered for regular
118 treatment with the soon to be deployed paediatric PZQ formulation (12).

119 Upon more detailed inspection of individual water contact patterns, whilst our GPS
120 sample of two infected mothers (“M1”, “M2”) and one infected PSAC (“X4”) was too small to
121 determine a precise relationship between water exposure and infection status, these
122 individuals are clear outliers in their level of water contact (4.6, 166.1, and 31.8 for “M1”,
123 “M2” and “X1”, respectively). The the latter two lying far outside the confidence intervals for
124 PSAC and mother averages, and demonstrates the importance of individual variation in
125 exposure and likely contamination, Figure 1B. Indeed, it is very plausible that the water

126 contact behaviours of “M2” and “X4” might classify them as ‘raised-spreaders’ who should be
127 specifically targeted for increased frequency of treatment(s) and behavioural change
128 interventions, especially if they play more pivotal roles than others in facilitating local
129 transmission.

130 Another interesting facet revealed by the GPS dataloggers is the similar geospatial
131 pattern of water contact between the two groups which illustrate that PSAC frequently
132 accompany their mothers to the same locations, Figure C. This is also consistent with other
133 studies using questionnaires (13, 21). Furthermore, observed water contacts were largely co-
134 clustered on the South-West lakeshore of the island, notably an area where activities of the
135 3 infected cases were concentrated. Micro-spatial heterogeneity of schistosome transmission
136 has been described elsewhere (26, 27) and is further evidenced here, Figure 1D. In the future
137 context of interruption of schistosome transmission (14, 27), as a cost-effective measure, it
138 would be sensible to apply focal molluscicides at this location rather than elsewhere, to have
139 highest impact upon removal of infected snail hosts.

140 Our findings document that GPS dataloggers are an accepted method of measuring
141 water exposure in PSAC and their mothers and directly compare environmental risk of
142 schistosomiasis exposure. We suggest that these two demographic groups should be
143 integrated into control strategies for elimination in Cameroon and elsewhere. The GPS
144 technology is also of value to identify putative transmission foci for spatial targeting of
145 interventions.

146

147 **Authors Contributions**

148 JRS and MS conceived the study; GM, MS, LATT and JRS designed the study protocol; GM
149 carried out the field work; GM and MS carried out the analysis and interpretation of these
150 data. GM and JRS drafted the manuscript with LATT and MS critically revising. All authors read
151 and approved the final manuscript.

152

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157 The funders had no role in study design, decision to publish, or preparation of the manuscript.

158 **Acknowledgments**

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160 fieldwork in Cameroon, as well as, the local community and field team volunteers at Barombi
161 Kotto.

162

163 **Competing interests**

164 None declared

165

166 **Ethical approval**

167 The study was approved by the Liverpool School of Tropical Medicine and the Cameroon
168 National Ethical Committee of Research for Human Health.

169

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258

259 **Figure Legend**

260 Figure 1. **A.** The *S. haematobium* egg count frequency for the 21 individuals found positive
261 at the time of community resurvey; **B.** Box and whisker plot of the number of water contact
262 events in 24 hours, for mothers (n=12) and PSAC (n=12). No significant difference was found
263 between mother and children groups ($P = 0.34$, *paired t-test*); **C.** GPS co-ordinates of
264 individuals over a 48-hour period stratified by *S. haematobium* infection status and age with
265 different colours representing individuals: (i) not infected PSAC (n=11); (ii) infected PSAC
266 (n=1); (iii) uninfected mothers (n=10); and (iv) infected mothers (n=2). The *S. haematobium*
267 infected mothers (M1 and M2) and child (X4) from the GPS study are identified in plots A
268 and B.

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272

Table 1. Characteristics of individuals enrolled in community-wide parasitological survey ($n = 179$) and subset of mother and PSAC pairs in GPS water-exposure study ($n = 24$).

Characteristic	Total	PSAC	SAC	Adults	P-value ^b
Community baseline demographics					
Number of individuals	179	20	55	104	
Female, n (%)	101 (57.1)	10 (50.0)	32 (60.4)	59 (56.7)	0.723
Age, mean(range) (years)	26.1 (1-84)	3.50 (1-6)	11.51 (7-16)	38.15 (17-84)	<0.001
Community parasitology					
<i>S. haematobium</i> positive, n (%)	21 (11.7)	1 (5.0)	7 (12.7)	13 (12.5)	0.610
[95% CI]	[0.07, 0.17]	[0.001, 0.25]	[0.05, 0.24]	[0.07, 0.20]	
Infection intensity, n (%)					
No eggs	158 (88.3)	19 (95.0)	48 (87.3)	91 (87.5)	0.032
1-50 eggs/10ml	20 (11.0)	0 (0.0)	7 (12.7)	13 (12.5)	
>50 eggs/10ml	1 (0.5)	1 (5.0)	0 (0.0)	0 (0.0)	
Mother and PSAC pair baseline demographics					
Number of individuals	24	12		12	
Female, n (%)	20(83.3%)	8 (66.6)		12 (100.0)	0.1
Age, mean (range) (years)	16.23 (0.5-52)	2.62 (0.5-6)		29.83 (20-52)	<0.001
Mother and PSAC pair parasitology					
<i>S. haematobium</i> positive, n (%)	3	1 (8.3)		2 (16.7)	1
[95% CI]		[0.002, 0.38]		[0.02, 0.48]	

^a Determined by filtration and microscopy egg-detection in 10ml urine sample.

^b P value is the difference between groups by Fisher exact test or Student's t test.