Public health policy pillars for the sustainable elimination of zoonotic schistosomiasis

Eva Janoušková [1,*], **Jessica Clark** [2,3], **Olumayowa Kajero** [1], **Sergi Alonso** [2,3], **Poppy H. L. Lamberton** [2,3], **Martha Betson** [1] **and Joaquín M. Prada** [1]

[1] *School of Veterinary Medicine, University of Surrey, Guildford, United Kingdom*
[2] *Institute of Biodiversity, Animal Health and Comparative Medicine, University of Glasgow, Glasgow, United Kingdom*
[3] *Wellcome Centre for Integrative Parasitology, University of Glasgow, Glasgow, United Kingdom*

Correspondence*:
Eva Janoušková
e.janouskova@surrey.ac.uk

Article type: Perspective

Number of words in the abstract: 223 of 250

Number of words in the main text: 2,997 of 3,000

Number of figures: 1

Number of tables: 0

Language: British English

ABSTRACT

Schistosomiasis is a parasitic disease acquired through contact with contaminated freshwater. The definitive hosts are terrestrial mammals, including humans, with some *Schistosoma* species crossing the animal-human boundary through zoonotic transmission. An estimated 12 million people live at risk of zoonotic schistosomiasis caused by *Schistosoma japonicum* and *Schistosoma mekongi*, largely in the World Health Organization's Western Pacific Region and in Indonesia. Mathematical models have played a vital role in our understanding of the biology, transmission, and impact of intervention strategies, however, these have mostly focused on non-zoonotic *Schistosoma* species. Whilst these non-zoonotic-based models capture some aspects of zoonotic schistosomiasis transmission dynamics, the commonly-used frameworks are yet to adequately capture the complex epi-ecology of multi-host zoonotic transmission. However, overcoming these knowledge gaps goes beyond transmission dynamics modelling. To improve model utility and enhance zoonotic schistosomiasis control programmes, we highlight three pillars that we believe are vital to sustainable interventions at the implementation (community) and policy-level, and discuss the pillars in the context of a One-Health approach, recognising the interconnection between humans, animals and their shared environment. These pillars are: (1) human and animal epi-ecological understanding; (2) economic considerations (such as treatment costs and animal losses); and (3) sociological understanding, including inter- and intra-human and animal interactions. These pillars must be built on a strong foundation of trust, support and commitment of stakeholders and involved institutions.

Keywords: *Schistosoma japonicum*, *Schistosoma mekongi*, NTD, epidemiology, economics, sociology, mathematical modelling, zoonotic transmission

1   INTRODUCTION

Neglected Tropical Diseases (NTDs) predominantly affect communities in low- and middle-income countries and impose a significant human, economic and social burden, thus perpetuating a cycle of poverty. Schistosomiasis is caused by infection with parasitic worms of the genus *Schistosoma*. An estimated 240 million people are infected[1] and the disease is classified by the World Health Organization (WHO) as an NTD. The main *Schistosoma* species responsible for human disease are *Schistosoma haematobium*, causing urogenital disease, and *S. mansoni*, *S. japonicum*, and *S. mekongi* causing intestinal disease. They differ in geographical distribution and host species they infect. *Schistosoma haematobium* and *S. mansoni* mainly infect humans as the definitive host. *Schistosoma japonicum* (found in the Philippines, China and Indonesia), and *S. mekongi* (Cambodia and Laos) use human and non-human mammals as definitive hosts, driving zoonotic transmission. Over 12 million people are estimated at risk of zoonotic infection in Asia with three million requiring treatment. Though vital to transmission, the number of animals at risk is generally not reported[2] (1). The life-cycle of zoonotic schistosomes is maintained by human and animal contact with contaminated freshwater sources, where the intermediate hosts (species-specific freshwater snails) are present, and where the access to safe water and sanitation is limited (Figure 1). Infections can occur through recreational, habitual and employment activities of humans, and watering or grazing of animals. Human intestinal schistosomiasis symptoms range from abdominal pain, diarrhoea, blood in the stool, to liver and spleen enlargement, cancers and death (2). There is a dearth of data regarding the clinical impact of *S. japonicum* and *S. mekongi* in animals.

In January 2021, schistosomiasis was targeted for elimination as a public-health problem (EPHP) globally in the WHO's *Road map for neglected tropical diseases 2021-2030* (3). This is achieved when the proportion of heavy intensity infections (over 400 eggs per gram of stool by Kato-Katz diagnostic) is reduced below 1% (3). The cornerstone of schistosomiasis control in endemic areas is preventive chemotherapy with the anthelmintic praziquantel. However, drug treatment alone is likely insufficient to reach elimination goals since only a few infected individuals can maintain the transmission cycle (4). Significant gains towards *S. japonicum* elimination have been achieved with integrated intervention approaches (including preventive and selective chemotherapy, mollusciciding, health-education, sanitation and environmental improvement) in countries such as China. Although transmission was interrupted in some provinces for over 10 years, other provinces remained endemic, and re-emergence has recently been observed (5, 6, 7, 1). Progress towards elimination seems to be slowing, with transmission still ongoing in many regions, and zoonotic schistosomiasis remains a public-health problem, particularly in the Philippines (8).

Efforts have been largely concentrated on the more common non-zoonotic schistosomiasis. Data needs have been reviewed for various NTDs (9) and models have been successfully used to inform control strategies (10, 11). Nevertheless, zoonotic schistosomes pose a unique challenge to achieving EPHP as multiple definitive host species contribute to transmission dynamics (12). The complexity of zoonotic schistosomiasis must be captured by these models if they are to continue playing a major role in public-health policy. Data on animal reservoirs need to be collected along with data on humans to adequately calibrate the models. Historical and current modelling approaches to capture the dynamics of schistosomes

---

[1] Who.int. 2021. Schistosomiasis. [online] Available at: `https://www.who.int/news-room/fact-sheets/detail/schistosomiasis` [Accessed 27 November 2021].

[2] Who.int. 2021. Preventive chemotherapy (PC) data portal [online] Available at: `https://www.who.int/GlobalHealthObservatory` [Accessed 27 November 2021].

67 and zoonotic transmission are reviewed elsewhere (8). Here we discuss the challenges of collecting and
68 analysing data and developing models to inform control programmes, and how a One-Health approach,
69 recognising the interconnection between people, animals, and their shared environment (13), can improve
70 them. Our vision builds on three cross-cutting pillars that are vital to sustainable public-health policy: (1)
71 understanding epidemiology; (2) economic considerations; and (3) accounting for sociological aspects. All
72 pillars must stand on a strong foundation of trust and support, requiring involvement and commitment of
73 stakeholders and other involved institutions (14). We illustrate the three pillars framework for building a
74 sustainable control programme in the context of zoonotic schistosomiasis EPHP, where animal reservoirs'
75 contribution to transmission accompanies all pillars. Nevertheless, this framework can be applied to
76 improve public-health policy across diseases.

Adapted from graphic development by SCI foundation,
originally adapted from illustration by Genome Research Limited.
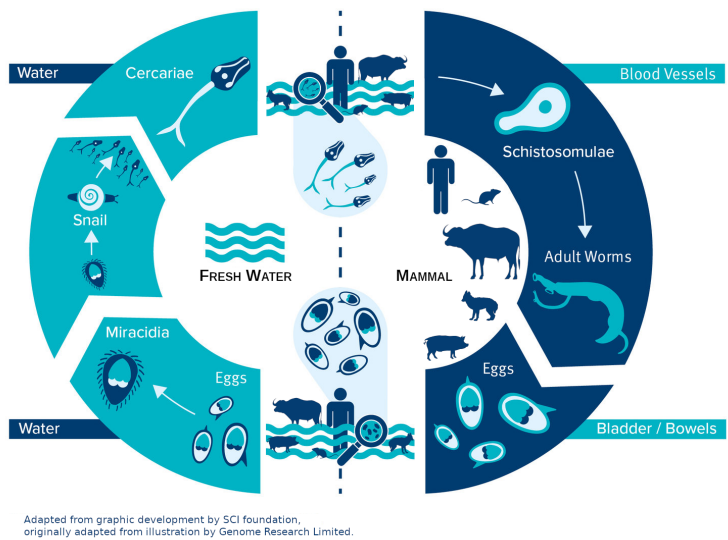
Figure 1. Life cycle of *S. japonicum* and *S. mekongi*. An infected definitive host, a mammal, passes
schistosome eggs through the faeces into freshwater. The eggs may hatch into free-swimming larval
miracidia that infect intermediate hosts, freshwater snails. After multiplication and development, snails
shed free-swimming cercariae daily. The cercariae penetrate the skin of a mammal which comes in contact
with water. Within the mammal, the cercariae shed their forked tail to form schistosomulae which mature
and become worms. Paired male and female adult worms copulate and migrate to the mesenteric venules of
the bowel and/or rectum where they lay thousands of eggs a day. Some of the eggs get back into the water
through faeces and start the life cycle again, while some eggs get trapped in the organs causing disease
symptoms.

2   PILLAR I: EPIDEMIOLOGY

77 This first pillar encompasses our understanding of the disease in its geographical context, including
78 environmental drivers, host heterogeneity, parasite interactions and intervention efficacy, derived from
79 a combination of epidemiological data (parasitological, surveys, etc.) and analyses. Prior to data
80 collection, mathematical modelling can inform on optimal study sample sizes, sampling frequencies,
81 and target participant groups necessary to accurately estimate parameters (15). Next, in collaboration
82 with stakeholders, optimal and accepted epidemiological and biological data collection can be undertaken
83 (16, 17, 18). To complete the understanding of disease transmission dynamics and to predict impacts of
84 interventions, mathematical models calibrated to, and informed by, available data provide quantitative

85 evidence, capable of informing both clinical trials and the final implementation of large-scale interventions,
86 thus making these critical aspects of disease control more ethical and effective in the long-term. Model
87 parameters and assumptions are based on field data, guided by stakeholder knowledge, in turn determining
88 model quality (9).

89   Mathematical models have informed intervention programmes and played a vital role in informing the
90 WHO's roadmap for NTDs 2021-2030 (19, 11). Model development and the coordination of necessary data
91 collection should be conducted in consultation with stakeholders, who are ideally placed to understand and
92 advise on local situations, expectations of modelled outputs, and optimal methods for data collection (14).
93 Ensuring that modelling results are interpreted correctly, and that strengths and limitations of the models
94 are recognised, requires communication at several structural levels. Introductory and follow-up meetings
95 with institutions involved in policy decision-making, and discussions with stakeholders at community,
96 district and national level (14) will result in the strongest interventions. Analyses focused exclusively on
97 this first pillar can identify the most effective strategies to achieve a target health outcome and determine
98 timelines for achieving them (20, 21, 22, 23).

99   It is widely acknowledged that to provide relevant insights, data quantity and quality needs to be improved
100 (24). Specific data needs for some NTDs, including schistosomiasis, are reviewed elsewhere (9). The
101 need for community-wide data is recognised, in particular, age-infection intensity profiles from adults –
102 hindered because most studies focus on school-aged children. Low sensitivity and questionable specificities
103 of available diagnostic tools (e.g. Kato-Katz and antigen-based diagnostics) also pose a challenge to data
104 quality (25, 26). This becomes a greater problem as infection intensities are reduced after decades of
105 preventive chemotherapy, further reducing the proportion of infections detected when egg-based diagnostics
106 are the norm. Regarding interventions, if not applied yet, the lack of data can be overcome by making
107 suggestions either based on data from different locations, or based on current interventions and expertise
108 assumptions from stakeholders increasing uncertainty of modelled results. Many infection and population
109 characteristics which influence disease transmission, such as present prevalence, age-intensity distributions,
110 community- and age-contact rates and transmission rates, vary spatially. Therefore, studies mapping the
111 spatial distribution in endemic areas need to be performed (27, 28, 29, 30, 31, 32). Furthermore, some
112 biological aspects of infection and hosts cannot be, or are difficult to be, measured. For example, it is still
113 not known what the dominant mechanism is behind age-intensity distribution – age-dependent water contact
114 rate, acquired immunity, worm density dependence, concomitant immunity or (likely) some combination.
115 These unknown aspects must be further explored (33, 34, 35, 36, 37).

116   Zoonotic transmission makes data collection and analyses more complicated. When human and animal
117 data are collected independently, it becomes harder to consolidate and unify, hindering calibration and
118 evaluation of multiple-host models. As highlighted by the WHO, providing centralised data access will
119 facilitate understanding, expediting analyses and consequently the decision-making process (3). An example
120 of this is the Pan-African Rabies Control Network, which established a platform for centralised rabies data
121 collection and analysis, with an option for open data sharing (38, 39). We see opportunity in extending such
122 a framework to other zoonotic diseases across a wider geographic area. Mapping the spatial distribution can
123 help to identify locations and groups where efforts should be concentrated to prevent infection, improve
124 interventions and increase coordinated communication across veterinary and human health teams (40).

125   In communities where zoonotic schistosomiasis is endemic, livestock can be a major asset, residing
126 closely with owners. However, this also fosters an environment where domestic animals can be responsible
127 for a considerable amount of transmission to humans (41, 4). Infection dynamics in these systems with
128 multiple hosts differ significantly from single-host systems, and are more complex to model with greater

129 data requirements. Transmission rates vary across definitive host species, which can be due to differing
130 behaviour like water contact, driving diversity in exposure and contamination rates. Similarly, each
131 definitive host species will have different epidemiological characteristics in terms of recovery, birth, and
132 mortality rates. Capturing definitive host heterogeneities in disease dynamic processes translates to more
133 accurately predicting higher prevalences and intensities of infection (42, 43). Additionally, estimating the
134 contribution of each definitive host species to parasite transmission is vital (19, 13).

135 The best combination of interventions is expected to vary spatially according to animal host species'
136 densities. For example, in China, attention had initially been exclusively on bovines, because historically,
137 most of the research was conducted in lake areas where bovines were ubiquitous (44, 41, 45, 46). It is
138 known today that rodent species are the main animal hosts of *S. japonicum* in mountainous provinces,
139 whilst bovines drive infection around the lakes (47, 4, 48, 49). To understand how to manage multi-host
140 zoonotic systems, it is crucial to determine prevalence in animals and identify location-specific dominant
141 animal reservoirs (50). Quantifying each host's contribution to transmission enables identification of
142 maintenance and essential hosts, and the predicted impacts of control strategies targeting these hosts
143 (51, 52, 53, 54, 55). Human-only treatment for schistosomaisis is insufficient to achieve EPHP in some
144 settings because transmission is maintained by untreated reservoirs. Alternatively, interventions focused
145 on the main reservoir predict success in reducing transmission to humans (4, 46, 49). Other work has
146 explored the possible impact of a range of animal- and environment-focused controls (56, 46, 55). Different
147 modelling approaches for the dynamics of intestinal helminths, including schistosomes and zoonotic
148 transmission are reviewed elsewhere (8).

3   PILLAR II: ECONOMICS

149 The second pillar accounts for the economic implications of, in this case, different interventions to achieve
150 EPHP. Primarily, a centralised data collection and analysis platform similar to that described above could
151 reduce costs, as similar data needs across NTDs facilitate cross-cutting data collection and treatment
152 activities (9). Furthermore, for an effective intervention strategy to be feasible, it must be affordable to
153 individuals, governments and/or donors in addition to biologically effective. This includes the generally
154 high upfront start-up investment, as well as recurrent maintenance costs. A useful economic evaluation
155 approach is cost-effectiveness analysis, where costs and non-monetary health effects of different control
156 interventions can be compared (57). Results are expressed as additional costs per unit of improved health
157 outcome, such as reduction in transmission rate, prevalence/incidence, or deaths (58). The communication
158 of results to policy-makers is key, as sometimes the most effective intervention for reducing disease might
159 not be cost-effective (14). Cost-effective analysis has already been used for numerous NTDs and can
160 be integrated into detailed infection transmission models. In the context of zoonotic diseases such as
161 *S. japonicum* and *S. mekongi*, it should be leveraged to explore the costs and effectiveness of animal-
162 based and other combined interventions (59). The costs to be considered include expected resources
163 used for implementing and eventually maintaining an intervention, including the net savings to patients
164 and healthcare providers due to reducing the disease burden (57). Savings comprise out-of-pocket and
165 health system expenses, travel costs of care-seeking and opportunity costs of ill health, such as reduced
166 patient productivity or school and work attendance, which are unfortunately often overlooked. In zoonotic
167 schistosomiasis, additional costs are incurred due to animal death or illness, which adds time and cost to
168 replace animals, as well as reduced livestock productivity (60).

169 One challenge remains regarding the appropriate metric to use for health outcomes that is generalizable.
170 Disability-adjusted life-years (DALYs) are widely used to measure disease burden, with one DALY

171 representing the loss of one life-year lived in optimal health, thereby translating both disease mortality
172 (the years of life lost, YLL), and morbidity (the years lived with disability, YLD) into a single metric
173 (61, 62). This enables comparison across studies, settings, and interventions targeting the same or different
174 diseases (58). However, DALYs face some limitations, as they frequently disregard the infection-associated
175 mental health burden or the need to adjust for co-morbidities. To estimate morbidity, DALYs rely on
176 general estimates of disability weights – most of them estimated by an expert medical panel, instead of a
177 preference-based valuation method, raising universality concerns (63). This leads to the health impacts of
178 infection being underestimated. Lastly, DALYs are unsuitable when evaluating zoonotic diseases because
179 they disregard effectiveness resulting from improving animals' and owners' quality of life and well-being
180 due to averted animal morbidity/mortality. Efforts have been made to quantify the zoonosis burden on
181 humans and animals simultaneously – zoonosis disability-adjusted life-years (zDALYs) (64). These include
182 an additional component called animal loss equivalents, which converts expected livestock production and
183 local per capita income losses to the equivalent number of human YLD. Nevertheless, this metric has been
184 rarely used in cost-effectiveness analyses of zoonotic diseases (65, 66), and only once for schistosomiasis
185 (67).

186 Most economic evaluations of schistosomiasis interventions have focused on chemotherapy with
187 praziquantel (68, 69, 70). The WHO NTD roadmap has highlighted the benefits, including financial,
188 of cross-cutting interventions (3). However, the use of different effectiveness measures (i.e. health
189 outcomes) for evaluation of new control interventions hampers comparison within and between NTDs
190 (71, 72). Standardising the use of a common metric across economic analyses will enable cost-effectiveness
191 comparisons across multiple NTDs and beyond. Such metrics should be extendable, as appropriate to
192 zoonotic diseases. Programmes that consider the first and second pillars together are more sustainable, as
193 knowledge of the most effective interventions from an epidemiological perspective can be supplemented
194 by evaluations of their economic impact and the time horizon for cost benefits.

4   PILLAR III: SOCIOLOGY

195 The third pillar acknowledges the impact of human behaviour on intervention outcomes. This is most
196 commonly considered in the context of adherence, referring to how individuals interact with a given
197 intervention. For example, when offered medication, whether a person will ingest it or not, in the context
198 of animal treatment, whether an owner gives the drug to the animal – an important differentiation between
199 treatment coverage and treatment compliance (73, 36). If enough individuals do not adhere to control
200 measures, effectiveness at population levels can be lower than predicted. This can lead to failure in meeting
201 targets like EPHP and/or increases in intervention costs, which could change the cost-effectiveness of the
202 programme. Indeed, numerous studies across diseases (not just NTDs) suggest that it is not realistic to
203 expect full compliance with any control measure (74, 75, 76, 77, 78). Intervention strategies can be better
204 informed when models explicitly account for inconsistent adherers (79, 36).

205 Assessing the impact of novel interventions in a given location can be challenging when the social
206 determinants of participation are unknown. The WHO has suggested that Water, Sanitation, and Hygiene
207 (WaSH) methods should be incorporated into NTD control programmes (3). This will be crucial in the
208 context of zoonotic schistosomiasis where efficacy of WaSH interventions can be strongly affected by
209 non-compliance because very few individuals (human or animal) are required to maintain transmission.
210 Modelling the impacts of WaSH interventions is not novel for non-NTDs (80, 81, 82) or NTDs (83). Existing
211 studies focused on WaSH interventions to control schistosomiasis have been reviewed (84), and new studies
212 have been performed (85) or are currently ongoing (86). Interventions that include participatory processes

213 are more likely to be successful as people are more interested and perceive responsibility/ownership for the
214 outcomes of the control programmes (87, 3, 88). Pre-intervention consultations with communities may help
215 identify challenges in intervention design that can be addressed. For example, lack of clarity of ownership
216 and maintenance obligations were reported as reasons to limit or halt usage of unmaintained boreholes
217 (89). Quantification of preferences for different WaSH interventions can be obtained using discrete
218 choice experiments (DCE) which enable the comparison of preferences for WaSH and health-education
219 interventions, considering monetary and non-monetary costs (90). Health-education interventions can help
220 people understand the transmission cycle, including animal contribution, and increase their perception
221 of the disease threat, thus improving the adherence to WaSH and other interventions (90). Interventions
222 informed by DCEs in areas endemic for zoonotic schistosomiasis will need to include preferences for
223 animal-related interventions. The outcome of a strategy built on these pillars will provide more robust,
224 sustainable policy recommendations.

5   DISCUSSION

225 Sustainability has been discussed in many fields, and always encompasses three pillars, environmental,
226 economic, and social. Here, we have linked these three pillars in the context of NTDs, for the purpose
227 of informing sustainable global-health policy. This is of particular importance for zoonotic NTDs (e.g.
228 schistosomiasis caused by *S. japonicum* and *S. mekongi*), where the interconnection between people,
229 animals, and their shared environment should be recognised – emphasising the importance of a One-Health
230 approach. For the first pillar, epidemiology, we focus on definitive host heterogeneity and quantifying
231 their contribution to overall transmission, enabling us to inform optimal intervention strategies and
232 timelines to programmatic targets. Epidemiological understanding will be strengthened through access to
233 improved cross-disease data. The second pillar, economics, can inform interventions by accounting for
234 costs to all stakeholders involved and the time horizon for cost benefits. Challenges remain in establishing a
235 standardised metric for cost-effectiveness evaluation that is appropriate for zoonotic diseases. The third, and
236 last, pillar, sociology, considers the impact of human behaviour – particularly adherence – on programmatic
237 success. A strong foundation of stakeholder engagement and commitment is needed from scientists across
238 disciplines, politicians, and public-health experts. Only by combining these three pillars and commitment
239 of all involved, can the best strategies to achieve the desired target health outcomes be developed, whilst
240 considering costs, that will be championed by relevant stakeholders approved by local communities. The
241 modelling community may use these recommendations to make the model predictions more accurate,
242 assisting decision-makers to design sustainable control programmes to reach the WHO's ambitious 2030
243 goal.

CONFLICT OF INTEREST STATEMENT

244 The authors declare that the research was conducted in the absence of any commercial or financial
245 relationships that could be construed as a potential conflict of interest.

AUTHOR CONTRIBUTIONS

246 E. J. and J. M. P. conceived the study. E. J., J. C., O. K. wrote the original draft. All authors critically
247 reviewed and edited the manuscript. J. M. P. provided overall supervision of the project.

FUNDING

248 This work was supported by the European Research Council (starting grant SCHISTO_PERSIST_680088
249 awarded to P. H. L. L., supporting J. C.); Wellcome Trust (grant 204820/Z/16/Z awarded to P. H. L. L.,
250 supporting J. C.); the Engineering and Physical Sciences Research Council (grant EP/T003618/1 to P. H. L.
251 L., J. M. P., supporting E. J. and S. A.); the Drugs for Neglected Diseases Initiative (grant awarded to P. H.
252 L. L., supporting J. C.); the Medical Research Council (grant MR/P025447/1 to P. H. L. L., supporting J. C.)
253 and the Newton Fund awarded through the Medical Research Council (MRC; grant number MR/R025592/1
254 to O. K., M. B. and J. M. P.).

REFERENCES

255 **1** .Gordon CA, Kurscheid J, Williams GM, Clements ACA, Li Y, Zhou XN, et al. Asian Schistosomiasis:
256   Current Status and Prospects for Control Leading to Elimination. *Tropical Medicine and Infectious*
257   *Disease* **4** (2019) 40. doi:10.3390/tropicalmed4010040.

258 **2** .Gray DJ, Ross AG, Li YS, McManus DP. Diagnosis and management of schistosomiasis. *BMJ* **342**
259   (2011) d2651. doi:10.1136/bmj.d2651. Publisher: British Medical Journal Publishing Group Section:
260   Clinical Review.

261 **3** .WHO. Ending the neglect to attain the Sustainable Development Goals: a road map for neglected
262   tropical diseases 2021–2030. (2020).

263 **4** .Rudge JW, Webster JP, Lu DB, Wang TP, Fang GR, Basáñez MG. Identifying host species driving
264   transmission of schistosomiasis japonica, a multihost parasite system, in China. *PNAS* **110** (2013)
265   11457–11462. doi:10.1073/pnas.1221509110. Publisher: National Academy of Sciences Section:
266   Biological Sciences.

267 **5** .Xiang J, Chen H, Ishikawa H. A mathematical model for the transmission of Schistosoma japonicum
268   in consideration of seasonal water level fluctuations of Poyang Lake in Jiangxi, China. *Parasitology*
269   *international* **62** (2013) 118–126. doi:10.1016/j.parint.2012.10.004.

270 **6** .Zhu HR, Liu L, Zhou XN, Yang GJ. Ecological model to predict potential habitats of oncomelania
271   hupensis, the intermediate host of schistosoma japonicum in the mountainous regions, china. *PLoS*
272   *neglected tropical diseases* **9** (2015) e0004028.

273 **7** .World Health Organization and others. Expert consultation to accelerate elimination of asian
274   schistosomiasis, shanghai, china, 22-23 may 2017: meeting report. Tech. rep., Manila: WHO Regional
275   Office for the Western Pacific (2017).

276 **8** .Betson M, Alonte AJI, Ancog RC, Aquino AMO, Belizario VY, Bordado AMD, et al. Chapter Two -
277   Zoonotic transmission of intestinal helminths in southeast Asia: Implications for control and elimination.
278   Rollinson D, Stothard R, editors, *Advances in Parasitology* (Academic Press), vol. 108 (2020), 47–131.
279   doi:10.1016/bs.apar.2020.01.036.

280 **9** .Toor J, Hamley JID, Fronterre C, Castaño MS, Chapman LAC, Coffeng LE, et al. Strengthening data
281   collection for neglected tropical diseases: What data are needed for models to better inform tailored
282   intervention programmes? *PLOS Neglected Tropical Diseases* **15** (2021b) e0009351. doi:10.1371/
283   journal.pntd.0009351.

284 **10** .Consortium NM, of Control of Neglected Tropical Diseases WD. Achieving NTD Control, Elimination
285   and Eradication Targets Post-2020 Modelling Perspectives and Priorities. *Gates Open Res* **3** (2019)
286   1664. doi:10.21955/gatesopenres.1116563.1. Number: 1664 Publisher: F1000 Research Limited.

11 .Clark J, Stolk WA, Basáñez MG, Coffeng LE, Cucunubá ZM, Dixon MA, et al. How modelling can help steer the course set by the World Health Organization 2021-2030 roadmap on neglected tropical diseases. *Gates Open Res* **5** (2021) 112. doi:10.12688/gatesopenres.13327.1.

12 .Webster JP, Borlase A, Rudge JW. Who acquires infection from whom and how? Disentangling multi-host and multi-mode transmission dynamics in the 'elimination' era. *Philosophical Transactions of the Royal Society B: Biological Sciences* **372** (2017) 20160091. doi:10.1098/rstb.2016.0091.

13 .Laing G, Vigilato MAN, Cleaveland S, Thumbi SM, Blumberg L, Salahuddin N, et al. One Health for neglected tropical diseases. *Transactions of The Royal Society of Tropical Medicine and Hygiene* **115** (2021) 182–184. doi:10.1093/trstmh/traa117.

14 .Behrend MR, Basáñez MG, Hamley JID, Porco TC, Stolk WA, Walker M, et al. Modelling for policy: The five principles of the Neglected Tropical Diseases Modelling Consortium. *PLOS Neglected Tropical Diseases* **14** (2020) e0008033. doi:10.1371/journal.pntd.0008033.

15 .Pinsent A, Hollingsworth TD. Optimising sampling regimes and data collection to inform surveillance for trachoma control. *PLOS Neglected Tropical Diseases* **12** (2018) e0006531. doi:10.1371/journal. pntd.0006531.

16 .Yang J, Zhou J, Jin J, Sun Q. The Stakeholders' Views on Planting Trees to Control Schistosomiasis in China. *International Journal of Environmental Research and Public Health* **17** (2020) 939. doi:10. 3390/ijerph17030939.

17 .Musuva RM, Odiere MR, Mwinzi PNM, Omondi IO, Rawago FO, Matendechero SH, et al. Unprotected water sources and low latrine coverage are contributing factors to persistent hotspots for schistosomiasis in western Kenya. *PLOS ONE* **16** (2021) e0253115. doi:10.1371/journal.pone.0253115.

18 .Dalisay SNM, Belizario VY, Joe JAS, Lumangaya CR, Cruz RD. Critical medical ecology and intersectionality perspectives in schistosomiasis prevention and control in selected communities in Mindanao, the Philippines. *Journal of Biosocial Science* (2022) 1–20. doi:10.1017/S0021932021000766.

19 .NTD Modelling Consortium Schistosomiasis Group. Insights from quantitative and mathematical modelling on the proposed WHO 2030 goal for schistosomiasis. *Gates Open Res* **3** (2019) 1517. doi:10.12688/gatesopenres.13052.2.

20 .Farrell SH, Coffeng LE, Truscott JE, Werkman M, Toor J, de Vlas SJ, et al. Investigating the Effectiveness of Current and Modified World Health Organization Guidelines for the Control of Soil-Transmitted Helminth Infections. *Clinical Infectious Diseases* **66** (2018) S253–S259. doi:10.1093/cid/ciy002.

21 .Toor J, Alsallaq R, Truscott JE, Turner HC, Werkman M, Gurarie D, et al. Are We on Our Way to Achieving the 2020 Goals for Schistosomiasis Morbidity Control Using Current World Health Organization Guidelines? *Clinical Infectious Diseases* **66** (2018) S245–S252. doi:10.1093/cid/ciy001.

22 .Kura K, Ayabina D, Toor J, Hollingsworth TD, Anderson RM. Disruptions to schistosomiasis programmes due to COVID-19: an analysis of potential impact and mitigation strategies. *Transactions of The Royal Society of Tropical Medicine and Hygiene* **115** (2021) 236–244. doi:10.1093/trstmh/traa202.

23 .Toor J, Adams ER, Aliee M, Amoah B, Anderson RM, Ayabina D, et al. Predicted Impact of COVID-19 on Neglected Tropical Disease Programs and the Opportunity for Innovation. *Clinical Infectious Diseases* **72** (2021a) 1463–1466. doi:10.1093/cid/ciaa933.

24 .Hollingsworth TD. Counting Down the 2020 Goals for 9 Neglected Tropical Diseases: What Have We Learned From Quantitative Analysis and Transmission Modeling? *Clinical Infectious Diseases* **66** (2018) S237–S244. doi:10.1093/cid/ciy284.

331 25 .Lamberton PHL, Kabatereine NB, Oguttu DW, Fenwick A, Webster JP. Sensitivity and Specificity of
332   Multiple Kato-Katz Thick Smears and a Circulating Cathodic Antigen Test for Schistosoma mansoni
333   Diagnosis Pre- and Post-repeated-Praziquantel Treatment. *PLOS Neglected Tropical Diseases* **8** (2014)
334   e3139. doi:10.1371/journal.pntd.0003139.

335 26 .Clark J, Moses A, Nankasi A, Faust CL, Moses A, Ajambo D, et al. Reconciling Egg- and Antigen-
336   Based Estimates of Schistosoma mansoni Clearance and Reinfection: A Modeling Study. *Clinical
337   Infectious Diseases* (2021b) ciab679. doi:10.1093/cid/ciab679.

338 27 .Clements ACA, Lwambo NJS, Blair L, Nyandindi U, Kaatano G, Kinung'hi S, et al. Bayesian spatial
339   analysis and disease mapping: tools to enhance planning and implementation of a schistosomiasis
340   control programme in Tanzania. *Trop Med Int Health* **11** (2006) 490–503. doi:10.1111/j.1365-3156.
341   2006.01594.x.

342 28 .Gomes de Amorim Santos I, Santos Ramos RE, Soares Gomes D, Pereira Bezerra L, Oliveira Silva L,
343   Martins Cirilo T, et al. Analysis and spatial distribution of schistosomiasis mansoni in a historically
344   endemic area of northeastern Brazil. *Tropical Medicine & International Health* **25** (2020) 1085–1092.
345   doi:10.1111/tmi.13458.

346 29 .Adekeye TA, Onile OS, Adebayo AS, Osundiran AJ, Anumudu CI, Awobode HO. Spatial distribution
347   and ecology of soil parasites and Schistosoma haematobium infection in Eggua, Nigeria. *Environmental
348   Advances* **5** (2021) 100080. doi:10.1016/j.envadv.2021.100080.

349 30 .Amoah B, Fronterre C, Johnson O, Dejene M, Seife F, Negussu N, et al. Model-based geostatistics
350   enables more precise estimates of neglected tropical-disease prevalence in elimination settings: mapping
351   trachoma prevalence in Ethiopia. *International Journal of Epidemiology* (2021) dyab227. doi:10.1093/
352   ije/dyab227.

353 31 .Giorgi E, Fronterrè C, Macharia PM, Alegana VA, Snow RW, Diggle PJ. Model building and assessment
354   of the impact of covariates for disease prevalence mapping in low-resource settings: to explain and to
355   predict. *J. R. Soc. Interface.* **18** (2021) 20210104. doi:10.1098/rsif.2021.0104.

356 32 .Johnson O, Fronterre C, Amoah B, Montresor A, Giorgi E, Midzi N, et al. Model-Based Geostatistical
357   Methods Enable Efficient Design and Analysis of Prevalence Surveys for Soil-Transmitted Helminth
358   Infection and Other Neglected Tropical Diseases. *Clinical Infectious Diseases* **72** (2021) S172–S179.
359   doi:10.1093/cid/ciab192.

360 33 .Warren KS. Regulation of the Prevalence and Intensity of Schistosomiasis in Man: Immunology or
361   Ecology? *The Journal of Infectious Diseases* **127** (1973) 595–609.

362 34 .Chan MS, Guyatt HL, Bundy DaP, Booth M, Fulford AJC, Medley GF. The development of
363   an age structured model for schistosomiasis transmission dynamics and control and its validation
364   for *Schistosoma mansoni.* *Epidemiology & Infection* **115** (1995) 325–344. doi:10.1017/
365   S0950268800058453.

366 35 .Buck JC, De Leo GA, Sokolow SH. Concomitant immunity and worm senescence may drive
367   schistosomiasis epidemiological patterns: An eco-evolutionary perspective. *Frontiers in Immunology*
368   **11** (2020).

369 36 .Graham M, Ayabina D, Lucas TC, Collyer BS, Medley GF, Hollingsworth TD, et al. SCHISTOX:
370   An individual based model for the epidemiology and control of schistosomiasis. *Infectious Disease
371   Modelling* **6** (2021) 438–447. doi:10.1016/j.idm.2021.01.010.

372 37 .Kura K, Hardwick RJ, Truscott JE, Anderson RM. What is the impact of acquired immunity on the
373   transmission of schistosomiasis and the efficacy of current and planned mass drug administration
374   programmes? *PLOS Neglected Tropical Diseases* **15** (2021b) e0009946. doi:10.1371/journal.pntd.
375   0009946.

376 **38** .Scott TP, Coetzer A, de Balogh K, Wright N, Nel LH. The Pan-African Rabies Control Network
377   (PARACON): A unified approach to eliminating canine rabies in Africa. *Antiviral Research* **124** (2015)
378   93–100. doi:10.1016/j.antiviral.2015.10.002.

379 **39** .Haselbeck AH, Rietmann S, Tadesse BT, Kling K, Kaschubat-Dieudonné ME, Marks F, et al. Challenges
380   to the Fight against Rabies—The Landscape of Policy and Prevention Strategies in Africa. *International
381   Journal of Environmental Research and Public Health* **18** (2021) 1736. doi:10.3390/ijerph18041736.
382   Number: 4 Publisher: Multidisciplinary Digital Publishing Institute.

383 **40** .Menghistu HT, Mersha TT, Shumuye NA, Woldie BM, Redda YT, Hadush B, et al. Neglected tropical
384   zoonotic diseases in Tigray region, northern Ethiopia: Spatial distribution and trend analysis of rabies,
385   tuberculosis, schistosomiasis, and visceral leishmaniasis in humans. *Zoonoses and Public Health* **68**
386   (2021) 823–833. doi:10.1111/zph.12874.

387 **41** .Guo J, Li Y, Gray D, Ning A, Hu G, Chen H, et al. A DRUG-BASED INTERVENTION STUDY ON
388   THE IMPORTANCE OF BUFFALOES FOR HUMAN SCHISTOSOMA JAPONICUM INFECTION
389   AROUND POYANG LAKE, PEOPLE'S REPUBLIC OF CHINA. *The American Journal of Tropical
390   Medicine and Hygiene* **74** (2006) 335–341. doi:10.4269/ajtmh.2006.74.335. Publisher: The American
391   Society of Tropical Medicine and Hygiene.

392 **42** .Barbour AD. Modelling the transmission of schistosomiasis: an introductory view. **55** (1996) 135–143.

393 **43** .Mari L, Ciddio M, Casagrandi R, Perez-Saez J, Bertuzzo E, Rinaldo A, et al. Heterogeneity in
394   schistosomiasis transmission dynamics. *Journal of Theoretical Biology* **432** (2017a) 87–99. doi:10.
395   1016/j.jtbi.2017.08.015.

396 **44** .Williams GM, Sleigh AC, Li Y, Feng Z, Davis GM, Chen H, et al. Mathematical modelling of
397   schistosomiasis japonica: comparison of control strategies in the People's Republic of China. *Acta
398   Tropica* **82** (2002) 253–262. doi:10.1016/S0001-706X(02)00017-7.

399 **45** .Gao SJ, Cao HH, He YY, Liu YJ, Zhang XY, Yang GJ, et al. The basic reproductive ratio of
400   Barbour's two-host schistosomiasis model with seasonal fluctuations. *Parasites Vectors* **10** (2017) 42.
401   doi:10.1186/s13071-017-1983-1.

402 **46** .Williams GM, Li Ys, Gray DJ, et al, McManus DP. Field Testing Integrated Interventions for
403   Schistosomiasis Elimination in the People's Republic of China: Outcomes of a Multifactorial Cluster-
404   Randomized Controlled Trial (2019).

405 **47** .Seto EYW, Remais JV, et al, Zhou XN. Toward Sustainable and Comprehensive Control of
406   Schistosomiasis in China: Lessons from Sichuan (2011).

407 **48** .Webster JP, Gower CM, Knowles SCL, Molyneux DH, Fenton A. One health – an ecological and
408   evolutionary framework for tackling Neglected Zoonotic Diseases. *Evolutionary Applications* **9** (2016)
409   313–333. doi:10.1111/eva.12341. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/eva.12341.

410 **49** .Zou HY, Yu QF, Qiu C, Webster JP, Lu DB. Meta-analyses of Schistosoma japonicum infections in
411   wild rodents across China over time indicates a potential challenge to the 2030 elimination targets.
412   *PLOS Neglected Tropical Diseases* **14** (2020) e0008652. doi:10.1371/journal.pntd.0008652. Publisher:
413   Public Library of Science.

414 **50** .Budiono NG, Murtini S, Satrija F, Ridwan Y, Handharyani E. Humoral responses to *Schistosoma
415   japonicum* soluble egg antigens in domestic animals in Lindu Subdistrict, Central Sulawesi Province,
416   Indonesia. *Int J One Health* **6** (2020) 99–108. doi:10.14202/IJOH.2020.99-108.

417 **51** .Streicker DG, Fenton A, Pedersen AB. Differential sources of host species heterogeneity influence the
418   transmission and control of multihost parasites. *Ecology Letters* **16** (2013) 975–984. doi:10.1111/ele.
419   12122. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/ele.12122.

52 .Fenton A, Streicker DG, Petchey OL, Pedersen AB. Are All Hosts Created Equal? Partitioning Host Species Contributions to Parasite Persistence in Multihost Communities. *The American Naturalist* **186** (2015) 610–622. doi:10.1086/683173. Publisher: The University of Chicago Press.

53 .Bielby J, Price SJ, Monsalve-CarcaÑo C, Bosch J. Host contribution to parasite persistence is consistent between parasites and over time, but varies spatially. *Ecological Applications* **31** (2021) e02256. doi:10.1002/eap.2256. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/eap.2256.

54 .Erazo D, Pedersen AB, Gallagher K, Fenton A. Who acquires infection from whom? Estimating herpesvirus transmission rates between wild rodent host groups. *Epidemics* **35** (2021) 100451. doi:10.1016/j.epidem.2021.100451.

55 .Borlase A, Rudge JW, Léger E, Diouf ND, Fall CB, Diop SD, et al. Spillover, hybridization, and persistence in schistosome transmission dynamics at the human–animal interface. *PNAS* **118** (2021). doi:10.1073/pnas.2110711118. Publisher: National Academy of Sciences Section: Biological Sciences.

56 .Dong Y, Du CH, Zhang Y, Wang LF, Song J, Wu MS, et al. Role of ecological approaches to eliminating schistosomiasis in Eryuan County evaluated by system modelling. *Infectious Diseases of Poverty* **7** (2018) 129. doi:10.1186/s40249-018-0511-7.

57 .Drummond MF, Sculpher MJ, Claxton K, Stoddart GL, Torrance GW. *Methods for the Economic Evaluation of Health Care Programmes* (Oxford University Press) (2015). Google-Books-ID: yzZSCwAAQBAJ.

58 .Turner HC, French MD, Montresor A, King CH, Rollinson D, Toor J. Economic evaluations of human schistosomiasis interventions: a systematic review and identification of associated research needs. *Wellcome Open Res* **5** (2020) 45. doi:10.12688/wellcomeopenres.15754.2.

59 .Adeyemo P, Léger E, Hollenberg E, Diouf N, Sene M, Webster JP, et al. Estimating the Financial Impact of Livestock Schistosomiasis on Traditional Subsistence and Transhumance Farmers Keeping Cattle, Sheep and Goats in Northern Senegal. preprint, In Review (2021). doi:10.21203/rs.3.rs-757540/v1.

60 .Narrod C, Zinsstag J, Tiongco M. A one health framework for estimating the economic costs of zoonotic diseases on society. *Ecohealth* **9** (2012) 150–162. doi:10.1007/s10393-012-0747-9.

61 .Murray CJ, Lopez AD, Jamison DT. The global burden of disease in 1990: summary results, sensitivity analysis and future directions. *Bull World Health Organ* **72** (1994) 495–509.

62 .Ung L, Stothard JR, Phalkey R, Azman AS, Chodosh J, Hanage WP, et al. Towards global control of parasitic diseases in the Covid-19 era: One Health and the future of multisectoral global health governance. *Adv Parasitol* **114** (2021) 1–26. doi:10.1016/bs.apar.2021.08.007.

63 .Chen A, Jacobsen KH, Deshmukh AA, Cantor SB. The evolution of the disability-adjusted life year (DALY). *Socio-Economic Planning Sciences* **49** (2015) 10–15. doi:10.1016/j.seps.2014.12.002.

64 .Torgerson PR, Rüegg S, Devleesschauwer B, Abela-Ridder B, Havelaar AH, Shaw APM, et al. zDALY: An adjusted indicator to estimate the burden of zoonotic diseases. *One Health* **5** (2018) 40–45. doi:10.1016/j.onehlt.2017.11.003.

65 .Okello WO, Okello AL, Inthavong P, Tiemann T, Phengsivalouk A, Devleesschauwer B, et al. Improved methods to capture the total societal benefits of zoonotic disease control: Demonstrating the cost-effectiveness of an integrated control programme for Taenia solium, soil transmitted helminths and classical swine fever in northern Lao PDR. *PLOS Neglected Tropical Diseases* **12** (2018) e0006782. doi:10.1371/journal.pntd.0006782. Publisher: Public Library of Science.

66 .Saadi A, Amarir F, Filali H, Thys S, Rhalem A, Kirschvink N, et al. The socio-economic burden of cystic echinococcosis in Morocco: A combination of estimation method. *PLOS Neglected Tropical Diseases* **14** (2020) e0008410. doi:10.1371/journal.pntd.0008410.

464 67 .Zayas LPN, Rüegg S, Torgerson P. The burden of zoonoses in Paraguay: A systematic review. *PLOS*
465   *Neglected Tropical Diseases* **15** (2021) e0009909. doi:10.1371/journal.pntd.0009909.

466 68 .Tan D, Yu D, Li Y, Xie MS, Wen HM, Cai WB, et al. Analysis of Cost-Effectiveness on Two
467   Chemotherapy Schemes to Schistosomiasis in Hyperendemic Villages of Hunan Province. *Practical*
468   *Preventire Medicine* (2001).

469 69 .Yu D, Sarol Jr JN, Hutton G, Tan D, Tanner M. Cost effectiveness analysis of the impacts on
470   infection and morbidity attributable to three chemotherapy schemes against *Schistosoma japonicum*
471   hyperendemic areas of the Dongting lake region, China. *Southeast Asian Journal of Tropical Medicine*
472   *and Public Health* **33** (2002) 441–457.

473 70 .Croce D, Porazzi E, Foglia E, Restelli U, Sinuon M, Socheat D, et al. Cost-effectiveness of a successful
474   schistosomiasis control programme in Cambodia (1995–2006). *Acta Tropica* **113** (2010) 279–284.
475   doi:10.1016/j.actatropica.2009.11.011.

476 71 .Zhang Hm, Yu Q, Zhang X, Coa Cl, Li Sz, Zhu H. [Cost-effectiveness evaluation on comprehensive
477   control measures carrying out in schistosomiasis endemic areas with regard to different layers of
478   administrative villages stratified by infection situation of human and domestic animals. I. Cost-
479   effectiveness study in inner embankment of marshland and lake regions from 2006 to 2010]. *Zhongguo*
480   *Xue Xi Chong Bing Fang Zhi Za Zhi* **26** (2014) 254–259.

481 72 .Ya Y, Jian-Bing L, Hao L, Shi-Gui L, Zhong H, Bin C, et al. [Cost-effectiveness of comprehensive
482   schistosomiasis control strategy with focus on cattle and sheep removal in Junshan District, Yueyang
483   City]. *Zhongguo Xue Xi Chong Bing Fang Zhi Za Zhi* **30** (2017) 14–17. doi:10.16250/j.32.1374.
484   2017136.

485 73 .Adriko M, Faust CL, Carruthers LV, Moses A, Tukahebwa EM, Lamberton PHL. Low Praziquantel
486   Treatment Coverage for Schistosoma mansoni in Mayuge District, Uganda, Due to the Absence of
487   Treatment Opportunities, Rather Than Systematic Non-Compliance. *Tropical Medicine and Infectious*
488   *Disease* **3** (2018) 111. doi:10.3390/tropicalmed3040111. Number: 4 Publisher: Multidisciplinary
489   Digital Publishing Institute.

490 74 .Babu BV, Babu GR. Coverage of, and compliance with, mass drug administration under the programme
491   to eliminate lymphatic filariasis in India: a systematic review. *Transactions of The Royal Society of*
492   *Tropical Medicine and Hygiene* **108** (2014) 538–549. doi:10.1093/trstmh/tru057.

493 75 .Chami GF, Kontoleon AA, Bulte E, Fenwick A, Kabatereine NB, Tukahebwa EM, et al. Community-
494   directed mass drug administration is undermined by status seeking in friendship networks and
495   inadequate trust in health advice networks. *Social Science & Medicine* **183** (2017) 37–47.
496   doi:10.1016/j.socscimed.2017.04.009.

497 76 .Inobaya MT, Chau TN, Ng SK, MacDougall C, Olveda RM, Tallo VL, et al. Mass drug administration
498   and the sustainable control of schistosomiasis: an evaluation of treatment compliance in the rural
499   Philippines. *Parasites Vectors* **11** (2018) 1–11. doi:10.1186/s13071-018-3022-2. Number: 1 Publisher:
500   BioMed Central.

501 77 .Chami GF, Bundy DAP. More medicines alone cannot ensure the treatment of neglected tropical
502   diseases. *The Lancet Infectious Diseases* **19** (2019) e330–e336. doi:10.1016/S1473-3099(19)30160-4.

503 78 .Cahapay MB. To get or not to get: Examining the intentions of Philippine teachers
504   to vaccinate against COVID-19. *Journal of Human Behavior in the Social Environment*
505   **0** (2021) 1–11. doi:10.1080/10911359.2021.1896409. Publisher: Routledge _eprint:
506   https://doi.org/10.1080/10911359.2021.1896409.

79 .Dyson L, Stolk WA, Farrell SH, Hollingsworth TD. Measuring and modelling the effects of systematic non-adherence to mass drug administration. *Epidemics* **18** (2017) 56–66. doi:10.1016/j.epidem.2017.02.002.

80 .Chun-Hai Fung I, Fitter DL, Borse RH, Meltzer MI, Tappero JW. Modeling the Effect of Water, Sanitation, and Hygiene and Oral Cholera Vaccine Implementation in Haiti. *Am J Trop Med Hyg* **89** (2013) 633–640. doi:10.4269/ajtmh.13-0201.

81 .Mellor J, Abebe L, Ehdaie B, Dillingham R, Smith J. Modeling the sustainability of a ceramic water filter intervention. *Water Research* **49** (2014) 286–299. doi:10.1016/j.watres.2013.11.035.

82 .Patrick R, McElroy S, Schwarz L, Kayser G, Benmarhnia T. Modeling the Impact of Population Intervention Strategies on Reducing Health Disparities: Water, Sanitation, and Hygiene Interventions and Childhood Diarrheal Disease in Peru. *Am J Trop Med Hyg* **104** (2021) 338–345. doi:10.4269/ajtmh.19-0775.

83 .Coffeng LE, Nery SV, Gray DJ, Bakker R, Vlas SJd, Clements ACA. Predicted short and long-term impact of deworming and water, hygiene, and sanitation on transmission of soil-transmitted helminths. *PLOS Neglected Tropical Diseases* **12** (2018) e0006758. doi:10.1371/journal.pntd.0006758.

84 .Grimes JE, Croll D, Harrison WE, Utzinger J, Freeman MC, Templeton MR. The roles of water, sanitation and hygiene in reducing schistosomiasis: a review. *Parasites & Vectors* **8** (2015) 156. doi:10.1186/s13071-015-0766-9.

85 .Mari L, Gatto M, Ciddio M, Dia ED, Sokolow SH, De Leo GA, et al. Big-data-driven modeling unveils country-wide drivers of endemic schistosomiasis. *Sci Rep* **7** (2017b) 489. doi:10.1038/s41598-017-00493-1.

86 .Mekete K, Ower A, Dunn J, Sime H, Tadesse G, Abate E, et al. The Geshiyaro Project: a study protocol for developing a scalable model of interventions for moving towards the interruption of the transmission of soil-transmitted helminths and schistosome infections in the Wolaita zone of Ethiopia. *Parasites Vectors* **12** (2019) 503. doi:10.1186/s13071-019-3757-4.

87 .Wood S, Sawyer R, Simpson-Hébert M. *Participatory Hygiene and Sanitation Transformation Initiative (PHAST) step by step guide: a participatory approach for the control of diarrhoeal disease* (World Health Organization) (1998).

88 .Mulopo C, Chimbari MJ. Water, sanitation, and hygiene for schistosomiasis prevention: a qualitative analysis of experiences of stakeholders in rural KwaZulu-Natal. *Journal of Water, Sanitation and Hygiene for Development* **11** (2021) 255–270. doi:10.2166/washdev.2021.182.

89 .Kosinski KC, Kulinkina AV, Abrah AFA, Adjei MN, Breen KM, Chaudhry HM, et al. A mixed-methods approach to understanding water use and water infrastructure in a schistosomiasis-endemic community: case study of Asamama, Ghana. *BMC Public Health* **16** (2016) 322. doi:10.1186/s12889-016-2976-2.

90 .Meginnis K, Hanley N, Mujumbusi L, Lamberton PHL. Non-monetary numeraires: Varying the payment vehicle in a choice experiment for health interventions in Uganda. *Ecological Economics* **170** (2020) 106569. doi:10.1016/j.ecolecon.2019.106569.