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Malaria prevalence and incidence in an isolated, meso-endemic area of Mozambique

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If malaria can be eliminated from anywhere it is from isolated areas such as the 2x7 km peninsula of Linga Linga in southern Mozambique. Currently available control strategies include bed nets impregnated with pyrethroid insecticides (long-lasting insecticidal bed nets; LLINs), artemisinin combination therapy (ACT) for treatment and rapid diagnostic tests (RDTs) for diagnosis. When these became available, they were applied and their effects on malaria prevalence measured over the years 2007 – 2011. Following a census of the population and mapping of 500 households, five annual all age prevalence surveys were conducted over the years 2007 – 2011. Information on LLIN use, house construction, and animal ownership was obtained. Mean prevalence varied from 16% (in 2007) to 65% (in 2009) according to the season in which the surveys were performed. The 5 – 9 year old age group had the highest prevalence rate in the first three surveys (2007 – 2009). A spatially structured generalised additive model indicated that malaria risk was greatest towards the northern end of the peninsula. The effect on the incidence of malaria of a clinic providing RDT's for diagnosis and ACT's for treatment was also monitored from March 2009 to May 2011. Malaria was diagnosed in 31% of the 4321 visits from residents attending the clinic and 72% of those tested were positive. People with confirmed malaria were younger than the median age of people attending the clinic. People with a fever were more likely to have malaria than people without a fever but bednet use did not affect the likelihood of having malaria. People living further away from the health post were less likely to attend. The number of attendees diagnosed with malaria decreased significantly from 35% (399 of 1144 attendees) in 2009 to 24% (271 of 1150 attendees) in 2011 ($\chi^2 = 19.1$, $p > 0.0001$). In order to reduce malaria prevalence in an area such as Linga Linga further measures of vector control need to be considered if reductions in malaria prevalence are to be achieved.

1 **Malaria prevalence and incidence in an isolated, meso-endemic, area**
2 **of Mozambique.**

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27 Background

28 If malaria can be eliminated from anywhere, it is from isolated areas such as
29 islands and peninsulas that are surrounded by mosquito-hostile
30 environments, be that sea, desert or uninhabited land, in which there is much
31 less immigration and emigration of vectors (and people) than in more
32 connected environments (Aregawi et al., 2011, Hagmann et al., 2003,
33 Ishengoma et al., 2013, Pinto et al., 2003, Lucas 2010, Lum et al., 2007,
34 Sudomo et al, 2004, Teklehaimanot et al., 2010).

35 The sandy, low altitude peninsula of Linga Linga, 500 km north of Maputo, is
36 such an area, since apart from a 2 km stretch of uninhabited land at the
37 narrow neck, it is surrounded by saline water making it a virtual ecological
38 island. *Anopheles funestus* is responsible for malaria transmission on the
39 peninsula (Charlwood et al., 2013). During the long dry season, the mosquito
40 may become gonotrophically discordant and individual mosquitoes may
41 survive for long periods taking several blood meals without laying eggs so
42 that, despite low numbers, transmission continues (Charlwood et al., 2013).

43 In 2007, a project to determine the impact on malaria of introducing currently
44 available control strategies was implemented on the peninsula. Should
45 transmission have been reduced then prevalence and incidence, especially in
46 the most affected age groups should drop and the mean age of maximum
47 prevalence should increase. Annual all age malaria prevalence surveys were
48 therefore undertaken for the years 2007–2011 and incidence from 2009–2011

49 was monitored in a clinic established by the project. The results are discussed
50 in relation to other potential control techniques that might be applied on the
51 peninsula.

52 **Methods**

53 Linga Linga (23°43'1.29"S, 35°24'15.04"E), which lies 6km to the east across
54 the Morrumbene Bay opposite the district capital Morrumbene, has been
55 described by Charwood et al., (2013) and Thomsen et al. (2013). People are
56 involved in fishing, the production of copra or the artisanal manufacture of
57 raffia baskets, hats and bags. A number of tourist lodges have been built in
58 recent years or are under construction, employing non-resident and local
59 labour. At the time of the initial survey there was no health centre on the
60 peninsula, the nearest health centres being in the village of Coche, five km to
61 the north of Linga Linga, or in Morrumbene itself (Fig 1). At the start of the
62 project residents were censused, informed of the purpose of the study and
63 consent to participate was obtained; houses were mapped (with Garmin e-
64 Trex hand held global positioning system (GPS) receiver units) numbered and
65 their dimensions noted.

66 Information on the age and number of residents, the number of animals kept
67 by householders, bednet ownership, the duration of residency, sources of
68 drinking and washing water, and details on the construction of the houses
69 were noted. Roof and wall categories were based on whether the material in

70 which they were constructed was made of 'natural' materials (reed, palm
71 leaf, grass, palm frond) or 'man-made' materials such as corrugated iron,
72 bricks or tiles. Water sources were separated into 'in the house', 'from a well'
73 or 'neighbours'.

74 In 2007, 130 blue double Long Lasting Impregnated Nets (LLINs) impregnated
75 with Deltamethrin were given to the households with the greatest number of
76 children below 10 years of age recorded in the census. In 2008, two days
77 prior to the prevalence survey, a further 100 pink, 200 green and 100 blue
78 LLINs were distributed. Householders were invited to a central distribution
79 point and were given the opportunity to choose their nets. When distributing
80 the nets, names were called out and people came up and chose their net. We
81 attempted to make sure that all three colours were always available and
82 equally easy to pick. The colour of the net chosen was recorded until that
83 particular colour was exhausted.

84 **Prevalence surveys**

85 Following the initial census, an all age baseline malaria prevalence survey
86 was performed in February 2007. Subsequent prevalence surveys were
87 conducted in February 2008, March 2009, April 2010 and June 2011,
88 coincident with increments in the distribution of interventions

89 Seven locations were chosen as survey field sites. Local residents were
90 informed the day prior to the survey that it would be taking place, and

91 requested to come to the site location to be surveyed. In addition, a survey
 92 was undertaken at the school to collect data of school-aged children who had
 93 not been previously screened. During the surveys, residents were asked if
 94 they have experienced malaria since the start of the year and where they
 95 went for treatment. In the initial survey (2007), information on absence from
 96 the peninsula (duration, location, means of transport and whether they had
 97 used a net when away) was also collected. In subsequent surveys, people
 98 were asked: 1. How long have you lived in your present house? 2. Where did
 99 you come from? 3. Do you have a mosquito bednet? 4. Did you sleep under
 100 it last night? 5. Where did you obtain your net? Thus, the parasitology
 101 datasets contained information on the individual's house number, name, age,
 102 sex, whether or not they tested positive for malaria, and whether or not they
 103 used a bednet the previous night.

104 Finger prick blood was used in the preparation of thick and thin blood films.
 105 Films were stained with 5% Giemsa for 20 minutes and examined at the
 106 Instituto Nacional de Saude (INS) reference laboratory for the presence of
 107 parasites. Slides were read twice and numbers of parasites per 500
 108 leucocytes were counted and converted to densities per micro-litre of blood,
 109 assuming a density of 8000 leucocytes per micro-litre (Bruce-Chwatt, 1985).
 110 Parasite density per micro-litre of blood was determined according to the
 111 formula:

112
$$\text{Density} = ([\text{P.f Count}] * [8000]) / [\text{White Blood Cell Count}]$$

113 People's temperature was also taken. In surveys from 2008 onwards, an RDT
 114 (OptiMal ®) for malaria was given to anyone with a fever (defined as an
 115 axillary temperature of $>37.5^{\circ}\text{C}$). Those that tested positive by RDT were
 116 treated with Coartem® (artesunate and lumefantrine) according to national
 117 guidelines.

118 Incidence data

119 A clinic was established in March 2009 in an unused cement house in a
 120 central location (Fig 1). The clinic was open from Monday to Friday in the
 121 mornings, with a resident nurse also available for emergency consultations at
 122 other times. It provided curative care for general ailments using the UNICEF
 123 Kit B stock of medicines. The age, sex and house number of attendees was
 124 recorded over the period March 2009 – May 2011. Attendees were asked how
 125 long they had had their symptoms, including headache and fever, defined as
 126 an axillary temperature of 37.5°C or above, and whether they had slept under
 127 a bednet the previous night.

128 RDTs were used to determine the likelihood of patients reporting with a
 129 headache or fever having malaria. At the same time (also when RDTs were
 130 not available), a blood slide was taken and subsequently read for parasite
 131 confirmation. Thick and thin blood films were prepared of diagnosed cases
 132 and subsequently read by a microscopist in Morrumbene. In the absence of
 133 RDT's treatment was, therefore, based on clinical diagnosis, which was
 134 subsequently checked by microscopy. People with parasites confirmed by

135 RDT, or presumptively diagnosed with malaria when RDTs were not available,
136 were treated with artemether -lumefantrine (Coartem®).

137 **Data analysis**

138 Data was entered into MS Excel spreadsheets and analysed with the software
139 R (R Core Team, 2013). Summaries of the 2007 census data were produced,
140 including the age distribution of the population and bednet ownership by sex.
141 LLIN colour preferences, and subsequent information on their reported use
142 were also summarised. Prevalence surveys (2007-2011) were matched with
143 the census data using the unique household ID number (additional file 1)
144 which enabled overall annual malaria prevalence to be tabulated, and
145 household-level malaria prevalence to be mapped using the software ArcGIS.
146 Annual prevalence and the geometric mean parasite density by age group
147 (<2, 2-4, 5-9, 10-19, 20-29, >29) were calculated to assess whether there
148 was any evidence of a change in the age distribution of cases. An individual-
149 level multiple logistic regression model was fitted to the prevalence data,
150 with potential predictors under consideration including age group, bednet
151 usage and household characteristics (roof type, door type, distance to the
152 health post, number of people, water and sanitation access). A backwards
153 stepwise model selection approach based on minimising the Akaike
154 Information Criterion (AIC) was used to determine which variables to include
155 in the final model. A generalised additive model (GAM) was then fitted to the
156 data by adding a spatially smooth term to the final model to account for any

157 possible residual spatial dependency in the data, and a map of this term was
158 produced.

159 The straight-line distance between households and the health post was
160 calculated using ArcGIS and the correlation between the number of visits per
161 person per household and distance to the health post was calculated to
162 assess whether or not those living further away were less likely to seek
163 treatment. Summaries of the percentage of health post attendees who were
164 diagnosed with, or tested for malaria were calculated by age group, sex,
165 resident status (resident or non-resident), reporting year, and bednet usage
166 and chi-squared tests were performed in order to elucidate whether there
167 was an association between malaria risk and these variables.

168 **Ethics**

169 The project received ethical clearance from the National Bioethics Committee
170 of Mozambique (reference 123/CNBS/06) on the 2nd of August 2006.

171 **Results**

172 **Population composition**

173 There were 467 households recorded in the census of 2007. A further 33
174 houses were recorded early in 2008 giving a total of 500. The locations of
175 the households are presented in Figure 1.

176 In 2007 5.7% of the population was between 55 and 64 years of age and
 177 9.1% was over 65 years of age (compared to a national average of 3.5% and
 178 2.9% respectively derived from www.theodora.com, z test $p < 0.05$). Of the
 179 195 households recorded with resident children less than 15 years of age 118
 180 had only one child, 46 had two children, 21 had three children, nine had four
 181 and one house had five children. Only 183 (19%) of the 975 people recorded
 182 used a bednet. Bednet use was equally divided amongst the 447 males and
 183 528 females. Half the households had a radio, 16% per cent owned a mobile
 184 phone and a small number owned fishing boats. Only three households
 185 owned a bicycle. Of the 410 people who completed the baseline prevalence
 186 survey, 163 (40%) had been out of Linga Linga in the previous year. Of these,
 187 146 had left by boat (Fig 2), five had gone by foot and only three had
 188 travelled by car. The majority of people who reported that they had been
 189 absent from the peninsula in the previous year had only spent one or two
 190 nights away.

191 **Net distribution**

192 The villagers preferred pink nets; nets of this colour being taken at twice the
 193 rate of the others Those villagers who took a green or a blue net at the start
 194 of the distribution process (i.e. when all three colours were still available) said
 195 that that they were acting on behalf of their neighbours and that therefore
 196 the colour 'did not matter'.

197 In the 2009 survey 96 pink, 39 blue, 50 green and 10 white nets were
 198 reported to be in use whilst in the 2010 survey 93 pink, 118 blue, 43 green
 199 and 27 white nets were reported to be in use. In the 2009 survey 16 of 282
 200 net owners did not use their net the night before the survey. The reasons
 201 given for non-use included that the net was 'too hot'; that there were no
 202 mosquitoes; that they were ill or that they just didn't like it.

203 **Prevalence and density of malaria parasites 2007-2011**

204 An overview of the parasitology datasets, including the number of individuals
 205 per survey, and the number of individuals that matched the 2007 census
 206 data, is presented in Table 1. Prevalence of malaria varied from one year to
 207 the next with a marked increase in prevalence in the 2009 survey (Fig 3). This
 208 was an exceptionally wet year whilst 2007, the year with the lowest
 209 prevalence, was an exceptionally dry one. The number of people who did not
 210 have an associated house number in the years following the initial census
 211 increased with each survey indicating that there was a considerable
 212 movement of people into (and perhaps out of) Linga Linga. There was,
 213 however, no significant difference in the use of nets between previously
 214 registered householders and new arrivals (i.e. people not registered in the
 215 original census).

216 In 2007, 24.4% (11 of 45) of the malaria positive individuals were children
 217 less than five years old whilst in 2011, only 8.9% (5 of 56) of the malaria

218 positive individuals were children less than five years old. In both 2007 and
219 2011 the majority of cases (55.5% in 2007 and 66.1% in 2011) were
220 individuals aged 5 – 19 years old. Thus there was a tendency towards the
221 older age groups being positive for malaria parasites in the later years of the
222 study.

223 From all the surveys, the 2 – 4 year age group had a significantly higher
224 geometric mean parasite density of 19983 (95% C.I. 12444) compared to all
225 the other age groups that had a mean of 2147 (95% C.I. 699)(t-test $p <$
226 0.0001). Parasite densities were also higher in the 2010 and 2011 surveys
227 combined compared to the previous years (i.e. 2007 – 2009) combined (Fig
228 4). *Plasmodium malariae* was recorded in two slides from the surveys of
229 2008, four from the survey of 2009 and from two slides in 2010. Blood stage
230 parasites were not seen in five of the 21 gametocyte carriers identified in
231 2009, in seven of 14 identified in 2010 nor in eight of 21 identified in 2011. In
232 all years the majority (67%) of gametocyte carriers were under 15 years of
233 age although they were seen in all age groups.

234 In the 2010 survey from 31 rapid tests that were negative 29 were slide
235 negative and two were slide positive whilst from the 27 rapid tests that were
236 positive seven were slide negative. This results in a sensitivity of 90.91%
237 (95% C.I. = 70.08% to 98.62%) and a specificity of 80.56% (95% C.I. =
238 63.97%-91.77%) in the RDT (assuming that the slide reading was 100%
239 accurate).

240 A multiple logistic regression model was fitted to the data from the 618
 241 surveyed people for which matching covariate data was available from the
 242 census. A significant relationship was observed between being infected with
 243 malaria and year of survey, age group, roof category, door category, number
 244 of people per household, water source category, washing water category and
 245 whether or not the surveyed person slept under a bed net on the previous
 246 night. Thus after adjusting for other risk factors, people who lived in houses
 247 having a roof made of thatch or other 'Green' material had an increased risk
 248 of having parasites than those who lived in houses with a roof of corrugated
 249 iron or other man-made material. The number of people living in the house
 250 was also a risk as was age.

251 Using a backwards, stepwise model selection approach, the final fitted model
 252 included year, age group, number of people in the house and roof category
 253 (Table 2). A generalised additive model (GAM), i.e. a logistic regression
 254 model with a smooth term for spatial location, was fitted to the individual-
 255 level data to determine whether there was any spatial pattern in malaria
 256 prevalence after accounting for observed risk factors (see the supplementary
 257 information). The fitted GAM indicated that there was an area of lower risk in
 258 the southeast of the study region, and an area of higher risk in the north and
 259 west of the study area (Fig 5).

260 Incidence data

261 In the 28 months that the clinic was operational there were 4949 visits to the
 262 Health Post, with 4321 (87%) of attendees residing in Linga Linga. Hence,

despite its isolation 628 (13%) of the people attending were non-residents. Among the residents only, 31% (1345/4321) were clinically diagnosed with malaria and 870 (65%) of these were tested by blood slide and/or RDT, resulting in 623 (72%) who tested positive for *P. falciparum*. A similar proportion (34%; 213/628) of non-residents were clinically diagnosed with malaria. Among these 142 (67%) were tested by microscopy and/or RDT and 79 (56%) were positive. Among non-residents, 84 of the diagnosed cases came from urban areas (where transmission is low or absent) and 117 (58%) came from nearby rural areas (where autochthonous transmission is likely to occur). There was no significant difference in the likelihood of urban and rural non-residents having a confirmed case of malaria (two tailed Fishers exact test $p = 0.217$).

People diagnosed with malaria were slightly younger than people attending the clinic for other ailments (median age: 20 years Interquartile range (IQR) 6 – 38 and median age: 23 years IQR 7 – 44, respectively). The median age of those confirmed to have malaria was younger still (12 years, IQR 4 – 30). The majority (80%) of attendees had used a bed net the previous night. People using a net the night before reporting ill were, however, as likely to have malaria as those who did not. Of the 820 people who reported using a net that were diagnosed and tested for malaria, 506 (62%) were positive, whilst of the 194 tested who did not use a net, 120 (62%) were positive for malaria.

284 In the 25 – 40 and the 41 – 64 years of age groups, more females than males
 285 were diagnosed or tested for malaria but the majority of these tests were
 286 negative (Fig 6). Significantly more of the attendees with fever were malaria
 287 positive than those without fever (Chi square for diagnosis = 131.9 $p <$
 288 0.0001, positivity among those tested Chi square = 12.6 $p = 0.0004$). Of the
 289 656 people who had, or reported having had, a fever when attending the
 290 health post, 390 (59.5%) were diagnosed with malaria and of the 233 tested,
 291 188 (80.7%) were positive. From the 2788 people recorded attending without
 292 a history of fever, 807 (28.9%) were clinically diagnosed with malaria out of
 293 which, 479 of these patients were tested (either microscopically or with RDT)
 294 and 246 (51.3%) were positive.

295 There was no significant clustering of cases attending the health post,
 296 although by mapping the number of visits per household and weighting these
 297 values by number of people in the household (obtained from the census
 298 data), there was evidence that those living away from the health post were
 299 less likely to attend (Spearman correlation co-efficient between distance to
 300 health post and number of visits per person per household = -0.1492, $p =$
 301 0.0031) (Fig 7).

302 The number of resident patients diagnosed with malaria decreased from 35%
 303 of all attendees in 2009 (399 of 1144 attendees) to 24% in 2011 (271 of 1150
 304 attendees) (Chi square = 19.1, $p < 0.0001$) (Fig 8).

305 Discussion

306 In Mozambique, malaria represents around 45% of all cases in outpatient
307 visits, approximately 56% of inpatient at paediatric clinics and around 26% of
308 all hospital deaths (WHO, 2013). In Linga Linga too it was a leading cause of
309 attendance at the clinic. The proportion of visits attributable to malaria,
310 however, decreased significantly during the years that the clinic was running.
311 Hence the widespread use of LLINs and the availability of ACTs (that have an
312 anti-gametocidal effect, Okell et al., 2008) may have resulted in a decrease in
313 transmission and incidence.

314 Malaria prevalence, however, was not reduced by an enhanced availability of
315 bednets (even pink ones) or the clinic. Net ownership and ACTs for treatment
316 are not likely to be sufficient to reduce overall prevalence in a setting like
317 Linga Linga where transmission is maintained by a low-density, long-lived,
318 insecticide resistant, anthropophilic vector like *An. funestus* (Charlwood et al.,
319 2013).

320 Most of the malaria infections detected in all but the 2 - 4 year age group in
321 the prevalence surveys were low density ones (below 300/ μ l) they are,
322 therefore, likely to be chronic asymptomatic ones. People with chronic
323 asymptomatic infections are less likely to seek treatment especially when, as
324 at the start of the study, available health centres are a considerable distance
325 away. They may continue to have parasites for long periods and so
326 prevalence among these people may be unaffected by vector control

327 measures such as LLINs. Although gametocyte carriage was apparently lower
 328 in these age groups than in 2 – 4 year olds, it is possible that gametocytes
 329 were present sub-microscopically. This may lead to a relatively large
 330 infectious reservoir and a rapid rise in transmission following rainfall with the
 331 associated increase in numbers of *An. funestus* (Charlwood et al., 2013). The
 332 exceptional rainfall in December 2008 and January 2009 may have been the
 333 cause of the high prevalence observed in 2009.

334 Although not quite statistically significant (due perhaps to the small sample
 335 size) the potential peak shift in prevalence rates from 1-4 year olds to older
 336 age groups and the reduction in the proportion of people attending the clinic
 337 diagnosed with malaria implies that, as was observed in Papua New Guinea
 338 (Smith et al., 2001) there may have been some effect on transmission rates.

339 The type of roof that a house had was associated with an enhanced malaria
 340 risk. *Anopheles funestus* may be more likely to rest inside houses that have
 341 thatch rather than iron roofs. Should the mosquito, due to the lack of
 342 suitable oviposition sites, have an extended gonotrophic cycle, as postulated
 343 by Charlwood et al., [2013] then occupants of thatched roofed houses may
 344 be at greater risk of transmission than those in iron roofed ones (Kirby et al.,
 345 2008, Tami et al., 2012). The number of inhabitants in a house and their age
 346 were also risk factors. Greater numbers of mosquito are attracted to houses
 347 as the number of occupants increase (Charlwood et al., 2013). Should

348 infected mosquitoes be more likely to take interrupted feeds on different
 349 hosts (Anderson et al., 2000) then even if the numbers of mosquito per
 350 inhabitant remain the same the risk of transmission will be greater. The risk
 351 of being parasite positive was lower towards the southern end of the
 352 peninsula, which is more exposed to wind and has a lower exposure to
 353 anophelines (Charlwood et al., 2013) than the northern end of the peninsula.

354 The increasing number of people who did not have an associated house
 355 number in the years following the census indicates that, despite its isolation,
 356 there was a considerable movement of people into, and perhaps out of, Linga
 357 Linga. Should people arrive without nets and should there not be a system
 358 that enables them to obtain them, then the risk of transmission will be
 359 maintained. Fortunately in the present study the likelihood of an immigrant
 360 (i.e. a person not included in the 2007 census) having slept under a net the
 361 night before a survey was the same at that of residents who had received a
 362 net during the distribution process. During the distribution process there was
 363 a marked preference for pink nets among the villagers of Linga Linga. Having
 364 had the opportunity to choose the colour of net may have enhanced
 365 utilization and when questioned during the surveys the majority of people
 366 said that they had used a net the night before.

367 Among non-residents 58% of attendees at the clinic came from areas where
 368 active transmission was likely to have occurred and so they may have been
 369 importing malaria into Linga Linga whilst 42% came from urban areas where

370 transmission is low or absent and they would probably have acquired their
371 malaria on the peninsula. Thus, not only do areas like Linga Linga pose a
372 threat to non-immunes (from the cities) but importation of malaria is also a
373 continuing possibility. Importation of malaria will pose problems for future
374 elimination projects in isolated areas like Linga Linga.

375 Elsewhere malaria has been eliminated or appears to be close to elimination
376 in a number of islands in which ACTs and bednets, (Ishengoma et al., 2013)
377 and/or indoor residual spraying of insecticides (Teklehaimanot et al., 2010)
378 combined with active surveillance of cases (Lucas, 2010, Lum et al., 2007)
379 have been used. Although the widespread use of nets may have impacted
380 the mosquito population in 2011 (when the expected rise in numbers was not
381 observed) additional control measures are likely to be needed in places like
382 Linga Linga. Applying shade cloth or old netting over house openings might
383 be useful (Kampango et al., 2013). This has the advantage that it does not
384 dramatically reduce airflow or illumination whilst preventing mosquito entry.
385 Another advantage of such a technique is that once in place it also does not
386 need the householder to do anything to maintain protection. Larviciding the
387 limited number of known breeding sites at the start of the rainy season would
388 be also be an obvious choice (Keiser et al., 2005) as might preventively
389 treating children under nine years of age, the most at risk group, at this time
390 (Aponte et al., 2009).

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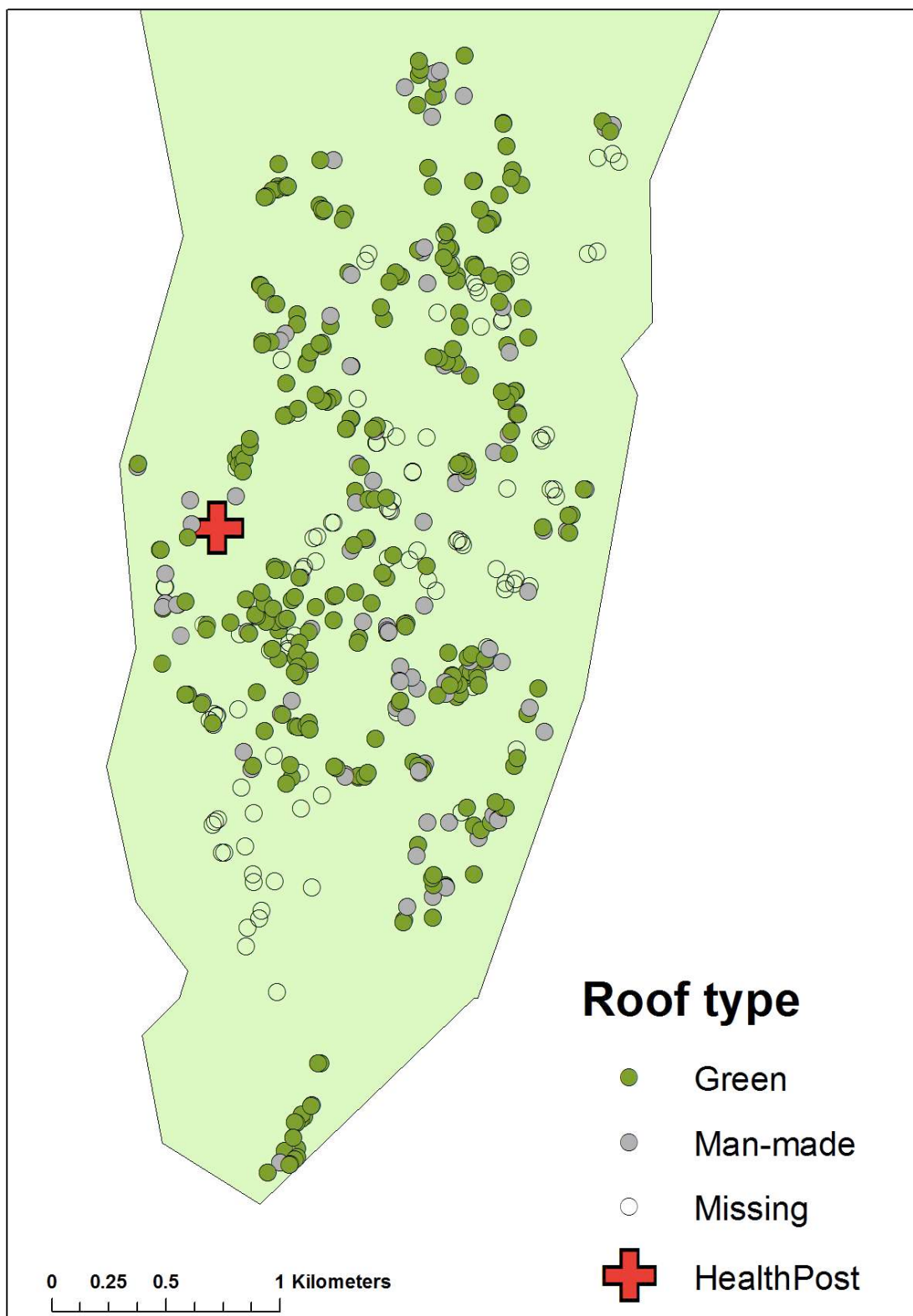
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Figure 1(on next page)

Map of Linga Linga showing the distribution of houses recorded in the census of 2007 according to roof type.



Local transport from Linga Linga to the 'mainland'.

The majority of people who traveled away from Linga Linga did so by boat, making the peninsula a virtual ecological island.



Figure 3(on next page)

Prevalence of *Plasmodium falciparum* by age group and year of survey, Linga Linga, Mozambique.

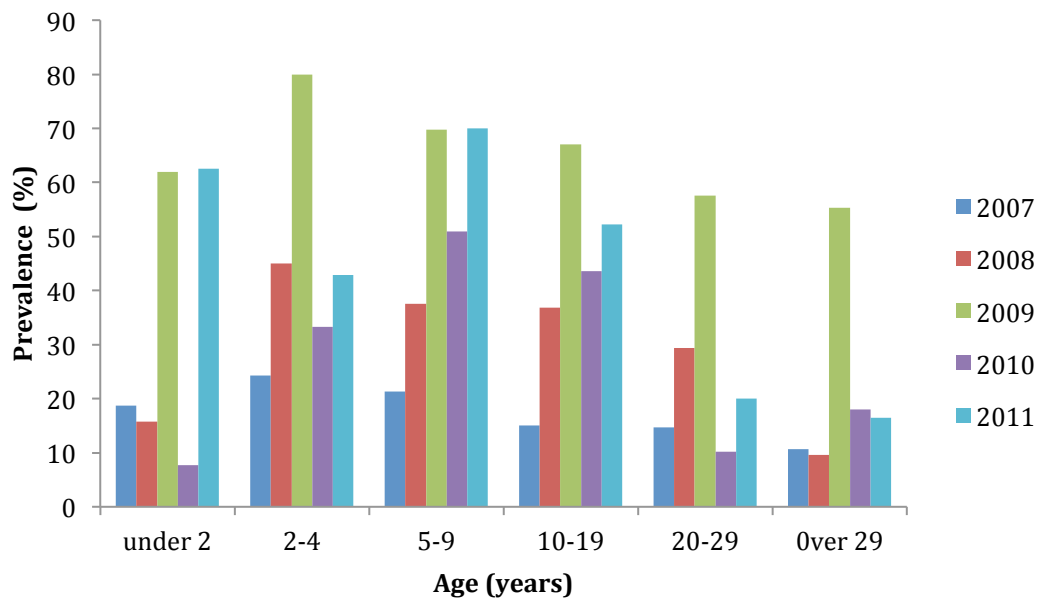


Figure 4 (on next page)

Geometric mean densities of *Plasmodium falciparum* positive people by age group and survey period, Linga Linga, Mozambique

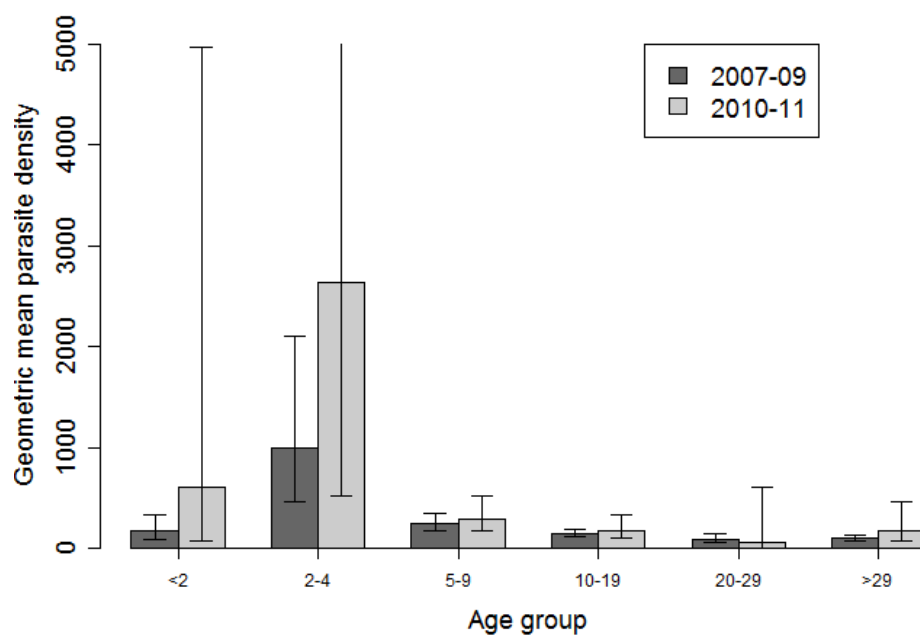


Figure 5(on next page)

Spatial pattern in malaria prevalence

Spatial pattern in malaria prevalence, after accounting for observed risk factors, determined by a Generalised Additive Model (GAM), fitted to the individual-level data. (For details see the supplementary information).

Linga Linga - Smoothed risk

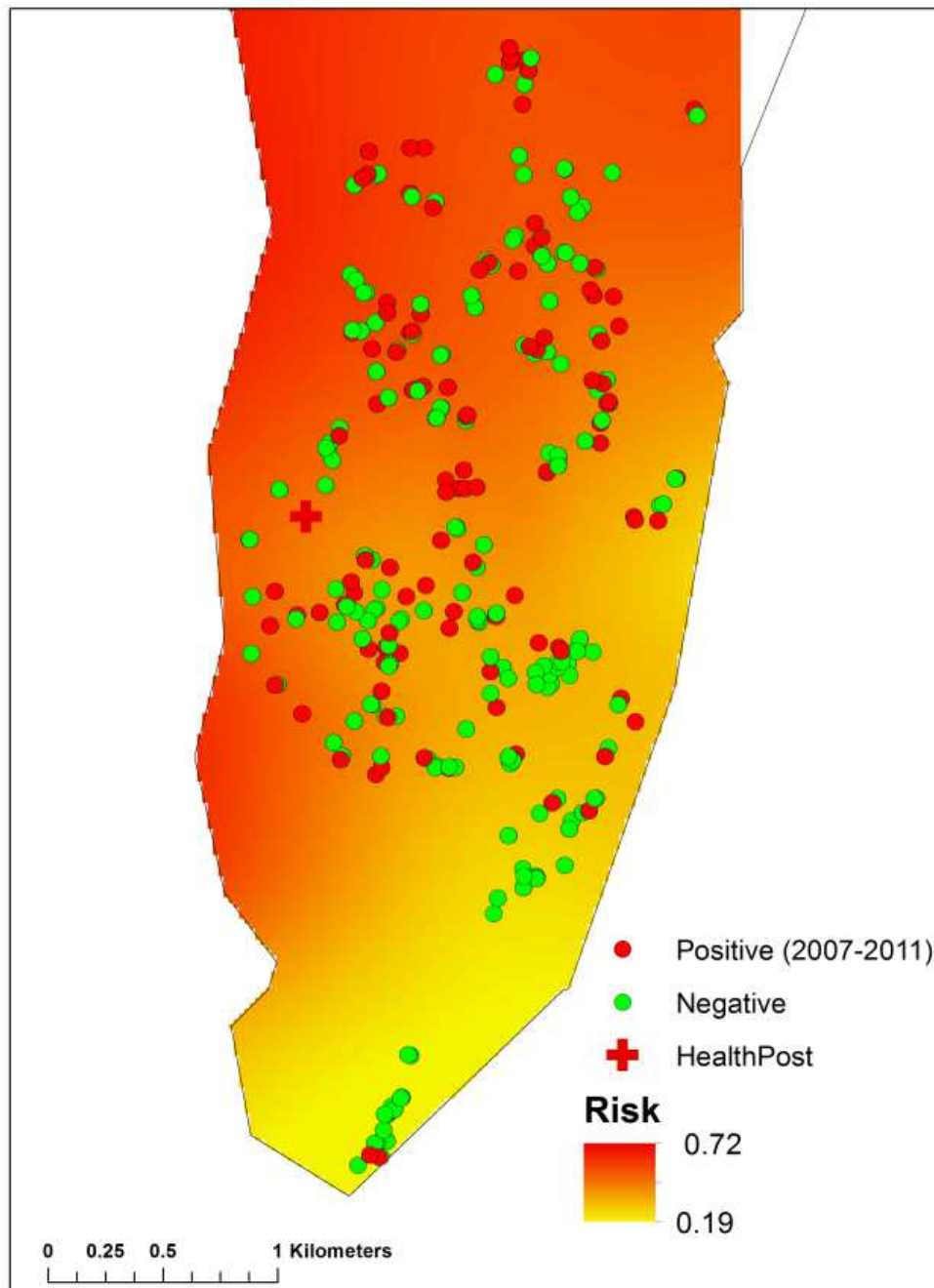
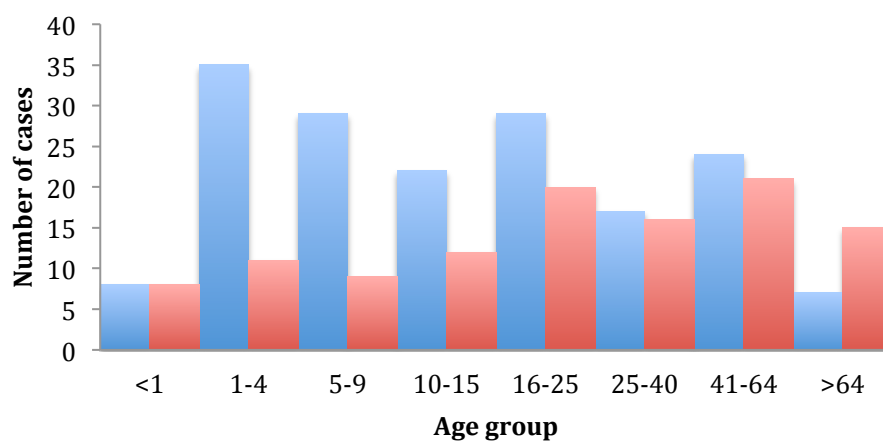


Figure 6 (on next page)

Number of people attending the Linga Linga Health Post (2009-2011) reporting symptoms of malaria by sex and age group and positivity

Males



Females

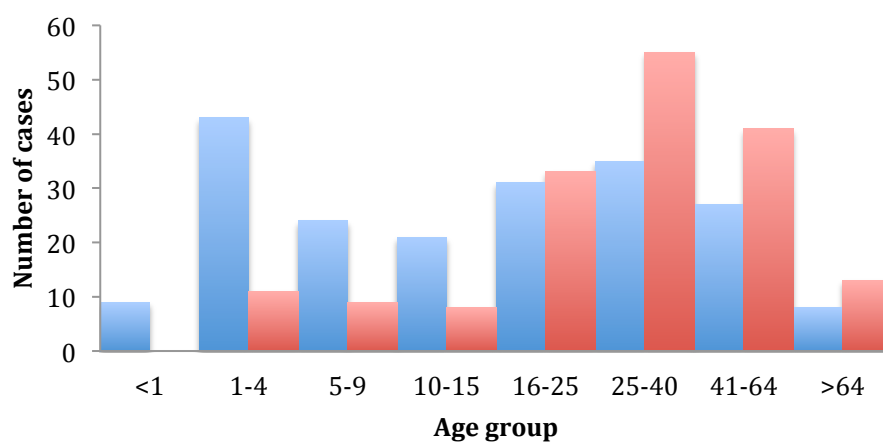


Figure 7 (on next page)

Distribution of people attending the Health Post by location according to the relative number of positive malaria tests performed.

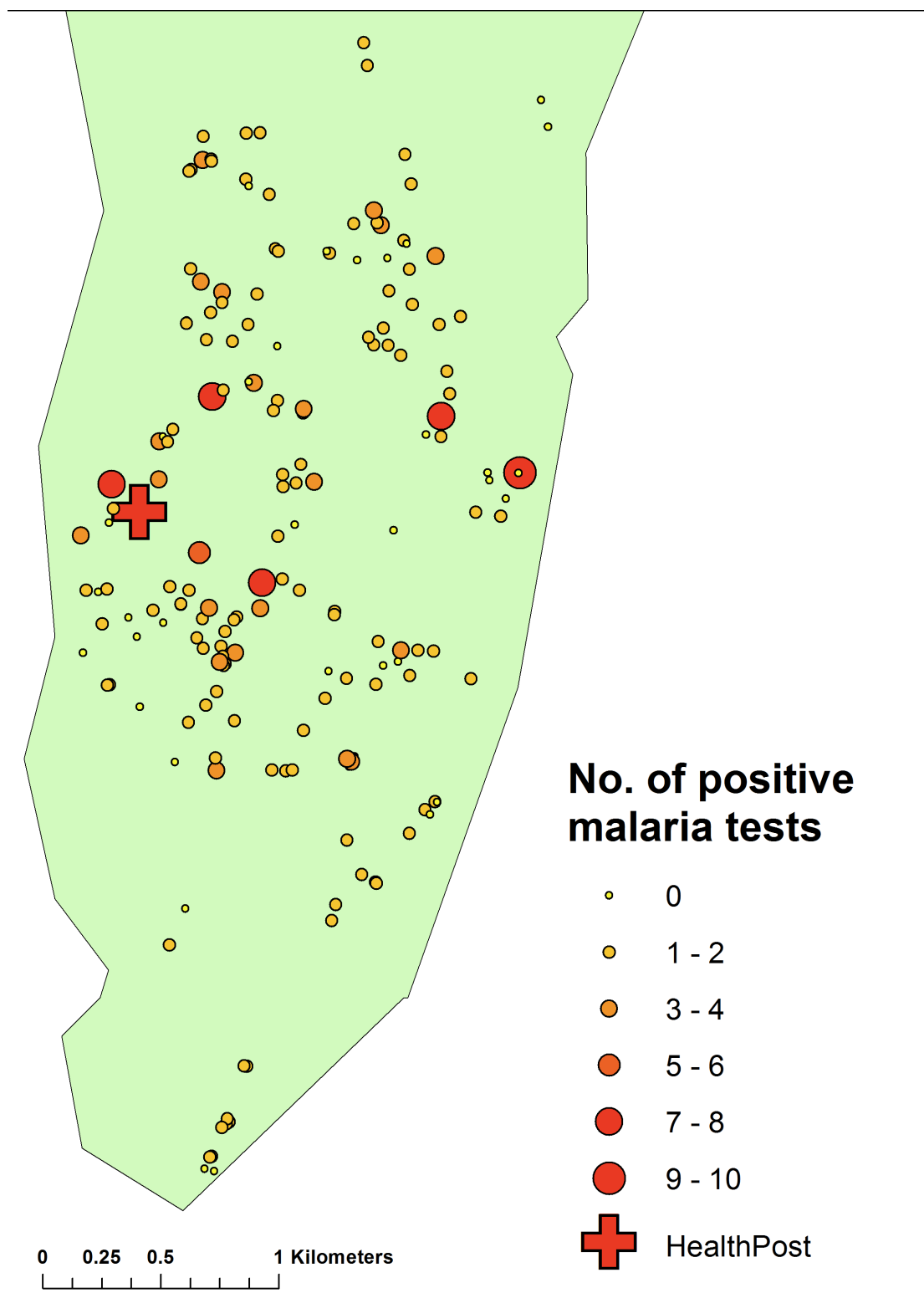
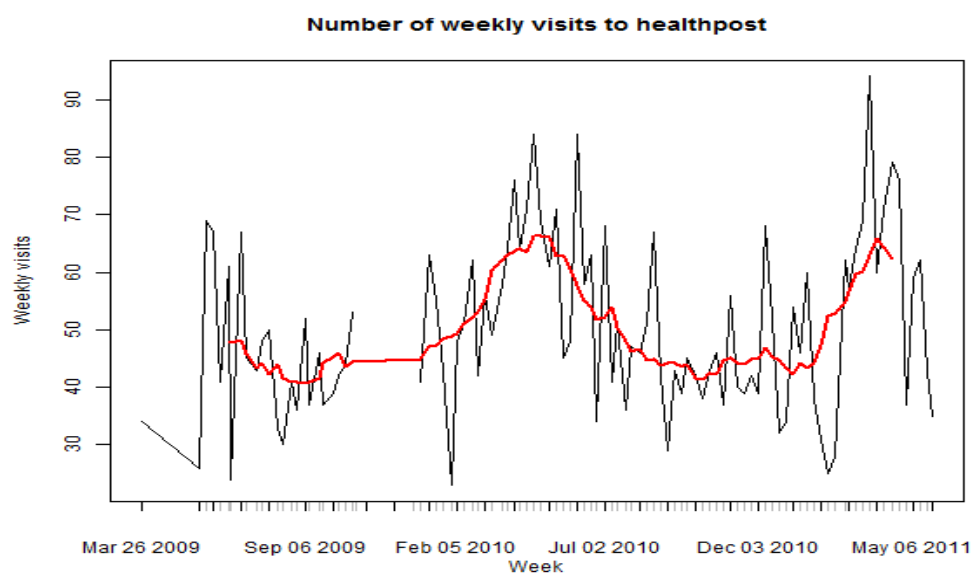
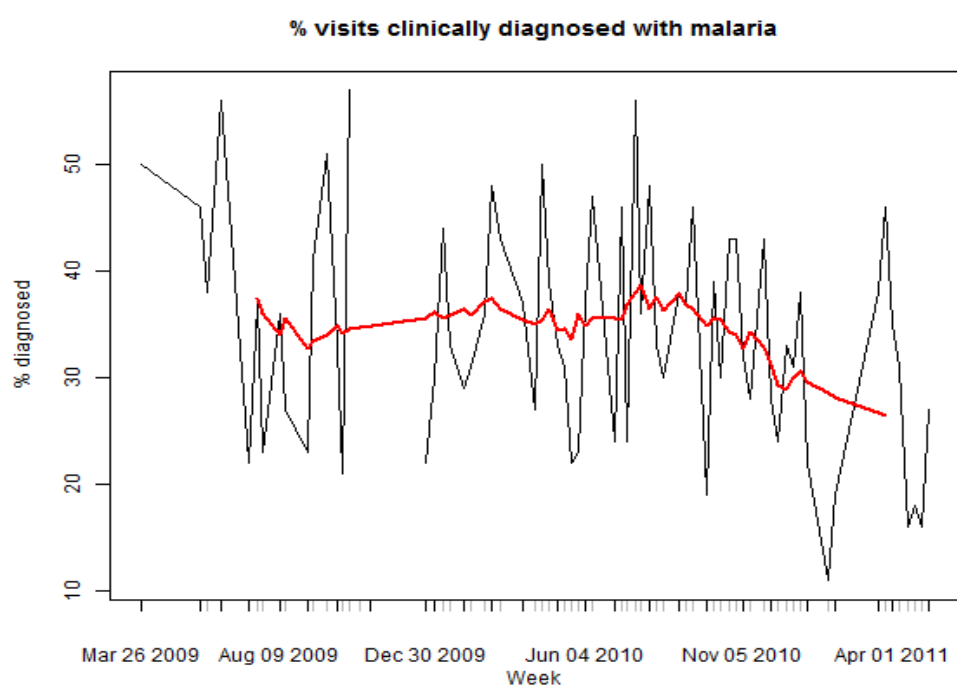


Figure 8 (on next page)

Proportion of patients attending the Health Post diagnosed with malaria 2009 -2011, Linga Linga, Mozambique.



A



B

Table 1(on next page)

Summary of data sets from the prevalence surveys 2007-2011, Linga Linga peninsular, Mozambique.

Year	Raw data				Matched data		
	Number of individuals	% with house number	Number of Houses	% Positive	Number of individuals	Number of Houses	% Positive
2007	411	91%	229	16%	308	179	15%
2008	345	59%	158	34%	191	136	24%
2009	435	68%	183	65%	285	160	67%
2010	398	56%	137	29%	220	127	27%
2011	282	48%	103	44%	131	99	44%
Total	1871	66%	230	38%	1135	332	35%

Table 2(on next page)

Individual and household characteristics by malaria status

Summaries of individual and household characteristics by malaria status and adjusted oddratios obtained from fitting a multiple logistic regression model to the data from malaria prevalence surveys 2007-2011, Linga Linga peninsular, Mozambique

	Malaria test result							
	Positive		Negative		Total	OR	95% CI	p-value
	N	(%)	N	(%)				
Year								
2007	45	(15%)	263	(85%)	308			
2008	46	(24%)	145	(76%)	191	1.9082	(1.10 3.29)	0.0206
2009	190	(67%)	94	(33%)	284	11.3694	(7.29 18.07)	<0.0001
2010	60	(27%)	160	(73%)	220	3.0543	(1.88 5.00)	<0.0001
2011	57	(44%)	74	(56%)	131	4.9673	(2.88 8.63)	<0.0001
Sex								
Female	226	(32%)	472	(68%)	698			
Male	167	(40%)	255	(60%)	422			
Missing	5	(36%)	9	(64%)	14			
Age group								
< 1	12	(27%)	32	(73%)	44			
1-4	39	(44%)	49	(56%)	88	2.7067	(1.04 7.50)	0.0472
5-9	108	(45%)	133	(55%)	241	3.3090	(1.40 8.44)	0.0086
10-15	106	(39%)	167	(61%)	273	2.2208	(0.94 5.64)	0.0783
16-25	21	(21%)	78	(79%)	99	0.7552	(0.28 2.14)	0.5879
>25	83	(27%)	223	(73%)	306	1.1822	(0.50 3.00)	0.7119
NA	29	(35%)	54	(65%)	83			

	Malaria test result							
	Positive		Negative		Total	OR	95% CI	p-value
	N	(%)	N	(%)				
Used net								
<i>No</i>	124	(30%)	289	(70%)	413			
<i>Yes</i>	143	(38%)	229	(62%)	372			
<i>NA</i>	131	(38%)	218	(62%)	349			
No people								
<i>1</i>	46	(26%)	134	(74%)	180			
<i>2</i>	137	(37%)	231	(63%)	368	1.425	(0.86 2.39)	0.1744
<i>3</i>	120	(43%)	160	(57%)	280	1.849	(1.09 3.17)	0.0236
<i>>3</i>	95	(31%)	211	(69%)	306	0.932	(0.55 1.61)	0.7987
No bedrooms								
<i>1</i>	314	(34%)	600	(66%)	914			
<i>2</i>	70	(38%)	113	(62%)	183			
<i>3</i>	14	(38%)	23	(62%)	37			
Own animals								
<i>Yes</i>	248	(35%)	468	(65%)	716			
<i>No</i>	150	(36%)	268	(64%)	418			
Wall category								
<i>Other</i>	53	(39%)	83	(61%)	136			
<i>'Green'</i>	331	(35%)	621	(65%)	952			

	Malaria test result							
	Positive		Negative		Total	OR	95% CI	p-value
	N	(%)	N	(%)				
<i>NA</i>	14	(30%)	32	(70%)	46			
Roof category								
<i>Other</i>	93	(30%)	222	(70%)	315			
<i>'Green'</i>	293	(37%)	501	(63%)	794	2.163	(1.41 3.38)	0.0005
<i>NA</i>	12	(48%)	13	(52%)	25			
Water source category								
<i>House</i>	62	(31%)	138	(69%)	200			
<i>Neighbouring</i>	84	(28%)	214	(72%)	298			
<i>Well</i>	252	(40%)	384	(60%)	636			
Washing category								
<i>House</i>	70	(27%)	188	(73%)	258			
<i>Neighbouring</i>	75	(30%)	175	(70%)	250			
<i>Well</i>	253	(40%)	373	(60%)	626			