Progress towards lymphatic filariasis elimination in Ghana from 2000-2016: analysis of microfilaria prevalence data from 430 communities

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Abstract

Background

Ghana started its national programme to eliminate lymphatic filariasis (LF) in 2000, with mass drug administration (MDA) with ivermectin and albendazole as main strategy. We review the progress towards elimination that was made by 2016 for all endemic districts of Ghana and analyze mf prevalence from sentinel and spot-check sites in endemic districts.

Methods

We reviewed district level data on the history of MDA and outcomes of transmission assessment surveys (TAS). We further collated and analyzed microfilaria (mf) prevalence data from sentinel and spot-check sites.

Results

MDA was initiated in 2001-2006 in all 98 endemic districts; by the end of 2016, 81 had stopped MDA after passing TAS and after an average of 11 rounds of treatment (range 8 – 14 rounds). The median reported coverage for the communities was 77-80%. Mf prevalence survey data were available for 430 communities from 78/98 endemic districts. Baseline mf prevalence data were available for 53 communities, with an average mf prevalence of 8.7% (0 - 45.7%). Repeated measurements were available for 78 communities, showing a steep decrease in mean mf prevalence in the first few years of MDA, followed by a gradual further decline. In the 2013 and 2014 surveys, 7 and 10 communities respectively were identified with mf prevalence still above 1% (maximum 5.6%). Two stopped MDA in 2015 and 2016 respectively, while the rest of the 15 communities above threshold are all within 13/17 districts where MDA is still ongoing.

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65 **Conclusions**

66 The MDA programme of the Ghana Health Services has reduced mf prevalence in sentinel sites
67 below the 1% threshold in 81/98 endemic districts in Ghana, yet 15 communities within 13 districts
68 (MDA ongoing) had higher prevalence than this threshold during the surveys in 2013 and 2014.
69 These districts may need to intensify interventions to achieve the WHO 2020 target.

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Author summary

Lymphatic filariasis (LF) control in Ghana has relied on ivermectin and albendazole since the year 2000 when the Ghana Filariasis Elimination Programme started. We analyzed trends in microfilaraemia prevalence during MDA, reported coverage, and transmission assessment survey using data obtained from the Ghana Health Services (GHS). The median reported treatment coverage varied between 77-80% over the years. Our results show that the treatment in Ghana made a significant impact in reducing infections <1% in majority of sentinel sites in endemic districts (81/98) by 2016. In the remaining 17 districts, extra efforts may be needed to achieve the same goal. Some of the challenges could be low coverage in some communities, high baseline endemicity, programme logistical challenges etc. The required average rounds of MDA needed for elimination was 11, higher than that proposed by the Global Filariasis Elimination Programme. This article is relevant to LF control programmes in assessing the impact of MDA. It is important for programmes to monitor infections especially within communities where mf prevalence is still above the 1% threshold to ensure that the WHO 2020 elimination target is achieved.

Introduction

Lymphatic filariasis (LF), commonly known as elephantiasis, is a debilitating and disfiguring tropical disease caused by lymphatic-dwelling filarial parasites *Wuchereria bancrofti, Brugia malayi* and *Brugia timori*. The disease is transmitted by different species of mosquitoes depending on the geographical location, including *Culex*, *Anopheles* and *Aedes* species. About 90% of the worldwide cases are caused by *W. bancrofti* and 10% caused by *B. malayi* and *B. timori*. Based on re-assessment of the global prevalence and distribution of LF [1], more than 120 million people were found to be infected and 40 million disfigured and incapacitated in the year 2000 [2]. In the same year, the Global Programme to Eliminate Lymphatic Filariasis (GPELF) was established, aiming to eliminate the disease as a public health problem by 2020 through annual mass drug administration (MDA) with albendazole in combination with diethylcarbamazine citrate (DEC) or ivermectin to all individuals at risk [3].

By the end of 2016, 20 out of 73 countries originally listed by WHO as being endemic for LF have stopped interventions after passing the first transmission assessment survey and are conducting surveillance to validate elimination. Additional 30 countries have delivered MDA at least once in all endemic areas and are also on track to achieve elimination [4]. While many have passed the TAS, there are also reports of failure [5] and of ongoing transmission in spite of passing the TAS [5-7].

A national survey carried out in Ghana in 1994 showed that the microfilaraemia prevalence varied from 0 - 20% between regions [8]. In the highly-endemic Kassena Nankana district (Upper East Region of Ghana), the prevalence of hydrocele was 30.8% and elephantiasis of the leg was 3.8%

in the population aged 10 years and above [9,10]; 12% of extended families reported to have at least one family member with elephantiasis of the leg [10]. The extensive mapping of endemic communities [11] provided a database on areas in Ghana and neighboring countries that needed more efforts to eliminate the disease.

The LF elimination programme in Ghana started in 2000 and gradually scaled up over the years and by 2006 all endemic districts were covered. The implementation and outcomes by district were described in two recent papers [12,13]. By 2016, 81 of 98 initially endemic districts had reached an mf prevalence <1%, had passed TAS survey and stopped MDA, while the remaining districts still had mf prevalence >1% [13] in spite of at least 10 years of MDA. The required duration of MDA turned out to be longer than the anticipated 5-6 years, which might be due to relatively high baseline mf prevalence levels. There were no major differences with other districts in reported coverage of MDA or long-lasting insecticide treated bednets [13].

Expected trends in infection during MDA will depend on multiple factors, including local baseline endemicity (depending on local transmission conditions) and the achieved coverage and compliance with MDA. To obtain better understanding of these factors, in this paper we present and analyze community-level data from microfilaraemia prevalence surveys and transmission assessment surveys (TAS) from sentinel and spot-check sites for all endemic districts in Ghana. So far, this study represents the longest and largest LF programmatic study in Africa.

Methods

Ghana Filariasis Elimination Programme

The Ghana Filariasis Elimination Programme (GFEP) was established in June 2000 following the establishment of the Global Programme to Eliminate Lymphatic Filaraisis. Mapping of communities started in 2000 using the 50-km sample grid, rapid assessment procedure for antigenaemia in sample villages and spatial analysis to plot prevalence contours from 2000 to 2001 [11,14]. Forty nine districts were initially identified as endemic and therefore selected for implementation of MDA. The GFEP implementation, programme outcomes, challenges and districts re-demarcation have been described in Biritwum *et al*. (2017a). Based on current demarcation, 98/216 districts (45%) are endemic with LF in Ghana.

The treatment implemented in Ghana was the combination of ivermectin (150 µg/kg) and albendazole (400 mg) given annually by the community-directed treatment approach [15] and implemented at the district level. MDA usually took place between March and June in all endemic communities across the country. Individuals eligible for treatment were those aged ≥5 years (excluding pregnant women, lactating mothers and the sick), and selection was solely based on height (≥90 cm) for those whose ages were not known. MDAs usually lasted for about 1 - 2 weeks per community. Individual treatment information (whether treated, absent, pregnant, sick, etc) was recorded in the community treatment book and summarized into treatment records by the Ghana Health Services (GHS). Community-level treatment coverage data (number treated out of total population at risk) across the country were reviewed and summarized by the GHS. For the purpose of this study, summary reports were reviewed.

There was no treatment offered in 2011 due to logistic and funding challenges; 2009 and 2012 treatment data were not available.

Monitoring and evaluation

Parasitological surveys

Parasitology data were collected by the GHS in programmatic yearly surveys (2000 - 2014) in selected endemic communities. In 2000, baseline mf surveys were carried out in 24 purposefully selected endemic communities (based on known high endemicity and population stability) [16,17] from the 8 districts where MDA was first initiated . From 2001-2004, baseline mf surveys were done in sentinel sites of remaining districts, as MDA was being extended into these districts. Subsequently, the previously selected sentinel sites per district were repeatedly surveyed to monitor progress to elimination (usually once every 2 or 3 years, but sometimes the interval was much longer due to financial constrains). Additional surveys were done in spot-check sites (same characteristics as sentinel) that were surveyed only once and often selected randomly from the same district where sentinel site is located to cross check the MDA performance in that district.

The mf surveys were usually done at the end of the year between November and December (before MDA treatment was done the following year between March-July). The target number of persons for sampling increased over time based on WHO guidelines; between 2000 - 2002 the target was 100 persons per community, between 2003 - 2009 it was 500 persons, and after 2009 it was 1000 - 1500 persons. The surveys were usually preceded by a community gathering or announcement by the team informing members of the community to converge for the night blood collection (9pm - 2am). Those selected for sampling were verbally consenting individuals (parent consented for

their children) aged ≥ 5years or with height ≥ 90cm height for those whose ages were not known, including pregnant women and lactating mothers. Blood was sampled from these individuals by finger pricking (middle or forth finger) and a volume of 60µl taken for thick blood smear test (2000 - 2009) [18]. In later years (2010 - 2014), the volume of blood sampled was increased to 100µl and the microfilariae were counted using a regular microscope with a rafter counting chamber [19], by trained GHS laboratory technicians.

Transmission assessment surveys

The transmission assessment surveys (TAS) in Ghana followed the WHO guidelines, using antigenaemia prevalence in children aged 6 - 7 years as indicator of active transmission of LF [20]. TAS has a different sampling system and a different target population than a full mf survey. In Ghana, the elimination programme used a district as an implementation unit (IU) for MDA. The evaluation unit (EU) to assess progress of programme may also be a district or a cluster of districts with a population not more than 2 million. In some of the cities where the district population was more than 2 million, the district was divided into different EUs. An EU qualified to be assessed after achieving treatment coverage of ≥65% for 5 years and also recording mf prevalence of <1%. Those EUs who met the criteria were selected for the TAS. The TAS involved sampling of children 6 - 7 years in primary schools within the EU after written consent from their parents. The schools to be surveyed, the number of children to be tested and the critical cut-off point (maximum number of positives to fail TAS) were estimated using a survey sample builder software recommended by WHO [21]. A volume of 100 µl blood was taken from the children by finger pricking and test done using immunochromatographic card test (ICT) [22]. The EUs where the number of positive children was less than the critical cut-off point, passed the TAS (TAS-1) and the MDA was stopped

after the last treatment. The MDA stop decision is based on TAS-1. After stopping MDA, two more TAS surveys (TAS-2 & TAS-3) are done after 2 - 3 years and 5 years respectively before elimination said to be achieved. During TAS-1, the EU with number of positive children above the critical cut-off point, failed the TAS and continued MDA for 2 - 3 years. In such EUs, a community survey was required to achieve an mf prevalence of <1% before TAS-1 was repeated [13].

Data collation and analysis

The longitudinal parasitological and treatment data from 2000 - 2014 were collated along with background information from the GHS and updates on TAS results till early 2016. Parasitological data comprised of number examined and number that were microfilarial positive in each community. Community mf prevalence was estimated as the number of microfilarial positives as a percentage of number examined. Mean mf prevalence (for districts and country) were calculated by estimating the percentage of total positive / total examined and total treated / total population of communities included in the sample respectively. We present data on community, district and country level.

Data limitations and special situations

We only consider mf prevalence data in our analysis of community-level trends in infection prevalence. No mf prevalence data were available for 2001 and data for 2002 were limited to few sites, as all community surveys in 2001 and part of the survey in 2002 only used ICT antigenaemia tests. For 3 districts in 2003 (with 2 communities surveyed per district) and all districts in 2005 (with 3-4 communities surveyed per district) mf prevalence was not reported for each community

222 separately, and we only know the overall mf prevalence - aggregated over the surveyed
223 communities. These aggregated data points were included in combined trends (averages) for all
224 communities, but were not matched to community specific data for analysis for time trend analysis.
225 There were no mf surveys carried out in 2006. Mf prevalence data in 2008 and 2010 were excluded
226 from trends and analysis since communities sampled in these years were not randomly selected
227 (mf data from individuals closely related to school children who were positive using ICT during
228 school surveys).
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230 **Ethics Statement**

231 Ethical clearance was obtained from the Ghana Health Service Ethical Review Committee (ID
232 NO: GHS-ERC-10/0/06) and the Liverpool School of Tropical Medicine's Research Ethics
233 Committee's Research Protocol Approval (06.47). The study obtained oral informed consent from
234 adult participants while parents and guardians orally consented for their children and wards to be
235 part of this study. Due to the programmatic nature of the study with regular MDA and mf surveys
236 done in many sites, participants in these communities were aware of the program. Given that the
237 communities were mainly rural with study participants having minimal or no education and being
238 suspicious of signing documents they did not well understand, oral consent was applied and noted
239 as part of questionnaires during the surveys. Oral informed consent was approved by the Ghana
240 Health Service and Liverpool School of Tropical Medicine's ethical review committees.
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Results

Overview of MDA implementation in Ghana

MDA started between 2000 and 2001 in 10/98 districts selected from the northern and coastal regions of Ghana. In 2002, 17 more districts were enrolled onto the MDA programme and in 2003, 2004 and 2005 a number of 27, 16 and 25 more districts were enrolled onto the MDA programme respectively. By 2006 all the 98 endemic districts had been enrolled (Figures 1 and 2, Table 1). All communities in each district were expected to be treated in the same year MDA started, thus geographical coverage within a district was expected to be 100%.

Reported coverage of MDA by calendar year in Ghana

The median reported treatment coverage in treated districts of Ghana seemed to be constant over time, around 77 - 80% between 2000 – 2010, and the interquartile range and distribution of outliers are also similar over time (Figure S2). Although mean reported coverage per year seem to be high, there are large differences between communities. Community-level coverage estimates varied from 10 to 120%, with at least 7952/41265 (19.3%) surveys having a coverage under 65% and 198/41265 (0.5%) surveys over 100%, indicating wrong denominators.

Fig 1: Implementation of district-level MDA in Ghana. A) Period of MDA by each district in order of start year. Each horizontal line represents a district. Bars with a dashed section on the right-hand side represent districts where MDA is still ongoing after 2016 with unknown end year. See supplementary Table S2 for more details. B) Frequency distribution of the number of treatments provided by district through 2016, presented separately for districts that had stopped MDA by 2016 and those with still ongoing MDA.

TAS was done in 5 districts in 2010, and all passed. Another 65, 9 and 2 districts had their first TAS in 2014, 2015 and early 2016, respectively and all passed. By the end of 2016, 81 out of the 98 endemic districts had passed the TAS in Ghana and had stopped MDA (Figures 1 and 2). 17

are left, of whom 4, 3, 8, 1 and 1 district have done 11, 12, 14, 15 and 16 rounds of MDA, respectively (see Table S2, supplementary data for details). The average number of treatment rounds in districts that stopped MDA was 11 rounds, varying from 8 – 14. In 6 communities that were re-surveyed in 2014 for mf prevalence after stopping MDA in 2010, mf prevalence was always below <1%. TAS-2 was performed in 69 districts in 2012 or 2015, and all districts passed. Details of the TAS surveillance in Ghana are given in Table S2, supplementary data.

Fig 2: Progress of MDA implementation in Ghana. NB: In the year 2011, there was no treatment due to some logistical challenges. The maps give an overview of the treatment progression to cover all the endemic districts in Ghana.

Trends in Mf prevalence

Mf prevalence data were available from 613 community mf surveys (datapoints), carried out between 2000 to 2014 in 430 communities (292 sentinel sites; 138 spot-check sites) in 78 out of the 98 endemic districts (within 8/10 regions of Ghana). Twenty districts were not represented in our compiled database, either because only antigenaemia data or TAS data were available or because no surveys had been done after re-demarcation of districts. 352 communities were measured only once and 78 measured multiple times (sampled between 2-6 times). Out of those measured multiple times, 35 communities also had data including baseline. Most of the single time point surveys were observed after 2007 (Figure 3A). Overall, the total number of individuals sampled per year ranged between 1,784 – 19,268 (Table 1).

Baseline mf prevalence

Baseline parasitological surveys were carried out in the years 2000 - 2004, before the start of MDA, examining 7,882 individuals from 53/430 communities within 21/98 districts. The number

of individuals examined per community at baseline ranged between 52 - 441 (mean 137, median 112). The average mf prevalence at baseline was 8.7% (range 0-45.7%) with the highest recorded in Gyahadze located in the central region of Ghana (See supplementary Table S1).

Trends in mf prevalence over time (2000-2014)

Community-level mf prevalence data are presented by calendar year (Figure 3A). The impact of MDA on mf prevalence cannot clearly be seen from this figure, due to the differences between communities in start year of MDA. In Figure 3B, therefore, the same data are presented by time since first treatment, while Figure 3C presents these data in boxplots to better visualize the distribution of the observed community-level mf prevalence. From these data, we conclude that the variation in baseline prevalence was huge. The mean and median mf prevalence in surveyed communities declined strongly with increasing duration of MDA. The small increase in median prevalence observed 1 year after the onset of sampling is a selection effect and does not indicate a lack of impact, because surveys were only done in districts with a relatively high baseline mf prevalence. Although 6-7 years after the onset of MDA the median prevalence had fallen below 1%, there was still huge variation between communities and many communities still had mf prevalence levels above 5%. The number of districts and communities surveyed declines over time, because districts that have stopped MDA are no longer included in surveys. In addition, surveys were selectively performed in communities in districts with low reported coverage or relatively high prevalence in previous surveys. For these reasons, trends in mean and median mf prevalence of surveyed villages during later stages of the control are difficult to interpret. Yet, we still see a continued decline in the maximum observed prevalence levels with increasing duration of MDA. In most communities with multiple measurement the mf prevalence steadily decreased over time, but 12 out of 78 (15%) communities had at least once an increase between 2 time points (Figure

3A & B). In the 2013 and 2014 surveys, 7 and 10 communities respectively were identified with mf prevalence still above 1% (maximum 5.6%). Only 2 stopped MDA in 2015 and 2016 respectively. The rest of the 15 communities above threshold are all within 13 out of the 17 districts where MDA is still ongoing.

In 34 districts, one or more communities were surveyed at least twice during the period of MDA. Data for these districts are shown in supplementary file Figure S1. When community data were aggregated at district level, there was a general decrease in average mf prevalence over time to approach zero in most districts (Figure S1, red line). In 4 districts (Bongo, Jirapa, Lambussie-K and Lawra) there were slight increases in mf prevalence after baseline before decreasing steadily. Almost all the districts we assessed, apart from two (Lawra and Wa-West), showed mf prevalence less than 5% after 6 years of MDA (Figure S1, supplementary data). In 31 out of these 34 districts (91%), mf prevalence eventually fell below <1% after 6 - 14 rounds of treatment; this was not the case in three districts (Bole, Jirapa and Wa-West) where the mf prevalence was still ≥1% in 2013 or 2014 and MDA is still ongoing. 51 out of the 78 examined districts/IUs (65%) needed more than 6 rounds of MDA to reach mf prevalence of <1%.

Fig 3: Observed lymphatic filariasis mf prevalence in sentinel and spot-check sites in Ghana, measured in the population aged 5 and above, for the period 2000-2014. A) Data presented by calendar year. Multiple observations from the same community are connected through thin grey lines. Observations from communities surveyed only once are highlighted in red. Observations presenting aggregated prevalence over multiple communities are displayed in blue (in 2003 and 2005). Dashed lines represent the average prevalence from all surveyed communities at each time point. Bullets at the same time point have been jittered to avoid overlapping of points at the same position; these do not represent time in months. B) As panel A but with time since first treatment on the horizontal axis. C) As B, but with data summarized in boxplots. The box at each time post treatment represents the interquartile range of mf prevalence in ≥5 years and the thick horizontal lines across each box represent the median mf prevalence. The bullets outside each box (above or below) represent the outliers and are defined as 1.5 times the interquartile range above or below the ends of the box (25^{th} and 75^{th} percentile). The vertical lines (whiskers) extend to the first value (mf prevalence) before the outlier cut-off and where there are no outliers, they represent the minimum and maximum mf prevalence at each time post treatment. The numbers in the boxes are the total number of communities examined at each time post treatment.

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Discussion

Ghana has made good progress towards elimination since the start of its elimination programme in 2000. The baseline mf prevalence in sentinel sites was 8.7% on average, ranging from 0 to 45.7%. The mf prevalence declined steeply during the first few years after starting MDA in communities, followed by a more gradual decline thereafter (Figure 3A). Surveys performed after 6-7 rounds of MDA showed high variation between communities in mf prevalence, with the mf prevalence often exceeding 1% or even 5% (Figure 3B & C). By the end of 2016, 81 out of 98 endemic districts had stopped mass drug administration (MDA) after an average of 11 rounds of treatment (range 8 – 14). Currently, treatment is still ongoing in 17 districts in Ghana.

We have created a unique longitudinal database on the long-term impact of MDA for lymphatic filariasis (LF) elimination in Ghana, containing data from 430 sentinel and spot-check sites. There are at least 12 countries that have reported longitudinal trend data on at least 3 microfilaria (mf) prevalence surveys of LF after at least 3 rounds of MDA, of whom 5 in Africa: Tanzania, Kenya, Nigeria, Egypt and Mali [23-28]. These African studies have reported the impact of 4 - 10 rounds of MDA on antigenaemia/mf prevalence within 4 - 20 sentinel/study sites where about 50 - 2000 participants were tested per year. Since we have more data (15 years MDA, 430 communities, 1,784 - 19,268 participants), this gives us more insight into the impact of MDA on mf prevalence, the dynamics involved over a period of time and the variability in outcomes between sites.

At country-level we observed huge variation in baseline endemicity level and trends towards elimination (Figure 3 A&B). Patterns became clearer with less variation within districts when we plotted and analyzed data by districts (Figure S1). For some districts only few observations were

available, especially in districts with relatively low baseline prevalence, where elimination was relatively rapidly achieved, obviating the need for further surveys. In districts with relatively high baseline mf prevalence, sometimes many rounds of MDA were needed to ensure that mf prevalence reach below 1%.

When GPELF was initiated, it was expected that elimination could be reached after 5 or 6 rounds of MDA with good coverage – ≥65% [3,29]. Although few countries were indeed able to reach elimination within the 5 - 6 years of MDA [2], the required treatment duration in Ghana was always longer, often considerably longer. This experience can help other African countries with planning their interventions. Previous modelling studies already suggested that 5-6 rounds of MDA would not be enough in case of low coverage and/or high baseline endemicity [7,30-32], and the same factors may explain why the required treatment duration in some Ghanaian districts is much longer than in others [13].

Our data confirm the importance of baseline endemicity for the required treatment duration, but the role of coverage was more difficult to proof. Reported coverage data at community level were collated for all endemic district of Ghana (see supplementary data; Figure S2 for details). Although the reported coverage was good for the majority of communities, coverage levels <50% are also frequently encountered. However, such data are notoriously unreliable, as also becomes clear from the frequent occurrence of reported coverage levels >100% and hence difficult to interpret [33]. Low coverage is problematic, particularly if it is sustained over multiple treatment rounds. We could not assess the importance of this phenomenon in our data, as it appeared difficult to match

400 coverage data from subsequent years at community level and to match them to the mf prevalence
401 data.
402
403 The high variation in mf prevalence after a given number of treatment rounds within districts, as
404 observed in Ghana (this study) and elsewhere [5-7] complicates decision making. If communities
405 with high residual mf prevalence are by chance not included in surveys, MDA may be stopped
406 prematurely with danger of resurgence [5]. This could be prevented by targeting pre-TAS surveys
407 to communities at high risk of residual transmission. High risk may occur due to programmatic or
408 demographic factors [12], including migration during treatment period, treatment fatigue, high
409 numbers of middle aged women (child bearing age; majority not taking drug due to pregnancy)
410 etc. Other local factors contributing to transmission may be high biting rate of the mosquitoes and
411 behavior of residents that influence exposure to mosquito bites [32,34]. Moreover, TAS is
412 designed to cover a larger geographical area, with the hope that pockets with residual transmission
413 would be identified in TAS surveys. However, it is unclear whether TAS is sufficiently sensitive
414 to pick up such pockets since not all communities within the evaluation unit (district) are sampled,
415 furthermore, some have reported transmission ongoing in spite of passing TAS [5,6]. Thus, the
416 validity of TAS for longer-term post-MDA surveillance requires further investigation [35].
417
418 We could not assess this in the current study, as most districts are usually not resurveyed shortly
419 after stopping MDA. We have data for only 6 communities surveyed after stopping MDA, and all
420 showed mf prevalence <1%.
421 Our data had some limitations. Firstly, we only considered mf data, as antigenaemia prevalence
422 data were not always collected. Survey sites (apart from spot-check sites) were not randomly

423 chosen, but rather based on previous results and location, and most mf sites have been surveyed
424 only once. The low number of persons sampled combined with less sensitive mf tests in early years
425 makes the mf prevalence observed in early years less reliable (wide 95% CI, data for baseline
426 shown in supplementary data, Table S1). Also, the selection of participants for night blood
427 collection in each community was also not random since some households were more likely to
428 attend than others. This is particularly problematic if those not participating in surveys are also
429 more likely not to participate in MDA, resulting in biased and possibly flattered mf prevalence
430 estimates.
431

432 Conclusions and recommendations

433 The Ghana Filariasis Elimination programme has had large impact, reducing mf prevalence <1%
434 in 81/98 endemic districts. The remaining 17 districts still need MDA but also seem to be
435 approaching elimination. There was variation in the required treatment rounds between and within
436 districts. Stopping MDA must be done with caution, taking into account the risk that communities
437 with residual transmission remain which could present a source for the resurgence of infection
438 after stopping MDA. Monitoring at the community level is required to be maintained to sustain
439 the gains that have already been made towards elimination of LF in Ghana.
440

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Table 1: Assessment of mf prevalence

Assessment of mf prevalence	2000	2001 *	2002	2003 *	2004	2005 *	2006 *	2007	2008 *	2009 *	2010 *	2011	2012 *	2013	2014	2015	2016
No. of IUs that started MDA	1	9	17	27	16	25	3	0	0	0	0	0	0	0	0	0	0
No. of IUs that stopped MDA	0	0	0	0	0	0	0	0	0	0	5	0	0	0	65	9	2
No. of communities included in mf prevalence surveys (No. of districts)	24 (8)	0 (0)	10 (5)	40 (18)	25 (12)	34 (10)*	0 (0)	59 (9)	0 (0)	111 (21)	0 (0)	109 (31)	103 (19)	24 (13)	74 (16)	-	-
No. of people examined for mf	2,607	–	1,784	4,603	2,933	4,579	–	7,643	–	15,175	–	15,675	19,268	11,026	13,901	-	-
Average mf prevalence (%) in examined communities (range)	23 (11-46)	–	2.8 (0-12)	7.1 (0-28)	8.1 (0-34)	2.0 (0-4)	–	3.5 (0-21)	–	2.4 (0-18.8)	–	0.23 (0-15)	0.68 (0-9.8)	0.85 (0-3.7)	0.57 (0-5.6)	-	-
No. of communities with mf prev >1% (%)	24 (100)	–	5 (50)	25 (62.5)	17 (68)	6 (60)	–	37 (62.7)	–	44 (39.6)	–	3 (2.8)	18 (17.5)	6 (25)	10 (13.5)	-	-

IU = implementation Unit, MDA = mass drug administration, Com=community, Cov=coverage, prev=prevalence, mf=microfilaraemia, No. = number

*Refer to Data limitations and Special situations above.

Supporting Information

S1 Checklist: STROBE Checklist

Table S1: Community-based Mf prevalence at baseline in year 2000 - 2004

Region	District	Community	Year of sampling	No. examined	No. positive	Mf prevalence % (95%-CI)
Brong-Ahafo	Techiman-Municipal	Kwesi-Gyan	2004	138	4	2.9 (0.1 - 5.7)
Brong-Ahafo	Techiman-Municipal	Nsokonee	2004	151	10	6.6 (2.7 - 10.6)
Brong-Ahafo	Techiman-Municipal	Tandanafo-1	2004	141	1	0.7 (0 - 2.1)
Brong-Ahafo	Techiman-Municipal	Tandanafo-2	2004	100	0	0.0
Central	Agona-East	Essusu	2002	84	10	11.9 (5 - 18.8)
Central	Agona-East	Kwesi-Paintsil	2002	52	0	0.0
Central	Effutu-Municipal	Ateitu	2000	103	16	15.5 (8.5 - 22.5)
Central	Effutu-Municipal	Atekyedo	2000	72	9	12.5 (4.9 - 20.1)
Central	Effutu-Municipal	Gyahadze	2000	92	42	45.7 (35.5 - 55.8)
Central	Effutu-Municipal	Gyangyanadze	2000	139	33	23.7 (16.7 - 30.8)
Central	Effutu-Municipal	Nsuekyir	2000	108	19	17.6 (10.4 - 24.8)
Central	Effutu-Municipal	Osubonpanyin	2000	92	25	27.2 (18.1 - 36.3)
Central	KEEA	Ankwanda_Teterem*	2003	400	3	0.8 (0 - 1.6)
Eastern	Ayensuano	Kofi-Pare	2004	277	0	0.0
Eastern	Ayensuano	Kwaboanta	2004	100	0	0.0
Eastern	Ayensuano	Onakwase	2004	142	5	3.5 (0.5 - 6.6)
Greater-Accra	Ga-West	Kofi-Quaye	2004	191	0	0.0
Greater-Accra	Ga-South	Kudehia	2004	188	1	0.5 (0 - 1.6)
Greater-Accra	Ga-South	Obom	2004	104	0	0.0
Northern	East-Gonja	Kalande_Kpembe*	2003	486	0	0.0
Northern	East-Mamprusi	Namaasim	2002	273	0	0.0
Northern	East-Mamprusi	Zaadantinga	2002	230	1	0.4 (0 - 1.3)
Northern	West-Mamprusi	Wungu	2002	441	5	1.1 (0.1 - 2.1)

Northern	Yendi	Adibo	2004	200	0	0.0
Northern	Yendi	Bumbung	2004	184	8	4.3 (1.4 - 7.3)
Northern	Yendi	Kulkpeni	2004	132	9	6.8 (2.5 - 11.1)
Upper-East	Bawku-Municipal	44	2002	104	6	5.8 (1.3 - 10.3)
Upper-East	Bawku-Municipal	Zawsie	2002	265	5	1.9 (0.2 - 3.5)
Upper-East	Bawku-Municipal	Ziako	2002	136	10	7.4 (3.0 - 11.7)
Upper-East	Builsa-North	Achangyeri	2000	102	26	25.5 (17.0 - 33.9)
Upper-East	Builsa-North	Chuchuliga-Namonsa	2000	107	22	20.6 (12.9 - 28.2)
Upper-East	Builsa-North	Kpandema	2000	121	29	24.0 (16.4 - 31.6)
Upper-East	Builsa-North	Pilsa	2000	111	26	23.4 (15.5 - 31.3)
Upper-East	KND-Municipal	Biu	2000	110	31	28.2 (19.8 - 36.6)
Upper-East	KND-Municipal	Korania	2000	121	43	35.5 (27.0 - 44.1)
Upper-East	KND-Municipal	Namolo	2000	126	41	32.5 (24.4 - 40.7)
Upper-East	KND-West	Baduna	2000	112	24	21.4 (13.8 - 29.0)
Upper-West	Daffiama-BI	Touri	2000	108	17	15.7 (8.9 - 22.6)
Upper-West	Sissala-East	Banu	2000	113	35	31.0 (22.4 - 39.5)
Upper-West	Sissala-West	Bouti	2000	109	12	11.0 (5.1 - 16.9)
Upper-West	Sissala-West	Sorbelle	2000	99	26	26.3 (17.6 - 34.9)
Western	Ahanta-West	Asemasa	2000	98	17	17.3 (9.9 - 24.8)
Western	Ahanta-West	Asemko	2000	112	14	12.5 (6.4 - 18.6)
Western	Ahanta-West	Busua	2000	124	29	23.4 (15.9 - 30.8)
Western	Ahanta-West	Butre	2000	123	35	28.5 (20.5 - 36.4)
Western	Ahanta-West	Cape-3-points	2000	99	17	17.2 (9.7 - 24.6)
Western	Ahanta-West	Mpataano	2000	106	19	17.9 (10.6 - 25.2)
Western	Ellembelle	Anwia	2002	100	0	0.0
Western	Ellembelle	Bomoakpoley	2002	99	0	0.0
Western	Shama	Shama_Shama-Kumasi*	2003	557	3	0.5 (0 - 1.1)

*Mf prevalence data were combined from two communities in the same district. Districts names in the table represent the current districts after the re-demarcations.

Mf = microfilaria, CI = confidence interval

Table S2. Overview of MDA implementation and progress towards elimination by district in Ghana, for the 98 districts that were identified as endemic.

District	District number	Region	District population (2010)	Mf data available - Time post 1st treatment (year)	Baseline mf prevalence (range)	MDA start year*	TAS-1 (Year of last treatment)	Total no. of treatment rounds received by 2016	TAS-2 (year)	TAS-3 (year)	Hotspot (2016) MDA on-going
Abura Asebu Kwamankese (AAK)	28	Central	117,185	8	-	2003	2014	11	2016	Not yet	-
Accra Metro	96	Greater Accra	1,848,614	7	-	2006	2014	8	2016	Not yet	-
Agona East	11	Central	85,920	0,1	6 (0 - 11.9)	2002	2010	9	2012	2015	-
Agona West Municipal	12	Central	115,358	-	-	2002	2010	9	2012	2015	-
Ahanta West	1	Western	106,215	0,3,7,12,14	-	2000	Not yet	16	Not yet	Not yet	Yes
Ajumaku Enyan Essiam (AEE)	29	Central	138,046	8	-	2003	2014	11	2016	Not yet	-
Akrumfi	30	Central	52,231	-	-	2003	2014	11	Not yet	Not yet	-
Akwapim South	71	Eastern	123,501	6	-	2005	2014	9	2016	Not yet	-
Aowin	55	Western	138,415	7	19.5 (12.5 - 28.5)	2004	2014	10	2016	Not yet	-
Asikuma Odoben Brakwa (AOB)	56	Central	112,706	7	-	2004	2014	10	2016	Not yet	-
Assin North	57	Central	161,341	-	-	2004	2014	10	2016	Not yet	-
Assin South	58	Central	104,244	7	-	2004	2014	10	2016	Not yet	-
Awutu Senya East Municipal	2	Central	108,422	-	-	2001	2010	10	2012	2015	-
Awutu Senya West	3	Central	86,884	6	-	2001	2010	10	2012	2015	-
Ayensuano	72	Eastern	77,193	0,6	-	2005	2014	9	2016	Not yet	-
Bawku Municipal	31	Upper East	217,791	0,9	5 (1.9 - 5.8)	2003	2014	11	2016	Not yet	-
Bawku West	32	Upper East	94,034	6,10	-	2003	2014	11	Not yet	Not yet	-
Binduri	33	Upper East	61,576	-	-	2003	2014	11	2016	Not yet	-

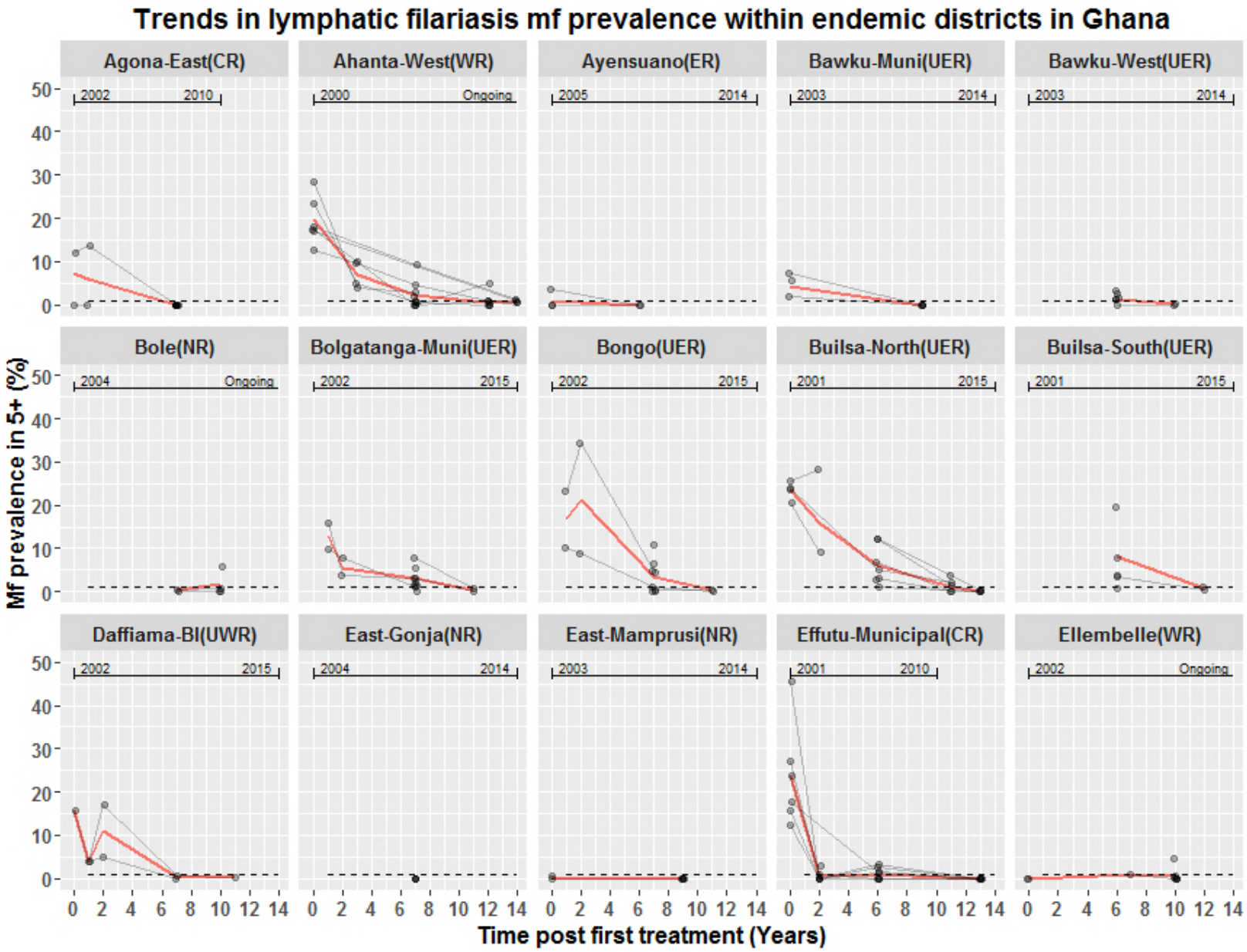
District	District number	Region	District population (2010)	Mf data available - Time post 1st treatment (year)	Baseline mf prevalence (range)	MDA start year*	TAS-1 (Year of last treatment)	Total no. of treatment rounds received by 2016	TAS-2 (year)	TAS-3 (year)	Hotspot (2016) MDA on-going
Bole	68	Northern	61,593	7,10	-	2004	Not yet	12	Not yet	Not yet	Yes
Bolgatanga Municipal	15	Upper East	131,550	1,2,7,11	-	2002	2015	13	Not yet	Not yet	-
Bongo	16	Upper East	84,545	1,2,7,11	-	2002	2015	13	Not yet	Not yet	-
Builsa North	7	Upper East	56,477	0,2,6,11	23.4 (20.6 - 25.5)	2001	2015	14	Not yet	Not yet	-
Builsa South	8	Upper East	36,514	6,12	-	2001	2015	14	Not yet	Not yet	-
Bunkprugu Yunyoo	73	Northern	122,591	7	-	2005	2014	9	2016	Not yet	-
Cape Coast	59	Central	169,894	7	-	2004	2014	10	2016	Not yet	-
Central Gonja	74	Northern	87,877	6	-	2005	2014	9	2016	Not yet	-
Chereponi	34	Northern	53,394	8	-	2003	2014	11	2016	Not yet	-
Daffiama Busie Issa	17	Upper West	32,827	0,1,2,7,11	-	2002	2015	13	Not yet	Not yet	-
East Gonja	60	Northern	135,450	7	0	2004	2014	10	2016	Not yet	-
East Mamprusi	35	Northern	121,009	0,9	0.22 (0 - 0.4)	2003	2014	11	2016	Not yet	-
Effutu Municipal	4	Central	68,597	0,2,6,13	23.7 (12.5-45.7)	2001	2010	10	2012	2015	-
Ellembelle	20	Western	87,501	0,7,10	-	2002	Not yet	14	Not yet	Not yet	Yes
Ga Central	75	Greater Accra	117,220	-	-	2005	2014	9	2016	Not yet	-
Ga East	76	Greater Accra	259,668	6	-	2005	2014	9	2016	Not yet	-
Ga South	77	Greater Accra	485,643	0,6	0.27 (0 - 0.53)	2005	2014	9	2016	Not yet	-
Ga West	78	Greater Accra	262,742	0,6	0	2005	2014	9	2016	Not yet	-
Garu Tempane	79	Upper East	130,003	7	-	2005	2014	9	2016	Not yet	-

District	District number	Region	District population (2010)	Mf data available - Time post 1st treatment (year)	Baseline mf prevalence (range)	MDA start year*	TAS-1 (Year of last treatment)	Total no. of treatment rounds received by 2016	TAS-2 (year)	TAS-3 (year)	Hotspot (2016) MDA on-going
Gomoa East	13	Central	207,071	9	-	2002	2014	12	2016	Not yet	-
Gomoa West	14	Central	135,189	-	-	2002	2014	12	2016	Not yet	-
Gushiegu	36	Northern	111,259	-	-	2003	2014	11	2016	Not yet	-
Jirapa	21	Upper West	88,402	1,2,7,11	-	2002	Not yet	14	Not yet	Not yet	Yes
Jomoro	37	Western	150,107	8	-	2003	2014	11	2016	Not yet	-
Karaga	38	Northern	77,706	8	-	2003	2014	11	Not yet	Not yet	-
KEEA	61	Central	144,705	7	0.75	2004	2014	10	2016	Not yet	-
KND-Municipal	9	Upper East	109,944	0,2,6,11,13	32.1 (28.1 - 35.5)	2001	2015	14	Not yet	Not yet	-
KND-West	10	Upper East	70,667	0,2,4,6,11,13	21.4	2001	Not yet	15	Not yet	Not yet	Yes
Kpandai	62	Northern	108,816	-	-	2004	2014	10	2016	Not yet	-
Kumbungu	39	Northern	39,341	6	-	2003	2014	11	2016	Not yet	-
La Dade Kotopon	97	Greater Accra	183,528	7	-	2006	2014	8	2016	Not yet	-
La Nkwantanang Madina	80	Greater Accra	111,926	-	-	2005	2014	9	2016	Not yet	-
Lambussie Karni	22	Upper West	51,654	1,2,7,12	-	2002	Not yet	14	Not yet	Not yet	Yes
Lawra	23	Upper West	100,929	1,2,7,11	-	2002	Not yet	14	Not yet	Not yet	Yes
Ledzokuku krowor	98	Greater Accra	227,932	7	-	2006	2014	8	2016	Not yet	-
Mamprugu Moaduri	40	Northern	46,894	6	-	2003	2014	11	2016	Not yet	-
Mfantsiman	41	Central	196,563	8	-	2003	2014	11	2016	Not yet	-
Mion	81	Northern	81,812	-	-	2005	2014	9	2016	Not yet	-
Mpohor	42	Western	123,996	-	-	2003	2014	11	2016	Not yet	-
Nabdam	92	Upper East	33,826	8	-	2005	Not yet	11	Not yet	Not yet	Yes

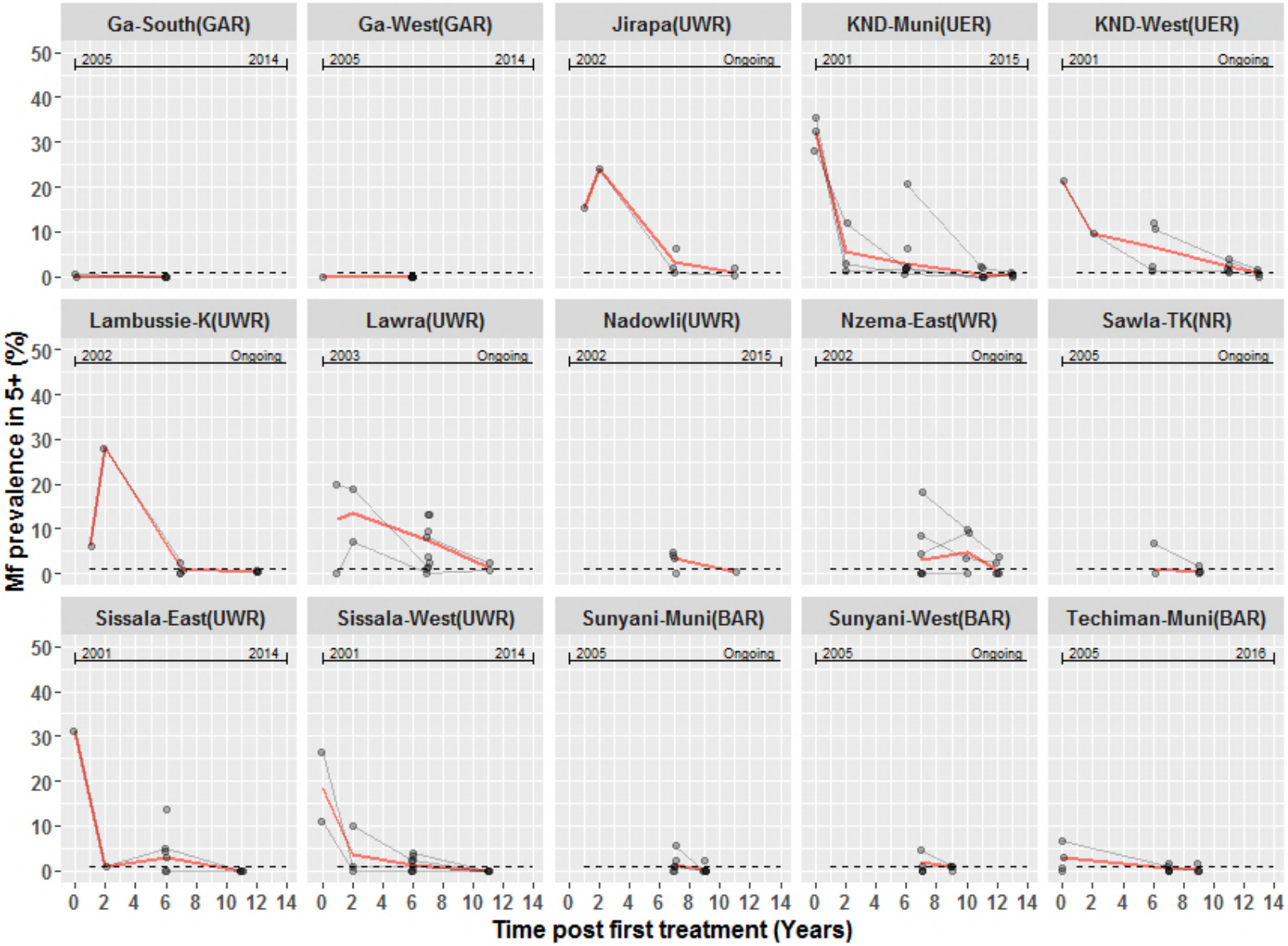
District	District number	Region	District population (2010)	Mf data available - Time post 1st treatment (year)	Baseline mf prevalence (range)	MDA start year*	TAS-1 (Year of last treatment)	Total no. of treatment rounds received by 2016	TAS-2 (year)	TAS-3 (year)	Hotspot (2016) MDA on-going
Nadowli	18	Upper West	94,388	7,11	15.7	2002	2015	13	Not yet	Not yet	-
Nandom	24	Upper West	46,040	-	-	2002	Not yet	14	Not yet	Not yet	Yes
Nanumba North	43	Northern	141,584	6	-	2003	2014	11	2016	Not yet	-
Nanumba South	44	Northern	93,464	-	-	2003	2014	11	2016	Not yet	-
North Gonja	69	Northern	43,547	10	-	2004	Not yet	12	Not yet	Not yet	Yes
Nsawam Adoagyiri	82	Eastern	86,000	-	-	2005	2014	9	2016	Not yet	-
Nzema East	25	Western	60,828	7,10,12	0	2002	Not yet	14	Not yet	Not yet	Yes
Prestea Huni Valley	45	Western	159,304	-	-	2003	2014	11	2016	Not yet	-
Pusiga	46	Upper East	57,677	-	-	2003	2014	11	2016	Not yet	-
Saboba	47	Northern	65,706	8	-	2003	2014	11	2016	Not yet	-
Sagnerigu	83	Northern	148,099	-	-	2005	2014	9	2016	Not yet	-
Savelugu Nanton	48	Northern	139,283	6	-	2003	2014	11	2016	Not yet	-
Sawla Tuna Kalba	93	Northern	99,863	6,9	-	2005	Not yet	11	Not yet	Not yet	Yes
Sekondi Takoradi metro	63	Western	559,548	8	-	2004	2014	10	2016	Not yet	-
Shama	64	Western	81,966	7	-	2004	2014	10	2016	Not yet	-
Sissala East	5	Upper West	56,528	0,6,11	0.54	2001	2014	13	2016	Not yet	-
Sissala West	6	Upper West	49,573	0,2,6,11	31	2001	2014	13	2016	Not yet	-
Suaman	65	Western	20,529	-	18.6 (11 - 26)	2004	2014	10	2016	Not yet	-
Suhum	84	Eastern	167,551	6	-	2005	2014	9	2016	Not yet	-
Sunyani Municipal	94	Brong Ahafo	123,224	7,9	1.2 (0 - 3.5)	2005	Not yet	11	Not yet	Not yet	Yes
Sunyani West	95	Brong Ahafo	85,272	7,9	-	2005	Not yet	11	Not yet	Not yet	Yes

District	District number	Region	District population (2010)	Mf data available - Time post 1st treatment (year)	Baseline mf prevalence (range)	MDA start year*	TAS-1 (Year of last treatment)	Total no. of treatment rounds received by 2016	TAS-2 (year)	TAS-3 (year)	Hotspot (2016) MDA on-going
Talensi	89	Upper East	115,020	8	-	2005	2015	10	Not yet	Not yet	-
Tamale Metro	85	Northern	371,351	6	-	2005	2014	9	2016	Not yet	-
Tarkwa Nsuaem	49	Western	90,477	5	-	2003	2014	11	2016	Not yet	-
Tatale Sanguli	50	Northern	60,039	6	-	2003	2014	11	2016	Not yet	-
Techiman Municipal	90	Brong Ahafo	206,856	0,7,9	-	2005	2016	11	Not yet	Not yet	-
Techiman North	91	Brong Ahafo	59,068	9	2.6 (0 - 6.6)	2005	2016	11	Not yet	Not yet	-
Tolon	51	Northern	112,331	6	-	2003	2014	11	2016	Not yet	-
Twifo Ati Mokwa	66	Central	61,743	-	-	2004	2014	10	2016	Not yet	-
Twifo Heman Lower Denkyira	67	Central	116,874	7	-	2004	2014	10	2016	Not yet	-
Upper West Akim	86	Eastern	87,051	6	-	2005	2014	9	2016	Not yet	-
Wa East	26	Upper West	72,074	11	-	2002	Not yet	14	Not yet	Not yet	Yes
Wa Municipal	19	Upper West	107,214	11	-	2002	2015	13	Not yet	Not yet	-
Wa West	27	Upper West	81,348	1,2,7,11	-	2002	Not yet	14	Not yet	Not yet	Yes
Wassa East	52	Western	81,073	8	-	2003	2014	11	2016	Not yet	-
West Akim Municipal	87	Eastern	195,349	6	-	2005	2014	9	2016	Not yet	-
West Gonja	70	Northern	84,727	7,10	-	2004	Not yet	12	Not yet	Not yet	Yes
West Mamprusi	53	Northern	168,011	0,6	1.1	2003	2014	11	2016	Not yet	-
Yendi	88	Northern	199,592	0,6	3.7 (0 - 6.8)	2005	2014	9	2016	Not yet	-
Zabzugu	54	Northern	123,854	6	-	2003	2014	11	2016	Not yet	-

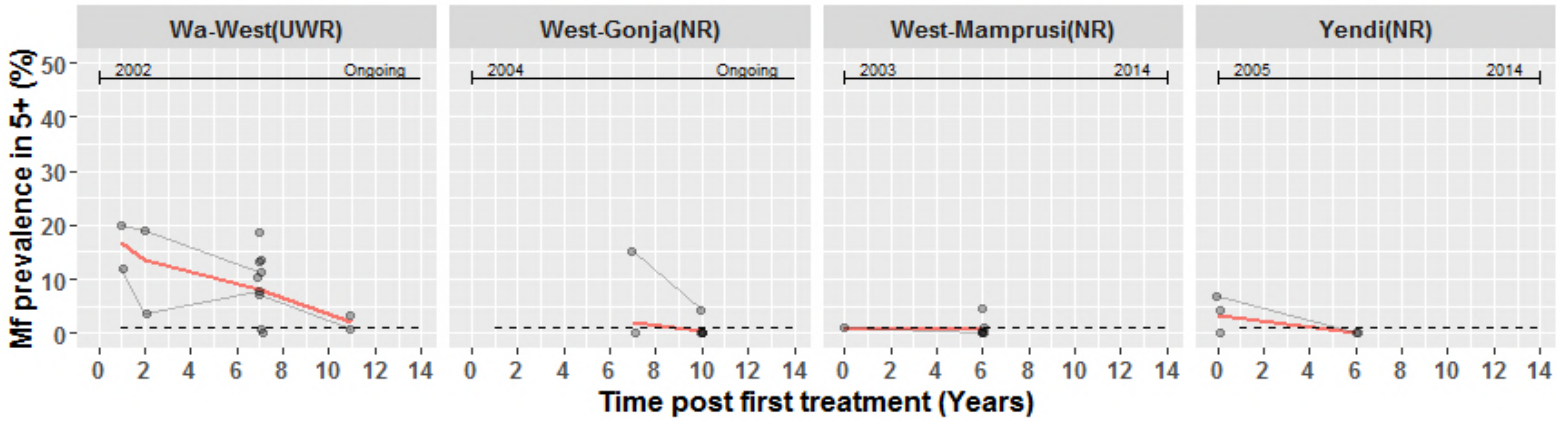
* All communities in each district were expected to be treated in the same year MDA started, so the geographical coverage at district level is 100% right from the start. So far, all TAS surveys were passed (no failures). The year in which TAS surveys were done, were the same year of last MDA. Districts names in the table represent the current districts after the re-demarcations. Need to explain all abbreviations here


Trends in lymphatic filariasis mf prevalence within endemic districts in Ghana
Agona-East(CR)
2002
2010
Ahanta-West(WR)
2000
Ongoing
Ayensuano(ER)
2005
2014
Bawku-Muni(UER)
2003
2014
Bawku-West(UER)
2003
2014
Bole(NR)
2004
Ongoing
Bolgatanga-Muni(UER)
2002
2015
Bongo(UER)
2002
2015
Builsa-North(UER)
2001
2015
Builsa-South(UER)
2001
2015
Daffiama-BI(UWR)
2002
2015
East-Gonja(NR)
2004
2014
East-Mamprusi(NR)
2003
2014
Effutu-Municipal(CR)
2001
2010
Ellembelle(WR)
2002
Ongoing
Mf prevalence in 5+ (%)
0
10
20
30
40
50
0 2 4 6 8 10 12 14
Time post first treatment (Years)

563


Ga-South(GAR)
2005
2014
Ga-West(GAR)
2005
2014
Jirapa(UWR)
2002
Ongoing
KND-Muni(UER)
2001
2015
KND-West(UER)
2001
Ongoing
Lambussie-K(UWR)
2002
Ongoing
Lawra(UWR)
2003
Ongoing
Nadowli(UWR)
2002
2015
Nzema-East(WR)
2002
Ongoing
Sawla-TK(NR)
2005
Ongoing
Sissala-East(UWR)
2001
2014
Sissala-West(UWR)
2001
2014
Sunyani-Muni(BAR)
2005
Ongoing
Sunyani-West(BAR)
2005
Ongoing
Techiman-Muni(BAR)
2005
2016
Mf prevalence in 5+ (%)
0
10
20
30
40
50
0 2 4 6 8 10 12 14
Time post first treatment (Years)

564



565

566 **Figure S1: Mf prevalence distribution overtime in 34/98 districts with data for multiple time points**

567 Each panel represents a district which was sampled multiple times during the survey. The red continuous line represent the average prevalence in the district at each time point
568 estimated from communities sampled within the same district. The bullets are community mf prevalence at each time point and multiple observations from the same community
569 are connected through thin grey lines. The dashed horizontal lines represent the threshold mf prevalence of 1%. The line at the upper part of each panel with the text indicate
570 the year MDA started and when it ended or if ongoing by September 2016. The suffix attached to district names represent the region in which district is located as follows:
571 Brong Ahafo (BAR), Central (CR), Eastern (ER), Greater Accra (GAR), Northern (NR), Upper East (UER), Upper West (UWR) and Western (WR). Districts names in the
572 figure represent the current districts after the re-demarcations.

573

574

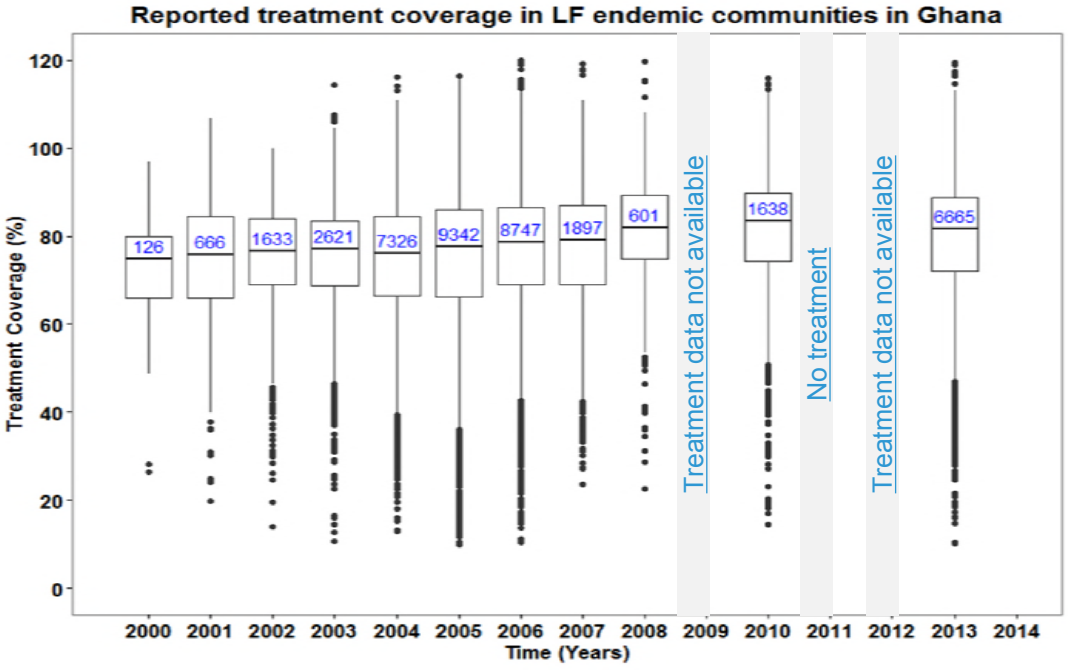
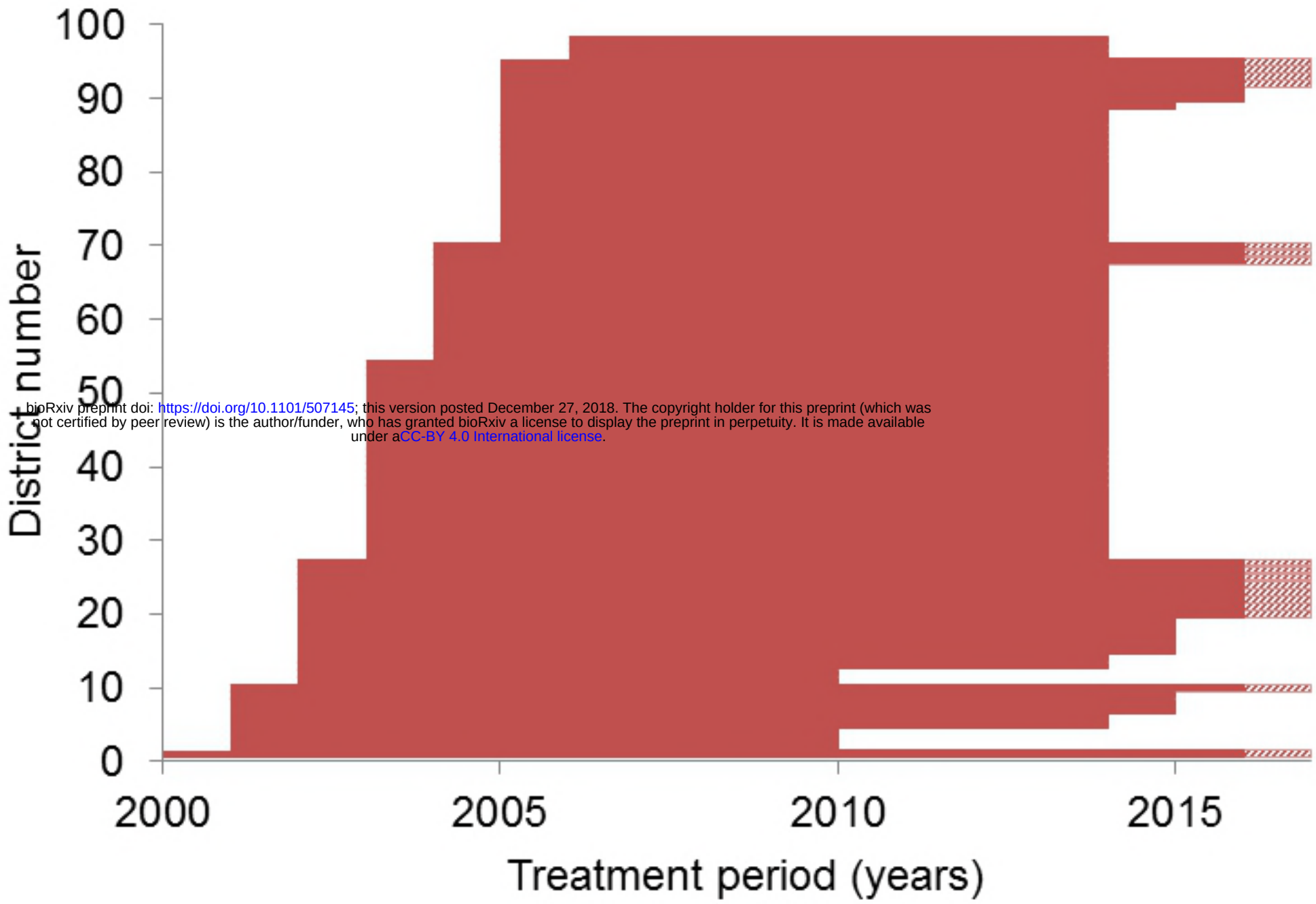


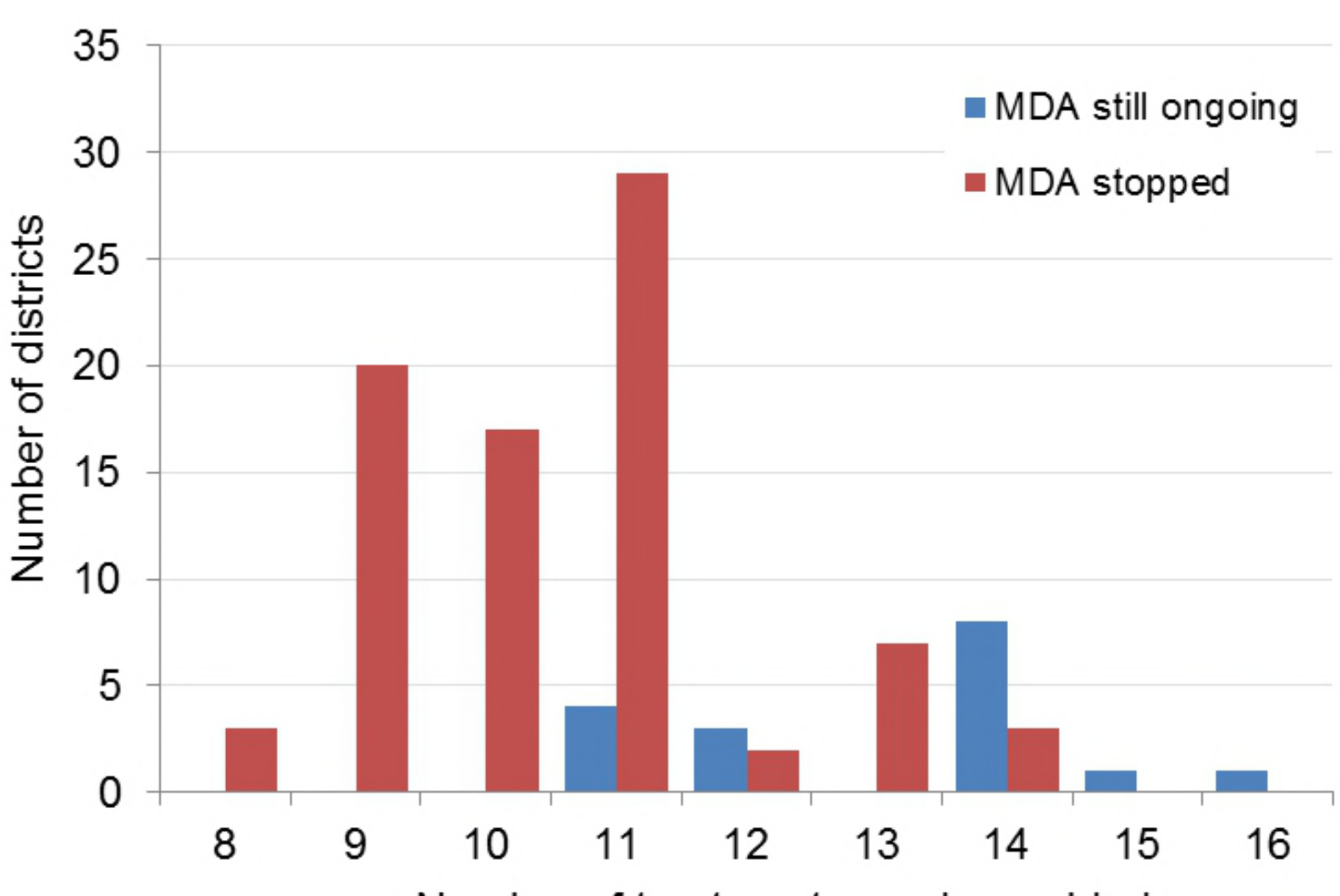
Figure S2: Reported treatment coverage in treated communities in Ghana. The box at each time point represents the interquartile range of coverage and the thick horizontal lines across each box represent the median coverage. The bullets outside each box (above or below) represent the outliers and are calculated as 1.5 times the interquartile range above or below the ends of the box (25th and 75th percentile). The vertical lines (whiskers) extend to the first value (coverage) before the outlier cut-off and where there are no outliers, they represent the minimum and maximum coverage at each time point. The numbers in the boxes are the total number of communities treated at each time point. There was no treatment offered in 2011 due to some challenges; 2009 and 2012 treatment data not available.

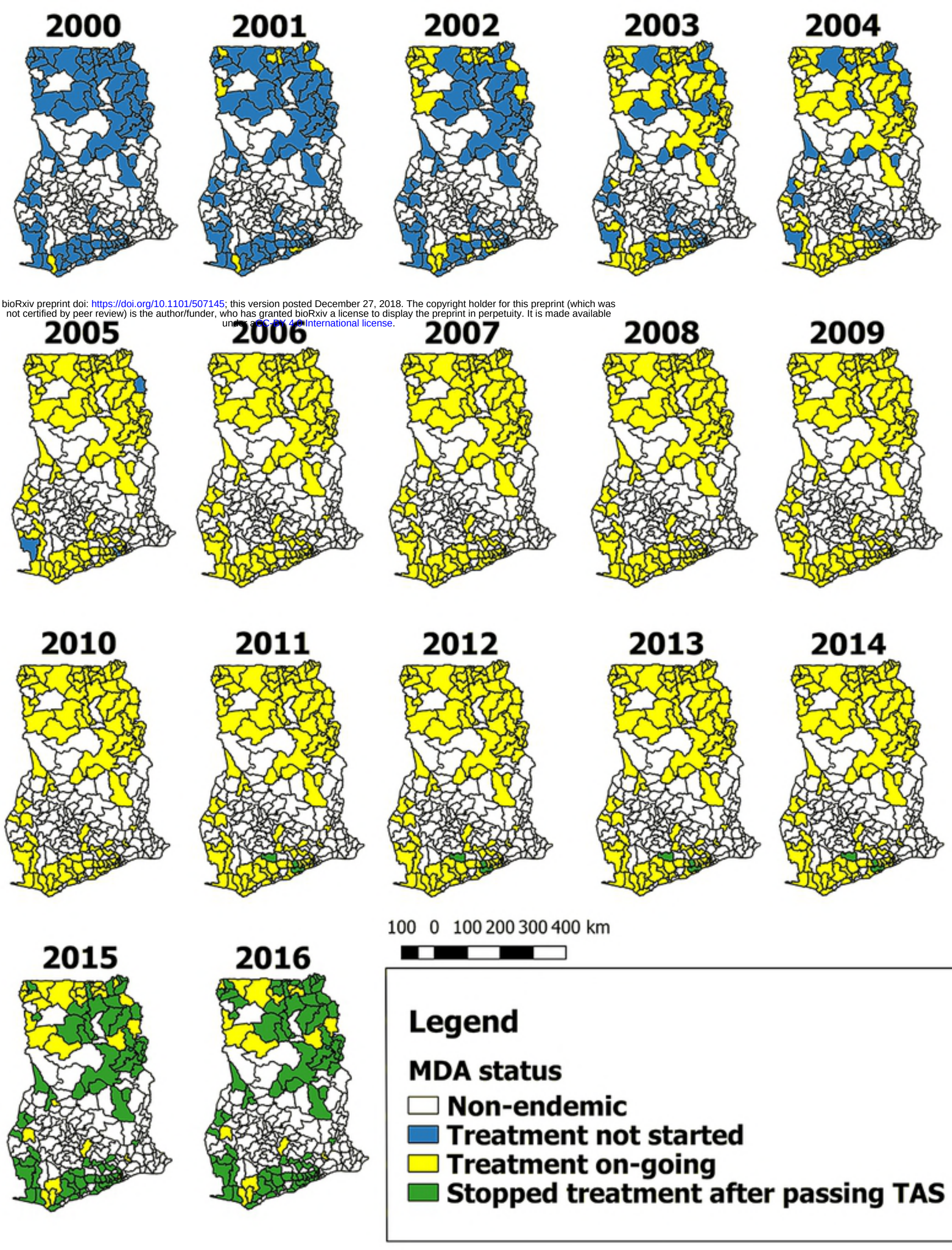
We acknowledge the fact that these reported coverage may not be very reliable [33] since some areas reported coverage more than 100% (Figure S2). Our data showed a relatively high and constant coverage over time. Some of the flaws may probably be caused by community registers used in estimating the population not being updated, resulting in high coverage and more individuals treated than the existing population in some cases. Treatment coverage may also be overestimated because community directed distributors (CDD) are recommended to treat by direct observed treatment (DOT) but they may not have observed all persons but may record as treated. On the other hand the incidental low coverage could also be due to under-reporting especially where individuals treated by the CDD (who sometimes kept leftover drugs from previous treatments) before or after the GHS treatment period when treatment books were in the possession of the GHS sub-district office.

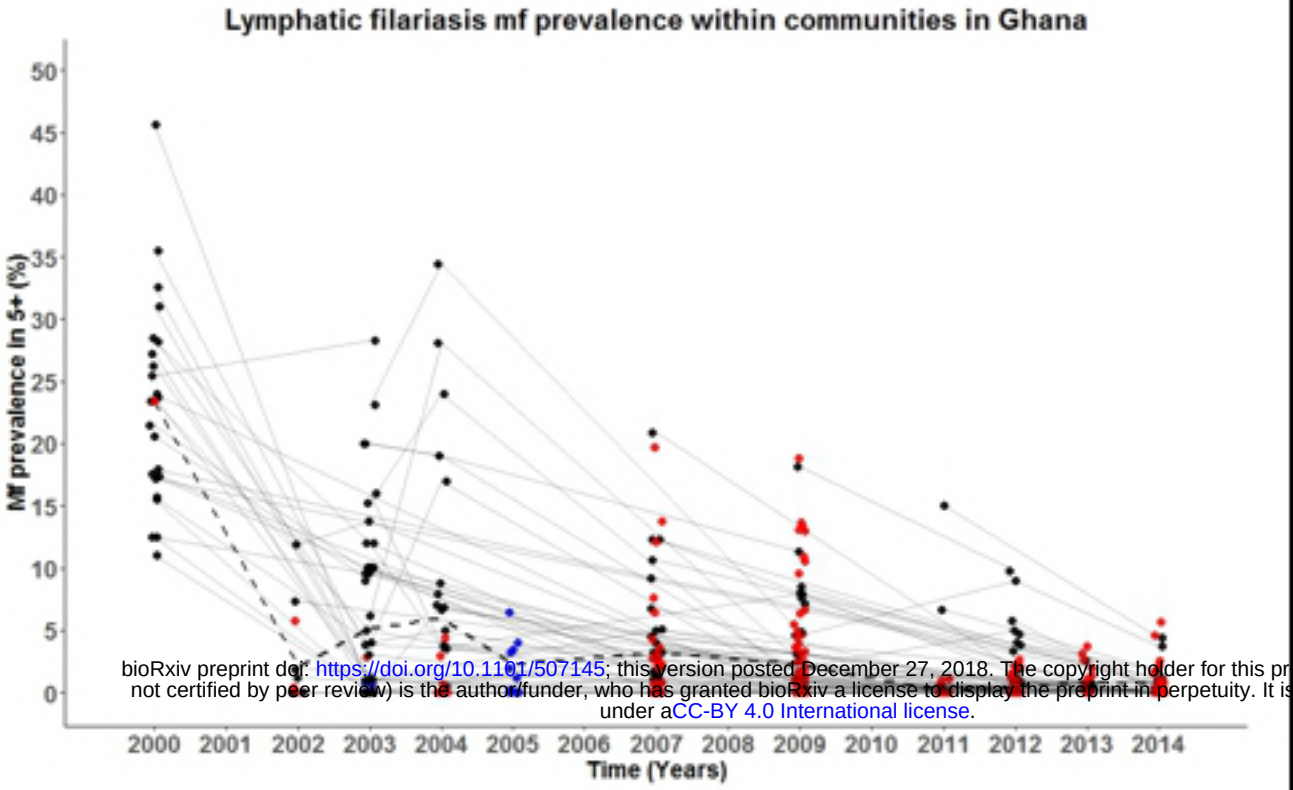
A



B







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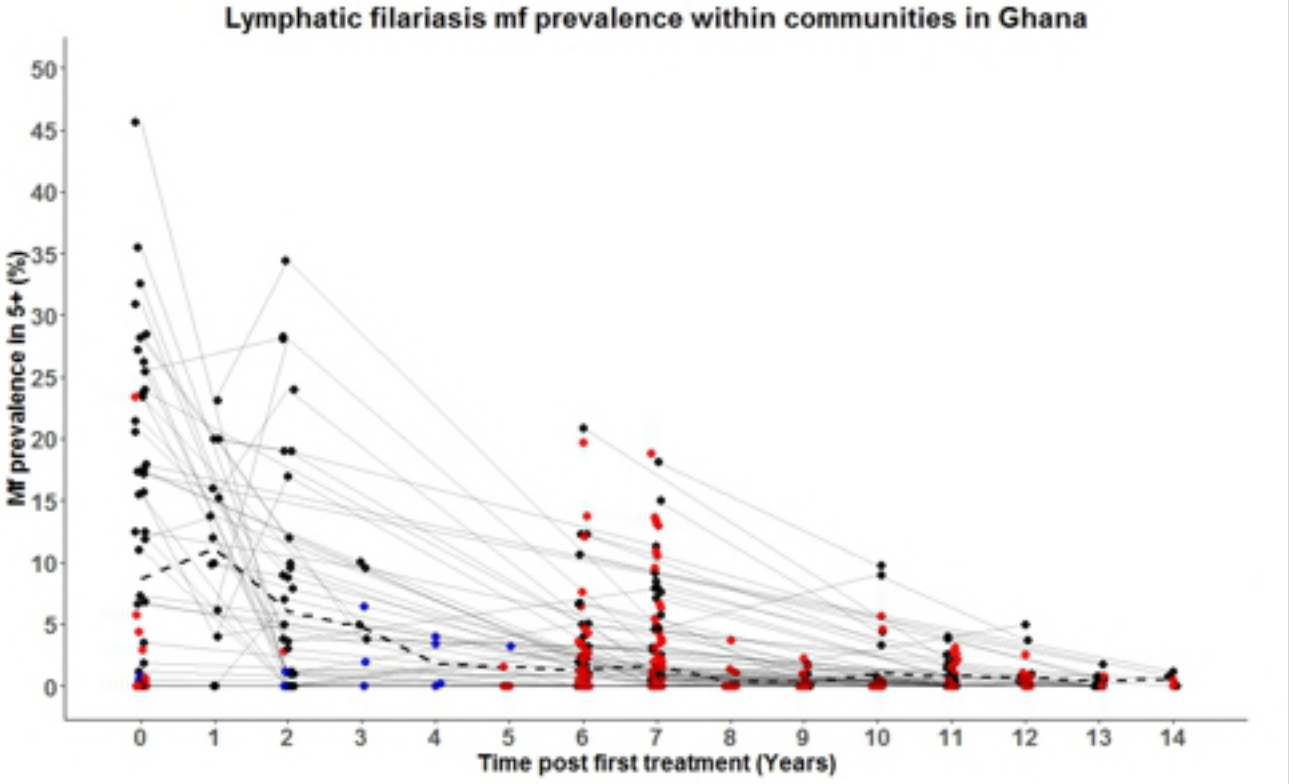

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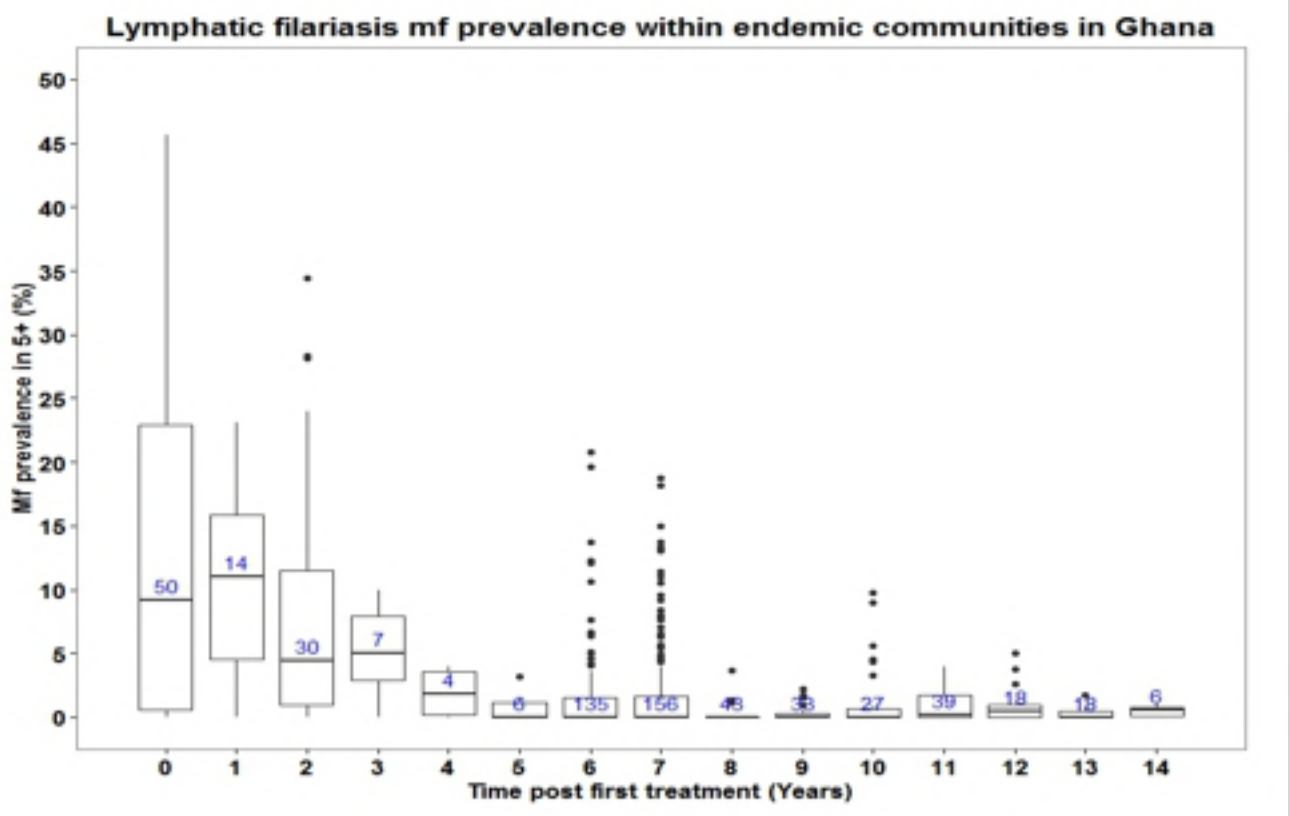

C