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ORIGINAL ARTICLE

Assessing the prevalence of trachoma in the East, North, Far North and Adamaoua regions of Cameroon, 2016–2022

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Background: Baseline prevalence surveys in Cameroon in 2010–2012 showed that trachoma was endemic primarily in the north of the country, with 23 evaluation units (EUs) requiring interventions against active (inflammatory) trachoma. This study presents data from prevalence surveys conducted in 2016–2022 following interventions against trachoma in the East, North, Far North and Adamaoua regions of Cameroon.

Methods: EUs were created based on health district boundaries. Within each EU, clusters were selected using probability of selection proportional to population size. Participants were examined for trachomatous inflammation—follicular (TF) and trachomatous trichiasis (TT).

Results: A total of 151 800 people were examined in 45 surveys across 35 EUs. Based on the most recent survey results, TF prevalence was greater than the 5% TF elimination threshold in two EUs. Ten EUs had TT prevalence estimates greater than the 0.2% elimination threshold.

Conclusions: Trachoma remains a public health problem in Cameroon. Continued interventions are needed in EUs with prevalence estimates greater than elimination thresholds, including antibiotic mass drug administration and improved access to TT surgery. Future surveys will be needed to determine when national elimination of trachoma as a public health problem has been achieved.

Keywords: Cameroon, prevalence surveys, trachoma, trichiasis, Tropical Data.

Introduction

Trachoma is the leading infectious cause of blindness worldwide and is estimated to be responsible for permanent vision loss in approximately 1.9 million people.[1] It is caused by ocular serovars of the intracellular bacterium *Chlamydia trachomatis*, with the associated active (inflammatory) disease predominantly found in children <10 y of age.[2] In the World Health Organization (WHO) simplified grading system, the signs of active trachoma are trachomatous inflammation–follicular (TF) and/or trachomatous inflammation–intense (TI).[3] Repeated infection over time can stimulate the development of scar tissue in the upper eyelid in

susceptible individuals.[2] Scar tissue may distort and invert the upper eyelid, which causes the eyelashes to rub against the eyeball, a condition that is referred to as trachomatous trichiasis (TT). In addition to being extremely painful, TT can cause corneal opacity resulting in visual impairment and blindness.[2]

In 1996, WHO launched the Alliance for the Global Elimination of Trachoma by 2020.[4] In order to achieve elimination, WHO recommends using the SAFE strategy: Surgery to treat TT, Antibiotics to clear infection, Facial cleanliness and Environmental improvement to reduce transmission.[5] To determine which parts of a country require SAFE intervention, standardized surveys have been designed to estimate the prevalence of TF and TT.[6,7] Elimination as a public health problem requires a prevalence of TF of <5% in children ages 1–9 y and a prevalence of TT unknown to the health system of <0.2% in people ≥15 y of age in each formerly endemic evaluation unit (EU).[8] EUs are based on administrative districts or health service management units, which usually have a population size of 100 000–250 000 people.[9] Considerable effort has been invested by health ministries and their partners to establish the locations where implementation of the SAFE strategy is required.[10]

In Cameroon, baseline prevalence surveys conducted between 2010 and 2012 showed that trachoma was endemic primarily in the North and Far North regions, with half of the districts (23 EUs) in those regions having a TF prevalence ≥5% and two-thirds having a TT prevalence ≥0.2%.[11–13] In response, antibiotic mass drug administration (MDA) campaigns were organized between 2011 and 2015 in all districts with a TF prevalence ≥5%, with treatment duration specific to each prevalence class.[14] The Ministry of Public Health (MPH) also began implementing TT surgery as a public health intervention in 2014, with the extension of TT case management activities into the Northern region in 2015. The WHO guidance for trachoma management states that surveys to determine the impact of MDA should be conducted 6–12 months after the last planned MDA round, with further MDA required if TF prevalence remains ≥5%. Once EUs have achieved a below-threshold TF prevalence, surveillance surveys are recommended at least 2 y after impact surveys to ensure that low TF thresholds have been maintained in the absence of ongoing MDA.[14]

While TT prevalence is routinely estimated during baseline, impact and surveillance surveys (standard surveys), TF is much more prevalent than TT and so the number of households that need to be surveyed to generate acceptable precision around TF prevalence estimates is lower than that for the less prevalent TT. In response, a WHO study to pilot test TT-only surveys was conducted in 2016 in Cameroon's Touboro district, and in one EU in each of three other countries.[7] TT-only surveys are now recommended to re-estimate TT prevalence in several situations, including after interventions in areas where baseline TT prevalence was ≥0.2% in ≥15-year-olds and TF prevalence was <5% in children.[7]

This study summarizes the data from 45 surveys conducted in 35 EUs: 7 baseline, 14 impact and 18 surveillance surveys and 6 TT-only surveys, conducted with Tropical Data technical support.[15,16] The overall objective of this article is to demonstrate the outcome of extensive intervention work conducted over many years following the initial baseline surveys as well as provide a general overview of the current status of trachoma prevalence in Cameroon.

Methods

Study population

The seven baseline surveys (Table 1) were conducted for a number of reasons. Two EUs were new refugee camps that had not yet been created prior to the surveys in 2010–2012. Violence in the Central African Republic (CAR) in 2013 led many hundreds of thousands of CAR residents to seek refuge in Cameroon. The five refugee camps located in the districts Yokadouma, Garoua Boulaye and Batouri in the Eastern region had a combined population of 54 000 people when the survey was conducted in 2019, a total area of approximately 180 hectares and 69 blocks. The Minawao refugee camp is located in the Mokolo district, in the Far North region. The camp was opened in July 2013 in response to a massive influx of Nigerian refugees fleeing Boko Haram insurgents. It covers an area of 623 hectares and includes four main sectors, which are organized into 80 blocks and municipalities. Its population was estimated at 58 000 inhabitants in July 2017; trachoma surveys were conducted in 2018. The camps were considered as separate EUs because of the particularities of the populations. First, the encampments were circumscribed, geographically defined environments, different from that of other populations in the surrounding districts. Second, the provenance of the vast majority of inhabitants of the two camps was discrete: in the Eastern region refugee camps, the majority of people originated from CAR, while in the Minawao camp, 97% of people originated from Borno State, Nigeria.

Kolofata EU was a unique situation, as it was shown to be endemic for trachoma in 2006 and had MDA intervention between 2008 and 2010 through an azithromycin eye drops (Azyter) clinical trial.[17–19] Impact surveys were conducted after each round of Azyter distribution, which indicated TF had decreased below the elimination threshold after three rounds, but a 2-y follow-up after the study indicated that TF was again ≥5%. Because none of these surveys had been conducted with the WHO-recommended survey methodology through the Global Trachoma Mapping Project (GTMP), there was also concern that survey results were not reliable. As a result, the MPH decided to remap the district. The other four EUs were surveyed because in June 2018 experts advised the MPH to conduct baseline prevalence surveys for trachoma in six health districts comprising four EUs (Garoua-Boulaye; Moloundou and Yokadouma; Kette and Batouri; and Ndelele) in the Eastern region bordering CAR; prior studies revealed high trachoma prevalences in CAR, raising concerns about potential endemicity in bordering Cameroonian districts.[20] These surveys did not include any people residing in the refugee camps, as refugee camps were surveyed separately from the populations in the host districts.

There were 13 impact surveys conducted to estimate TF prevalence post-MDA. These surveys took place in 2017 in three health districts in the Northern region and 10 health districts in the Far North region. Surveillance surveys were conducted in 18 EUs in 2019 after each respective EU had completed 24 months without MDA after the impact survey. One surveillance survey was above the threshold, so an additional impact survey was conducted for that EU in 2022 after an additional round of MDA. TT-only surveys were conducted in six EUs in which baseline TF prevalence was below the 5% threshold but TT prevalence was ≥0.2%. One of

Table 1. Timing of standard surveys and estimated population size for each evaluation unit (EU) in Cameroon.

EU	Population size	Year of survey			
		Baseline survey	Impact survey	Surveillance survey	Impact survey 2 (after surveillance survey)
Garoua Boulaye	110 502	2019	–	–	
Goulfey	125 217	**2010**	2017	2019	2022
Guéré	125 765	**2010**	2017	2019	
Guidiguis	178 091	**2010**	**2015**	2019	
Hina	136 521	**2010**	**2014**	2019	
Kette and Batouri	84 373, 110 198	2019	–	–	
Kousseri	383 710 163 163 220 548	**2010**	2017	–	
Kousseri 1		–[a]	–[a]	2019	
Kousseri 2				2019	
Makari and Fotokol	144 528, 74 705	**2010**	2017	2019	
Maroua 3 and Gazawa	153 155, 72 709	**2010**	2017	–	
Meri	170 132	**2010**	2017	2019	
Mogode and Bourha	119 494, 79 285	**2010**	**2014**	2019	
Mokolo	243 565	**2010**	**2015**	2019	
Mokolo (Minawao refugee camp)	58 000	2018	–	–	
Moutourwa	53 468	**2010**	2017	2019	
Moutourwa and Gazawa	53 468, 72 709	–[a]	–[a]		
Ndelele	102 258	2019	–	–	
Pété	59 964	**2010**	2017	2019	
Pété and Maroua 3	59 964, 153 155	–[a]	–[a]		
Poli	110 985	**2011**	2017	2019	
Rey-Bouba	176 740	**2011**	2017	2019	
Roua and Koza	94 524, 199 387	**2010**	**2014**	2019	
Tchollire	178 331	**2011**	2017	2019	
Tokombere	149 613	**2010**	2017	2019	
Yagoua	248 526	**2010**	2017	2019	
Yokadouma, Garoua Boulaye and Batouri (refugee camps)	54 377	2019	–	–	
Yokadouma and Mouloundou	111 655, 48 564	2019	–	–	
Kolofata	127 438	2022	–	–	

EU population size as per the latest census data available at the time of the survey. Where more than one survey was conducted, the most recent population data are presented. Surveys conducted prior to the series published in this article are in bold. Dashes indicate surveys were not or have not yet been conducted.
[a]EUs derived from baseline EUs that were split or combined for subsequent surveys.

the six TT-only EUs was Touboro, data for which were previously presented in the WHO report on validation of the TT-only survey methodology;[7] the data are included here again for completeness because Touboro was part of this overall survey series. The TT-only surveys described here started in 2016 and were completed in 2019 (Table 2).

Survey design

EU boundaries were based on existing health districts. In accordance with the WHO guidelines on EU size, where the population should be between 100 000 and 250 000 people,[21] Kousseri and Garoua I were each split into two separate EUs (Tables 1 and 2). Conversely, districts with smaller population sizes were combined into a single EU, providing they were geographically contiguous, socio-economically similar and the grouping made geopolitical and programmatic sense (Table 1). WHO-standardized trachoma survey methodologies were used to estimate the prevalence of TF and TT.[6,14,15] The target sample size for each EU was calculated for each survey type, using the expected prevalence (baseline surveys: TF=10%, impact and surveillance surveys: TF=4%, TT-only surveys: TT=0.2%), the desired absolute width of the 95% confidence interval (CI; baseline surveys: TF=3%, impact and surveillance surveys: TF=2%, TT-only surveys: TT=0.2%),

Table 2. TT-only survey prevalence and demographics (2016–2019) tabulated against the 2012[12,13] baseline prevalence of trachomatous—inflammation follicular (TF) and trachomatous trichiasis (TT) in the six evaluation units (EU) chosen for TT-only surveys in Cameroon. Confidence interval (CI).

		Baseline prevalence survey (2012)												
Region	District/EU	TT prevalence, % (95% CI)	TF prevalence, % (95% CI)	TT-only survey year	Clusters surveyed, n	Households surveyed, n	≥15-year-olds examined, n (%)	Male, n	≥15 years old with TT[a], n	Females ≥15 years old with TT, n (%)	Eyes with post-operative TT, n	Female eyes with postop-erative TT, n (%)	≥15 years old with TT unknown to the health system, n	Age- and gender-adjusted prevalence of TT unknown to the health system in those ≥15 years of age (95% CI)
Adamaoua	Meiganga	0.27 (0.1 to 0.7)	0.24 (0.1 to 0.6)	2018	30	901	1831 (95.7)	39	8	5 (63)	2	2 (100)	6	0.22 (0.03 to 0.54)
North	Touboro	0.4 (0.2 to 0.9)	3.0 (2.4 to 3.9)	2016	36	1087	2662 (98.2)	44	35	18 (51)	12	10 (83.3)	20	0.55 (0.21 to 0.84)
North	Garoua 1-1	0.3 (0.1 to 0.8)	0.4 (0.2 to 0.8)	2019	30	906	2594 (98.5)	40	4	0 (0)	0	0 (0)	4	0.12 (0 to 0.30)
North	Garoua 1-2	0.3 (0.1 to 0.8)	0.4 (0.2 to 0.8)	2019	30	899	2723 (97.6)	43	1	1 (100)	0	0 (0)	1	0.02 (0 to 0.06)
Far North	Mada	0.7 (0.4 to 1.4)	1.8 (1.3 to 2.5)	2017	30	901	2077 (98.2)	46	50	34 (68)	3	3 (100)	43	1.63 (0.98 to 2.46)
Far North	Kar Hay	1 (0.6 to 1.7)	0.5 (0.2 to 0.9)	2019	30	898	2621 (97.0)	42	10	6 (60)	3	2 (66.7)	4	0.10 (0 to 0.26)

Data from Touboro have previously been presented elsewhere.[7]

[a]TT is defined as at least one eyelash from either the upper or lower eyelid, of either eye, touching the eyeball or evidence of recent epilation of in-turned eyelashes from either the upper or lower eyelid of either eye.

a design effect (pre-2019 baseline surveys=2.65, post-2019 baseline surveys=3.69, impact and surveillance surveys=2.63, TT-only surveys=1.47) and a non-response inflation multiplier of 1.2.[6,7,14] Including these values in the proportion for precision formula for a single population resulted in target sample sizes of 1222 children ages 1–9 y for pre-2019 baseline surveys, 1701 children ages 1–9 y for post-2018 baseline surveys, 1164 children ages 1–9 y for impact and surveillance surveys and 3382 adults ≥15 y of age for TT-only surveys.[15] The two refugee camp EUs had substantially smaller populations; a finite population correction factor was applied for the Eastern refugee camps,[15] resulting in target baseline survey sample sizes of 1558 children. A finite population size correction factor was not applied to the 2018 Minawao refugee camp survey, as the number of clusters was increased to 30 to have more precision around the TT prevalence estimate.[22]

The surveys used a two-stage sampling strategy, the first stage being a random selection of clusters whose probability of selection is proportional to size within each EU, and the second being a random selection of a segment within each cluster. The availability of clusters (communities) to be sampled within each EU was determined using a list provided by a national census and with assistance from village chiefs, religious leaders or other community representatives. Selected clusters were then divided into segments of 30 households each with the help of village leaders. A segment was chosen at random and all households within that segment were eligible for survey. The number of clusters required to meet the target sample size was calculated based on the estimated average number of children (or adults for TT-only surveys) per household and the number of households (30) that could be surveyed by a team in 1 d. The average household size was estimated at 5.9 persons in the North region and 5.4 persons for the Adamaoua, Far North and East regions,[23] with children ages 1–9 y representing 27.3% of a household in the North and Far North and 28.3% in the East.[24] This gave an average number of children per household of 1.47 in the Far North, 1.61 in the North and 1.53 in the East. The predicted average number of ≥15-year-olds was 3.1 in Adamaoua and 3.0 in the Far North and North regions. Modeling indicates that 30 clusters of 30 households provides sufficient precision around the trachoma prevalence estimate even if the sample size is not attained,[7] and thus a maximum of 30 clusters was surveyed per EU.

Definitions

The WHO's simplified trachoma grading system defines TF as the presence of five or more follicles, each at least 0.5 mm in diameter, in the central part of the upper tarsal conjunctiva.[3] The definition of TT at the time of the TT-only and 2017–2019 standard surveys was at least one eyelash on either the upper or lower eyelid of either eye touching the eyeball or evidence of recent epilation of in-turned eyelashes.[25] At the 4th Global Scientific Meeting on Trachoma in 2018 (GSM4), the definition of TT was modified, limiting it to eyelashes from the upper eyelid touching the eyeball or evidence of recent epilation of in-turned eyelashes from the upper eyelid.[3,26] Only the two surveys conducted in 2022 used this updated definition of TT. A case of TT 'unknown to the health system' is a person with TT who has not been offered (or undergone) surgery or epilation by a health worker or responded 'don't know' to TT management questions.[9,15] The definition of a household in most EUs was a group of people who had been living together (eating, lodging, spending the night) for at least 1 month.

Fieldworker training and qualification

To help ensure the quality of the data collected,[27] training sessions were conducted for those assessing participants for clinical signs of trachoma (graders) and those recording the information (recorders).[21,28] Training was provided by experienced trainers, certified by Tropical Data, following a published methodology, and involved both theoretical learning and practical field experience. In early 2017, graders and recorders were trained using the Tropical Data training manual (version 1.2), while those trained between July 2017 and May 2019 used version 2. Training conducted from June 2019 to April 2021 used version 3 and all those conducted after May 2021 used version 3.1. The same group of graders was used for all surveys and consisted of specialized ophthalmology technicians and a small number of trichiasis surgeons (usually nurses trained by the National Program to conduct trichiasis surgery). Prospective graders were assessed on correct examination procedures and the ability to consistently identify the presence or absence of TF and TT, and were required to achieve a κ score for TF of ≥0.7 compared with a certified grader trainer. Recorders trained in 2019 and later underwent a separate reliability test, with only those achieving a passing grade of ≥90% allowed to be part of the survey team.[15]

Examination process

Graders used 2.5× binocular magnifying loupes and sunlight or torches to examine eyes for signs of TF, TI and TT, with graders also looking for trachomatous scarring (TS) in individuals with TT. To look for TF, TI and TS, the upper eyelids were everted. To look for TT, the eye was examined from the side and the front in its primary gaze position. The presence or absence of trichiasis in the upper and lower eyelids was recorded separately in post-GSM4 standard surveys and in all TT-only surveys. Individuals with TT were questioned regarding previous management of this condition. Telephone numbers of people with TT were collected to offer TT management. If active trachoma was identified, 1% tetracycline eye ointment was administered and a 5-week supply provided free of charge.

Water, sanitation and hygiene (WASH) facilities

In addition to the physical exam, the head of each household was asked questions about WASH access, with the questions adapted from the UNICEF/WHO Joint Monitoring Programme.[29] In brief, questions related to the source and collection time of face-washing water and drinking water, the location of disposal of human faeces and the presence or absence of a hand-washing station.[15,16]

Data collection, analysis and storage

Tropical Data (www.tropicaldata.org) supported data collection, management and analysis, in addition to protocol review and training. Data collected in the field were entered into Android

smartphones and transmitted directly to a secure cloud-based remote server, following the methods put in place by the GTMP.[16] Data were transferred in encrypted form.

To estimate the prevalence of TT and TF and the associated CIs, data collected from 2016 to 2022 were separated by survey type and analyzed as previously described.[16] The association analyses between TF prevalence, age, gender and WASH variables and (separately) TT and age and gender were performed using the glmer function in R (version 4.0.4; R Foundation for Statistical Computing, Vienna, Austria). Age was separated into three groups of 15–45, 46–75 and >75 y for TT association analyses and 1–3, 4–6 and 7–9 y for TF association analyses. The lowest age bracket was used as the reference. Relatively wide age brackets were used for the TT analysis because the narrower ones recommended elsewhere[30] resulted in cells containing zero TT cases and therefore failure of the model. Odds ratios (ORs) and 95% CIs were calculated for the final model, which was selected based on maximum likelihood values. As the majority of surveys in this study defined TT using the pre-GSM4 definition,[25] both upper and lower eyelid trichiasis were used as the independent variable in regression analyses. Data on TT from both the standard surveys and the TT-only surveys were combined into a single dataset for this purpose. For consistency, in the data from the 2022 surveys, TT status was determined using findings from both the upper and lower eyelid. All data were analyzed using the statistical software R version 4.0.4.[31]

Results

A total of 151 800 people were examined across 45 surveys from a total of 156 476 residents enumerated in the selected households, giving an overall response rate of 97.0%. There were 53 170 children ages 1–9 y examined in total from 53 535 enumerated 1- to 9-year-olds (99.3%). Age- and gender-adjusted TF prevalence ranged from 0.34 to 5.8% at baseline, 0 to 3.7% at impact and 0.06 to 10.0% at the surveillance survey (Figure 1, Table 3). At the most recent survey, 2 EUs were above the elimination threshold for TF and 10 for TT (Figures 2 and 3). TF prevalence was above the 5% threshold in three EUs, Kolofata at baseline (2022 survey) and Makari and Goulfey at surveillance (2019 surveys). Goulfey underwent another impact survey in 2022 and was found to be under the 5% threshold. The prevalence of TT unknown to the health system for the standard surveys ranged from 0.01 to 1.28% at baseline, 0 to 0.73% at impact and 0 to 0.44% at the surveillance survey, with Kolofata exhibiting the highest TT prevalence (1.28%). In the TT-only surveys, the range was 0.02–1.63%; three of the TT-only EUs (Garoua 1-1, Garoua 1-2 and Kar Hay) had a TT prevalence below the 0.2% threshold, whereas the remaining three (Touboro, Mada and Meiganga) had prevalence estimates ≥0.2% (Table 2, Figure 3). A total of 448 TT cases (using any definition) were identified and referred for case management. Overall there were 10 EUs with a TT prevalence ≥0.2%.

The EU with the lowest proportion of households with an improved drinking source was Poli, with 25% in the 2017 impact survey, and the highest EUs were Makari and Kousseri 2 with 100% in the 2019 surveillance surveys (Figure 4, Table 3). Makari also had the highest proportion (100%) of households with a source of drinking water within 30 minutes. The baseline surveys in the refugee camps in the Eastern region had the highest proportion (90%) of households with access to an improved latrine, and Tchollire had the lowest proportion, with 0.2% of households having access to an improved latrine in the 2017 impact survey.

Age, gender and WASH association analysis

There was no evidence to suggest that any of the WASH variables tested, nor the number of children per household, were significantly associated with TF in the univariable models for any survey type (Supplementary material Tables S1, S2, and S3). There was evidence to suggest that age was significantly associated with TF for all three survey types, with the older age group (7–9 y) being significantly less likely to have TF than the youngest age group (1–3 y). Gender was also statistically significant in baseline surveys, with girls slightly less likely to have TF than boys (p=0.01, OR 0.51 [CI 0.31 to 0.85]), a pattern that was replicated in the multivariable model (p=0.03, OR 0.55 [CI 0.32 to 0.94]).

The TT association analysis showed that the likelihood of TT was 108 times higher in the ≥75 years age group than in the 15–45 years age group (p<0.001, OR 108.9 [CI 47.9 to 247.5]). Women were 2.5 times more likely than men to have TT (p<0.001, OR 2.5 [CI 1.7 to 3.6]).

Discussion

The standard survey results demonstrate that after years of MDA interventions, all but two EUs in Cameroon now have a TF prevalence below the WHO elimination threshold of 5% within the surveyed regions. The 2010–2012 baseline survey results showed that there were 23 EUs that had a TF prevalence >5%, and it has only been through substantial efforts of the Cameroon MPH and supporting partners that the TF prevalence has been reduced to such an extent. However, TT prevalence remains high, both in data from standard surveys and TT-only surveys, with seven and three EUs being above the elimination threshold, respectively.[8] Cameroon has included trachoma control in its integrated national Neglected Tropical Diseases (NTD) Control Program since 2009, incorporating all components of the SAFE strategy. Districts in which TT prevalence was ≥0.1% have been targeted as a priority, with 63 trichiasis surgeons trained in the Far North, 30 of whom were certified in 2014 and 6 in 2016. In the North, four surgeons were trained and certified in 2016 and two in 2019. With support from multiple partners, the government has also established four surgical centres in the Far North and two in the North. However, more work needs to be done to reduce the number of TT cases in the community, including identifying affected people and encouraging and supporting them to receive appropriate treatment.[32,33] The impression of the program staff is that the primary cause for low TT case management is refusal, with the main reasons being fear of surgery and having to miss harvesting or market days. These issues could be improved through education on the benefits and safety of TT surgery. There were also two EUs in the standard surveys that increased from below the TT threshold to above the threshold in subsequent surveys,

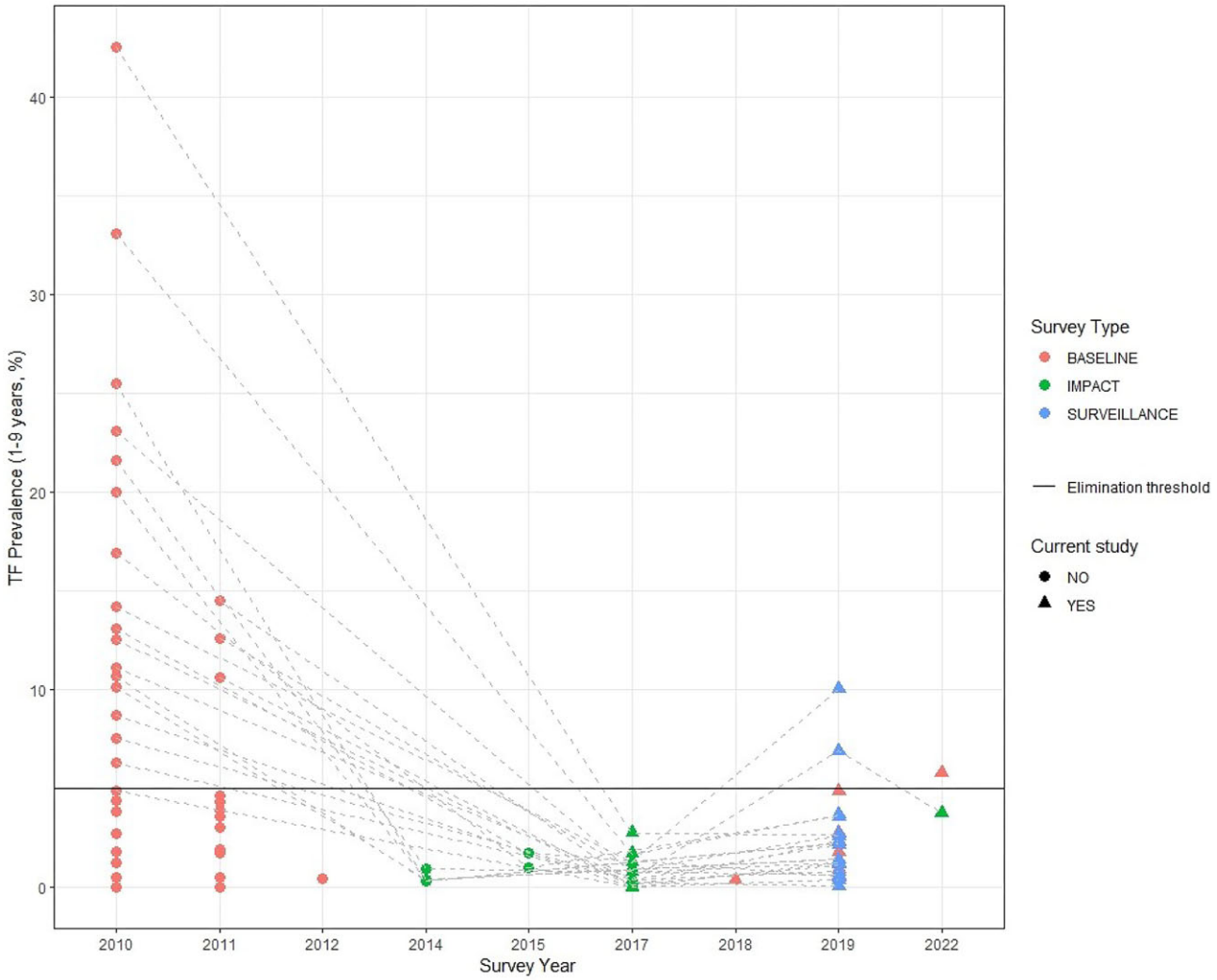

Figure 1. The prevalence of trachomatous inflammation—follicular (TF) over time for each evaluation unit (EU) surveyed in Cameroon since 2010. Prevalence estimates from 2017 to 2022 include trachoma baseline, impact and surveillance survey data generated with support from Tropical Data and presented in this article. Prevalence estimates from 2010 to 2015 were generated using other methods and different partners. Some baseline and impact surveys were carried out using EU boundaries different from those used in these surveys and therefore direct comparisons are not appropriate.

Rey-Bouba and Goulfey. We hypothesize, without proof, that this is likely due to sampling variation. The recommendation from WHO in this scenario is to use model-based geostatistics to re-estimate the TT prevalence with more precision before considering further surveys.[34,35]

Two EUs, Kolofata and Makari-Fotokol, remained above the TF threshold at their most recent surveys, in 2022 and 2019, respectively. Both of these EUs are situated in the Far North region and lie in close proximity to Nigeria and Chad. In previous surveys, TF and TT prevalences were high in both Chad and northeastern Nigeria.[36–41] Additionally, there has been an ongoing security crisis since 2013 in the Far North linked to non-state armed groups, which has caused hundreds of thousands of refugees, returnees and internally displaced persons to move into and within this region.[42] This may have contributed to the high TF prevalence observed in this study due to circulation of *C. trachomatis* infection and mixing of populations across national borders.[43] The Kolofata survey was a new baseline survey, conducted in 2022, as it had been nearly a decade since the previous survey in 2013 after the end of the Azyter trial and large demographic changes due to the aforementioned security situation had taken place. As the TF prevalence estimate in our study was only 5.8%, it is likely that one round of MDA will be sufficient to reduce the prevalence to <5%.[44,45] The TF prevalence in Makari-Fotokol EU, however, increased from 1.27% at the impact survey in 2017 to 10.01% at the surveillance survey in 2019. It is possible that as TF prevalence was >10% at baseline, it may be recrudescence from some focal infection left after MDA, or potentially mobile populations, such as refugees, with higher rates of *C. trachomatis* infection having settled in the area. WASH factors may also be involved, as while the proportion of households with an improved drinking source within 30 minutes increased between 2017 to 2019, access to an

Table 3. Survey population, trachomatous inflammation—follicular (TF) and trachomatous trichiasis (TT) prevalences and WASH access for each standard survey evaluation unit (EU) in Cameroon: baseline, impact and surveillance surveys, 2017–2022. Confidence Interval (CI).

EU	Region	District	Subdistrict	Survey type	Survey year	Clusters surveyed, n	Households surveyed, n	1- to 9-year-olds examined, n (%)	Age- and gender-adjusted prevalence of TF (95% CI)	≥15-year-olds examined, n (%)	Age- and gender-adjusted prevalence of TT unknown to the health system (95% CI)	Surveyed households with an improved drinking water source, %	Surveyed households with a drinking water source within 30 minutes, %	Surveyed households with an improved latrine, %
10711	East	Garoua Boulaye		Baseline	2019	30	897	1087 (98.5)	1.75 (1.02 to 2.73)	1512 (98.4)	0.01 (0 to 0.03)	76	82	49
10713	East	Kette and Batouri		Baseline	2019	30	896	1347 (99.5)	0.89 (0.24 to 1.56)	1610 (99.4)	0.12 (0.04 to 0.23)	74	86	34
10712	East	Ndelele		Baseline	2019	30	895	1174 (99.2)	4.87 (3.69 to 6.37)	1408 (95.3)	0.17 (0.03 to 0.38)	41	80	22
10715	East	Yokadouma, Garoua Boulaye and Batouri	Timangolo Refugee Camp, Ngarisingo Refugee Camp, Mbile Refugee Camp, Lolo Refugee Camp and Gado Badzere Refugee Camp	Baseline	2019	30	895	1150 (99.7)	0.49 (0.14 to 0.97)	1365 (96.8)	0.19 (0.01 to 0.48)	100	96	90
10714	East	Yokadouma and Moulourdou		Baseline	2019	30	903	1155 (99.2)	2.77 (1.18 to 4.12)	1799 (95.0)	0.52 (0.21 to 0.86)	40	64	22
80354	North	Poli		Impact	2017	30	905	1452 (98.7)	0.88 (0.33 to 1.62)	1957 (86.7)	0.16 (0.05 to 0.26)	25	9	4
60373	North			Surveillance	2019	24	716	1069 (99.9)	2.57 (1.01 to 3.96)	1359 (98.8)	0.10 (0 to 0.28)	46	9	4
80355	North	Rey-Bouba		Impact	2017	30	900	2023 (99.8)	0.15 (0 to 0.35)	2502 (97.8)	0.12 (0.01 to 0.27)	40	94	14
60374	North			Surveillance	2019	24	722	1027 (99.4)	1.13 (0.58 to 1.65)	1487 (99.1)	0.30 (0.08 to 0.58)	26	68	4
80356	North	Tcholliré		Impact	2017	30	900	2801 (100)	0.26 (0.12 to 0.43)	2254 (96.0)	0.07 (0 to 0.17)	41	27	0
60375	North			Surveillance	2019	24	720	1328 (100)	0.06 (0 to 0.18)	1713 (99.7)	0.19 (0.04 to 0.41)	54	87	6
80344	Far North	Goulfey		Impact	2017	30	899	1436 (100)	0.40 (0.10 to 0.79)	1586 (98.2)	0.35 (0.16 to 0.61)	99	35	1
60367	Far North			Surveillance	2019	27	842	1084 (98.8)	6.91 (4.13 to 10.40)	1220 (87.0)	0.15 (0 to 0.42)	87	92	4
81843	Far North			Impact	2022	30	906	1646 (99.0)	3.74 (2.45 to 5.24)	1690 (94.7)	**0.24 (0.04 to 0.43)**	97	92	13
80345	Far North	Guéré		Impact	2017	30	895	1128 (97.4)	0.35 (0 to 0.86)	1667 (96.9)	0.27 (0.02 to 0.70)	74	39	3
60368	Far North			Surveillance	2019	27	807	769 (99.7)	2.15 (0.81 to 3.86)	1404 (99.4)	0.09 (0 to 0.22)	68	33	1
60369	Far North	Guidiguis		Surveillance	2019	27	808	1162 (99.7)	3.57 (2.32 to 5.04)	1919 (99.7)	0.06 (0 to 0.14)	72	46	7

Table 3. Continued

EU	Region	District	Subdistrict	Survey type	Survey year	Clusters surveyed, n	Households surveyed, n	1- to 9-year-olds examined, n (%)	Age- and gender-adjusted prevalence of TF (95% CI)	≥15-year-olds examined, n (%)	Age- and gender-adjusted prevalence of TT unknown to the health system (95% CI)	Surveyed households with an improved drinking water source, %	Surveyed households with a drinking water source within 30 minutes, %	Surveyed households with an improved latrine, %
60370	Far North	Hina		Surveillance	2019	27	818	1190 (99.1)	0.62 (0.22 to 1.05)	1444 (97.7)	0.05 (0 to 0.14)	50	76	6
11011	Far North	Kolofata		Baseline	2022	30	899	1389 (98.2)	5.80 (4.46 to 7.52)	1631 (94.3)	**1.28 (0.67 to 2.08)**	89	77	33
80346	Far North	Kousséri	Kousseri 1 and 2	Impact	2017	30	893	1705 (99.6)	0.06 (0 to 0.18)	1900 (99.5)	0	98	93	15
60362	Far North		Kousseri 1	Surveillance	2019	27	809	1141 (99.7)	1.69 (0.93 to 2.70)	1704 (98.2)	0.10 (0 to 0.25)	99	96	58
60363	Far North		Kousseri 2	Surveillance	2019	27	829	1339 (99.4)	2.34 (1.46 to 3.46)	1820 (97.6)	0.11 (0 to 0.29)	100	69	13
80347	Far North	Makari and Fotokol		Impact	2017	30	896	1663 (98.9)	1.27 (0.60 to 2.15)	1578 (76.9)	0.63 (0.28 to 1.11)	90	43	14
60371	Far North			Surveillance	2019	27	816	1361 (99.6)	10.01 (7.30 to 12.24)	1685 (92.3)	0.44 (0.18 to 0.71)	100	100	1
80348	Far North	Maroua 3 and Gazawa		Impact	2017	29	864	1283 (99.1)	0	1908 (91.4)	0.01 (0 to 0.04)	67	94	12
80349	Far North	Meri		Impact	2017	30	900	1163 (99.3)	1.68 (0.77 to 2.74)	2014 (98.6)	0.73 (0.31 to 1.12)	44	82	3
60364	Far North			Surveillance	2019	27	833	1281 (99.8)	3.66 (1.84 to 5.13)	1951 (97.8)	0.07 (0 to 0.12)	67	38	5
60358	Far North	Mogode and Bourha		Surveillance	2019	27	810	1129 (100)	1.40 (0.68 to 2.46)	1505 (95.6)	0	35	8	27
10642	Far North	Mokolo	Minawao refugee camp	Baseline	2018	30	894	1167 (98.1)	0.34 (0.05 to 0.72)	1444 (94.2)	0.48 (0.12 to 1.04)	87	61	46
60361	Far North			Surveillance	2019	27	809	1352 (100)	0.56 (0.17 to 0.92)	1684 (93.0)	0.35 (0.11 to 0.63)	74	98	49
80350	Far North	Moutourwa		Impact	2017	30	900	1678 (99.9)	0.34 (0.08 to 0.68)	2474 (98.0)	0.02 (0 to 0.07)	90	89	1
60360	Far North	Moutourwa and Gazawa		Surveillance	2019	27	813	1079 (99.8)	0.80 (0.34 to 1.38)	1716 (95.6)	0.04 (0 to 0.11)	72	77	25
80351	Far North	Pete		Impact	2017	30	905	1674 (99.6)	0.75 (0.35 to 1.28)	1815 (89.6)	0.17 (0 to 0.44)	73	57	1
60366	Far North	Pete and Maroua 3		Surveillance	2019	27	814	1069 (99.4)	1.24 (0.46 to 2.27)	1813 (97.8)	0.04 (0 to 0.12)	88	76	34
60359	Far North	Roua and Koza		Surveillance	2019	27	810	1092 (99.7)	2.24 (1.24 to 3.22)	1706 (97.8)	0.02 (0 to 0.07)	51	64	15
80352	Far North	Tokombere		Impact	2017	30	889	1803 (97.6)	2.73 (1.16 to 4.44)	1503 (84.2)	0.35 (0.17 to 0.58)	64	18	19
60365	Far North			Surveillance	2019	27	835	1424 (99.2)	2.68 (1.45 to 4.27)	1873 (96.0)	0.19 (0.03 to 0.43)	70	55	7
80353	Far North	Yagoua		Impact	2017	30	899	1140 (99.0)	0	1610 (82.4)	0.04 (0.01 to 0.07)	80	27	20
60372	Far North			Surveillance	2019	27	822	1099 (99.9)	0.35 (0 to 0.79)	1971 (98.8)	0.01 (0 to 0.04)	71	63	19

Values in bold represent TT estimates calculated using the updated definition of TT, which includes only trichiasis present in the upper eyelid. All other values include both upper and lower eyelid trichiasis.

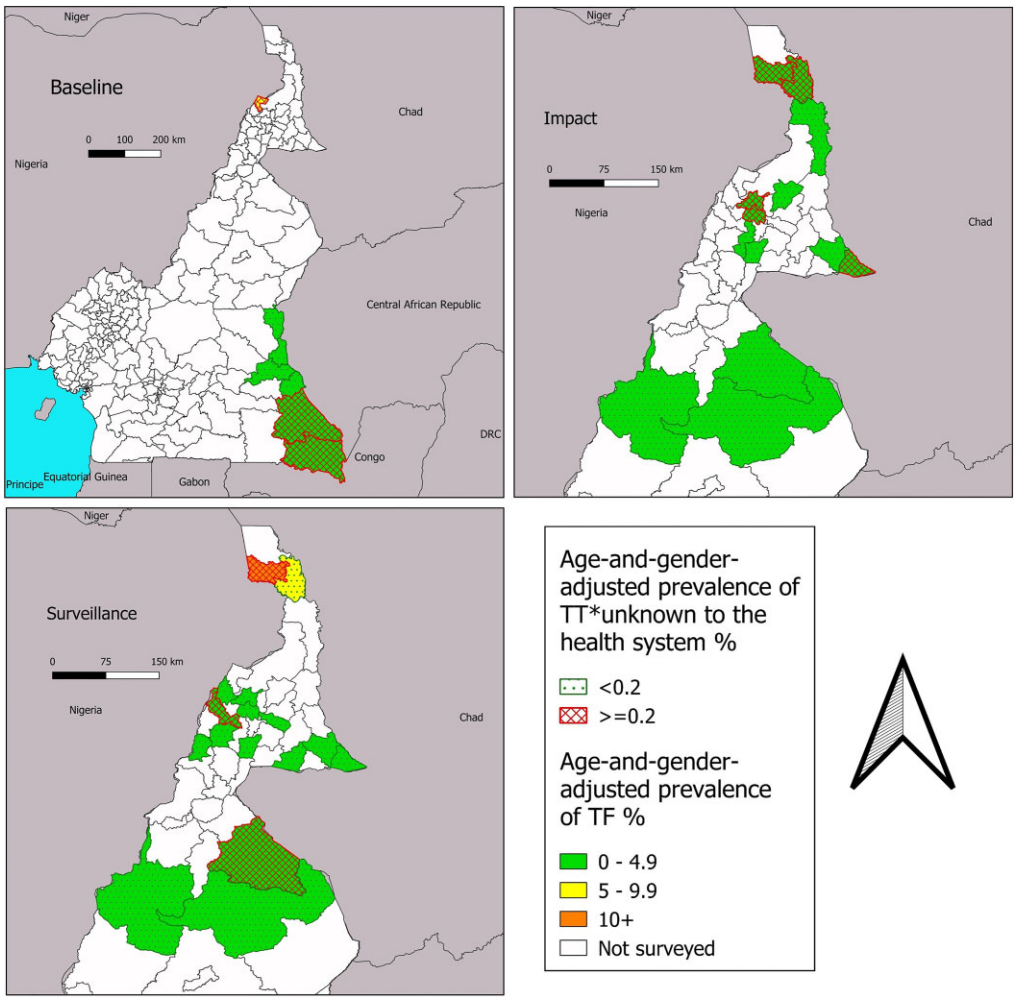

Figure 2. Age- and gender adjusted prevalence of trachomatous inflammation—follicular (TF) and trachomatous trichiasis (TT) in Cameroon baseline, impact and surveillance surveys from 2017 and 2022, not including surveys of refugee camps, as these do not have geographical boundaries available. Only the most recent data for each evaluation unit (EU) are shown. The boundaries and names shown and the designations used on this map do not imply the expression of any opinion on the part of the authors or the institutions with which they are affiliated concerning the legal status of any country, territory, city or area or of its authorities or concerning the delimitation of its frontiers or boundaries. *The 2022 EUs represent TT specifically as defined at The 4th Global Scientific Meeting,[26] with prevalence estimates based on upper eyelid trichiasis only.

improved latrine decreased from 14% to just 1%. The cause of this reduction in access to improved latrines is unknown, and it is possible this is partly responsible for the apparent increase in TF prevalence. Efforts to identify programmatic causes are currently underway to investigate the increase in TF, which is suspected to be related to the implementation of the A, F and E components of the SAFE strategy. WHO recommends that EUs with a TF prevalence ≥10% receive a further three rounds of MDA,[14] and this has been implemented every 6 months rather than annually in 2022 and 2023 in Makari-Fotokol EU, in line with the recommendations from the WHO's Informal Consultation on End-Game Challenges for Trachoma Elimination.[46] A single round of MDA was conducted in Kolofata in 2023. Additionally, the Programme national de lutte contre la cécité is planning to conduct 'TIS+' (incorporation of serological and infection indicators into the standardized impact surveys) for the upcoming surveys in both Makari-Fotokol and Kolofata to determine future programmatic action.

A previously published G-computation analysis suggests that at least 30% of households need access to WASH to achieve consistent decreases in TF.[47] While in most EUs that we surveyed the proportion of households with close access to safe water was >60%, access to an improved latrine was quite low overall. An improved latrine is one where waste is flushed into an enclosed container or sewer system, as opposed to an open drain and open defecation.[29] Studies have shown that increased latrine use is associated with a reduction in TF, however, latrine use needs to be relatively high, with an estimated proportion >85% needed to reduce TF by approximately 25%.[47] This is also true for other NTDs; increased schistosomiasis

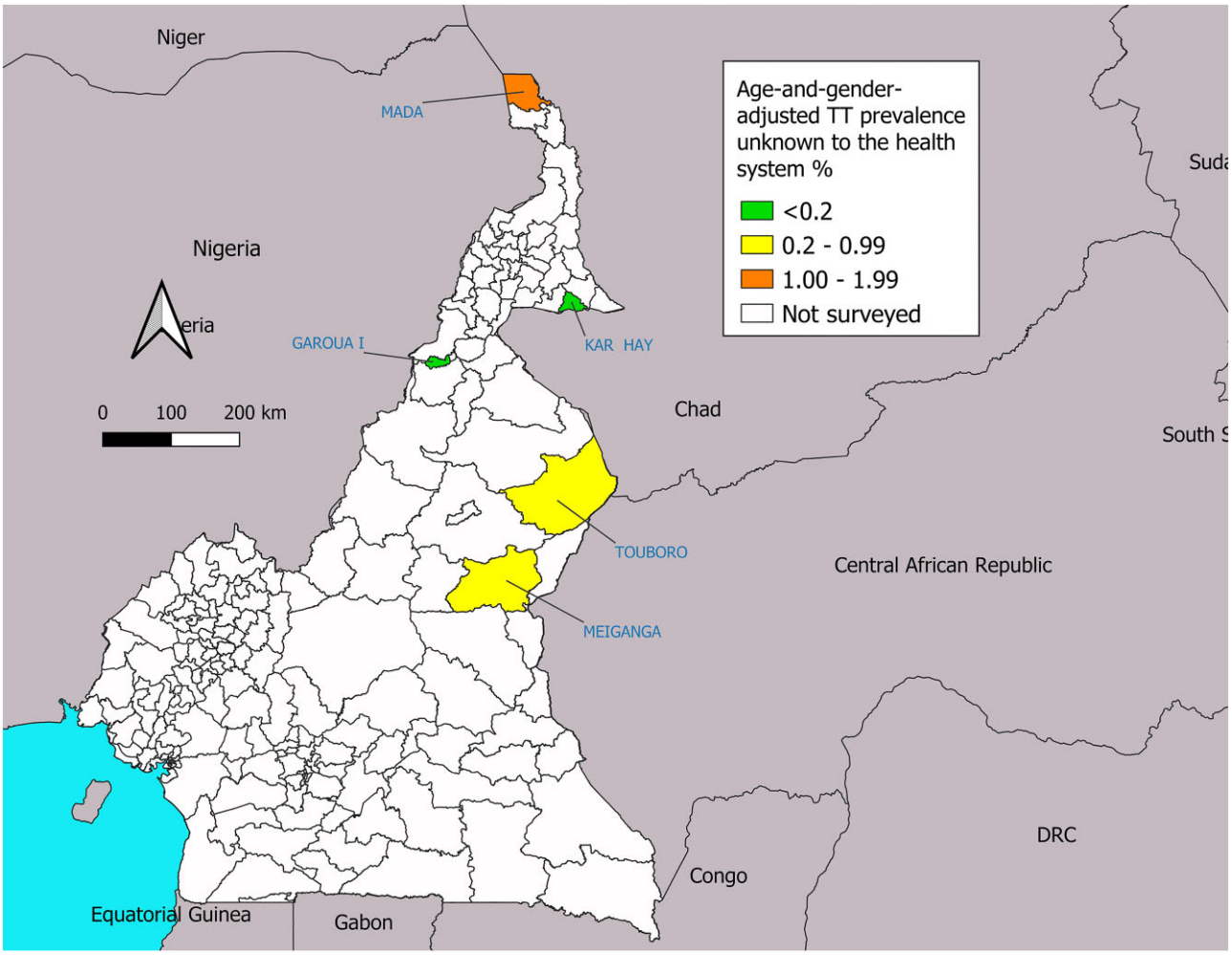

Figure 3. The six Northern Cameroon evaluation units (EUs) surveyed using the TT-only methodology (2016–2019), with trachomatous trichiasis (TT) prevalence category shown for each EU. Garoua 1 district was split into two EUs (Garoua 1-1 and 1-2) due to the size of the population, but appears here as one district; the TT prevalence categories were the same for the two constituent EUs. The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the authors or the institutions with which they are affiliated concerning the legal status of any country, territory, city or area or of its authorities or concerning the delimitation of its frontiers or boundaries.

transmission is linked with open defecation,[48] and access to improved sanitation is associated with reduced soil-transmitted helminth transmission.[49] The Cameroon Ministry of Health is currently working in partnership with the Ministry of Water and Energy and a number of non-governmental organizations to build wells in communities and schools as part of a WASH sustainability strategy.

Our association analyses indicated strong associations of TT with both increased age and female gender. In past studies, gender has been found to be highly associated, with women being at much greater risk of TT, possibly because of higher lifetime exposure to infection through closer contact with children.[50] The association with age is likely due to the time it takes for scarring damage from repeated infections to accumulate to a point at which eyelash direction is altered.[51] The TF association analyses showed that while no WASH variables were associated, age and gender were, with younger children and boys more likely to have TF than older children and girls. The association of TF with younger age is well documented.[51,52] Although reasons for it are not known with certainty, it may relate to differences in behaviour or immunological responses to exposure.[2] A relationship between gender and TF is less commonly observed, however, it is possible that young boys engage more frequently than girls in close-contact activities with their peers, which could enhance the spread of ocular *C. trachomatis*.

This study had a number of limitations. In all six TT-only EUs, the number of adults examined was less than the target of 2818. While the number of ≥15-year-olds per household was estimated to be approximately 3.0 in the study regions, the actual average based on the data collected was 2.1.

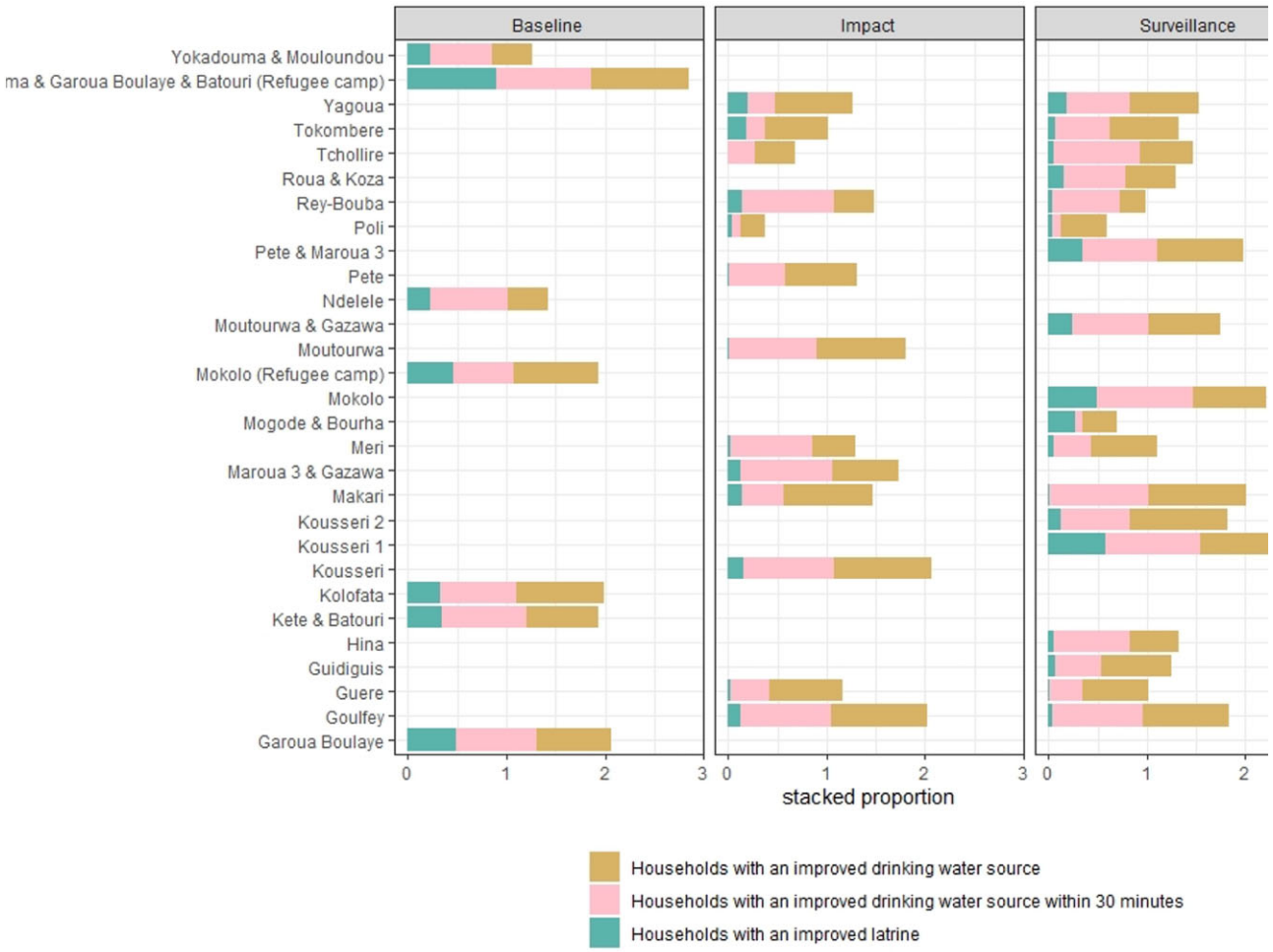

Figure 4. The proportion of households from baseline, impact and surveillance surveys conducted in Cameroon from 2017 to 2022 with access to Water, sanitation and hygiene, separated by evaluation unit (EU) and survey type.

All six surveys included at least 30 clusters, however, and the modeling undertaken during the development of the TT-only methodology suggested that 30 clusters provided sufficient power to accurately estimate TT prevalence.[7] There were also a number of standard surveys that did not meet their respective target sample size for number of children examined, including all 7 of the baseline surveys, 2 impact surveys and 11 surveillance surveys. Guéré had a particularly low number of 1- to 9-year-olds examined (n=769). The most recent census in Cameroon was in 2005, with all the population figures after that estimated using percentage growth, so even if this is accurate at the country level, there are likely to be differences by region and/or district. The limitation itself might therefore be inaccurate population figures.

Also, the refugee camps were outside of the recommended population sizes for EUs; however, these are special populations and the sample size calculations were adjusted accordingly. Refugee camps are created in response to conflict or environmental disasters that cause large numbers of people to become displaced, often in a short period of time.[53] When there is population movement between areas undergoing trachoma MDA campaigns, this can create issues for implementing surveys and interpreting results.[54,55] The International Coalition for Trachoma Control has created a plan to identify special populations defined as 'hard to reach', which includes refugees (among others), as traditional programmatic implementation may not be able to access these populations.[56] According to the WHO Alliance for GET2020 Database, as of 25 April 2023, there were an estimated 198 districts in 15 countries that are defined as 'hard to reach', and this may pose a considerable challenge to meeting the 2030 targets.[57]

These data show that in most parts of the North, Far North and East regions of Cameroon, TF is no longer a public health problem, following years of MDA, except in two EUs in which research is being carried out to better understand the epidemiology. Increased WASH investment is required to maintain the prevalences below the threshold in the long-term. In contrast, TT remains a public health problem in more EUs in the surveyed regions.

Further work to identify and manage these cases or to undertake geostatistical-based modelling to obtain more precision around the prevalence estimate is needed for Cameroon to reach the elimination target.

Supplementary data

Supplementary data are available at *International Health* online (http://inthealth.oxfordjournals.org).

Authors' contributions: EE, CFT, CJ, CBB, AK, PH, ET, YZ, JMN, IT, EMHE, AWS, SMC, JCNN, GN, AGEM, AOE and ABe were responsible for the study design. EE, ABa, SB, CJ, WG, SR, ET, DAC, FG and JMN were responsible for study implementation. ABa, RW, AJH, SR, ET and EMHE were responsible for analysis and interpretation of data. EE, AJH, AK, SLP, DAC, EMHE and AWS were responsible for drafting, reviewing and editing the manuscript.

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Competing interests: AB and SB are (and RW was) employed by the International Trachoma Initiative at the Task Force for Global Health, which receives an operating budget and research funds from Pfizer, the manufacturers of Zithromax (azithromycin). EMHE receives salary support from the International Trachoma Initiative.

Ethical approval: Ethical approval for this study was granted by the Cameroon MPH and the London School of Hygiene & Tropical Medicine Ethics Committee (reference 16105). The consent form was explained to each village chief, the head of each household and each individual participant in their native language and written consent (via signature or thumbprint) was obtained. Parents or guardians gave consent on behalf of children <15 y of age. Children <1 y of age were not included.

Data availability: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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