Reaching semi-nomads for NTD programmes in Cameroon

Research Summary

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Sightsavers

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Executive summary

Introduction and methods: Test and treat with doxycycline (TTd) in Massangam Health District did not equally reach semi-nomadic and settled populations and twice as many semi-nomads were missed from treatment. Qualitative research suggests that this is due to a combination of factors including remote settlements, high mobility, linguistic and cultural barriers, use of settled community drug distributors (CDD) and inadequate programme planning. We made programme adaptions to address these challenges, implemented and evaluated them among the semi-nomads. These adaptions included: nomad-specific sensitisation, using satellite imagery to identify camps, adapted timing and treatment monitoring and camp outreach. Participation in the intervention, prevalence and the intensity of onchocerciasis by a skin snip microscopy examination were used to determine effectiveness.

Results: A total of 62 occupied camps were found and four of these were previously unknown to the settled community. A further 11 camps were identified but were unoccupied at the time of our visit. The community approach of camp identification was 85% sensitive and 100% specific. The use of satellite imagery was 65% sensitive and only 32% specific. The semi-nomadic population in this area is very young and dynamic and have a mean age of 19.5 years and a median of 15 years. Over one year, 17% of the baseline population immigrated and 32% emigrated, resulting in a turnover of 47%. In terms of participation for test and treat, 47% of eligible semi-nomads participated in testing with a resultant onchocerca volvulus mf prevalence of 15%. This, together with the high turnover of 47%, reinforces the hypothesis of a roaming reservoir of transmission. All those infected completed a 35 day treatment with doxycycline 100mg. Among those retested after six months, all were negative on microscopy and there was only one positive by PCR. Prevalence by microscopy dropped from 8.9% at baseline to 4% at endline (non-overlapping confidence intervals and $p<0.05$). 46% of the semi-nomadic population reported taking ivm, with 38% saying they took it in the previous round. This strategy cost 76 USD per person tested and 307 USD per person treated.

Conclusion and recommendations: The participation rates were closer to the settled population's 54% for test and treat. This narrows the reach gap previously noted between the two populations. It can be concluded that:

- satellite and community-based identification of hard-to-reach populations are complementary.
- given the high prevalence of mf and the dynamic and young semi-nomadic population, these nomads could constitute or become a roaming reservoir and are a threat to elimination of onchocerciasis.
- mobile and nomad-specific sensitisation and engagement are successful in reaching a hard-to-reach population
- the test and treat strategy successfully reduced the prevalence of infection detected by microscopy.

The recommendation is:

- for the programme to consider adapting sensitisation and delivering strategies that achieve equity in this hard-to-reach group;
- consider the use of satellite and community-based identification for hard-to-reach populations as one way to validate community knowledge;
- consider developing strategies that detect and reach nomad/semi-nomads through regular register updates and checking of unoccupied camps and
- programmes should consider a curative strategy for hard-to-reach populations instead of a 20-year ivermectin mass drug administration (MDA) commitment.

Background and justification for the study

More than 20 years of annual ivermectin MDA in the Massangam Heath Area (MHA) in the West Region of Cameroon has not interrupted onchocerciasis transmission and microfilaria (mf) prevalence is as high as 37% and a blackfly infective rate of 2.0% was reported in 2016 (Bakajika et al., 2018). Based on these findings, it was concluded that continuing annual ivermectin treatment alone would be unlikely to achieve the elimination of onchocerciasis by 2025. To accelerate elimination, three alternative treatment strategies (ATS) have been implemented since 2017. These include TTd which was implemented in three high mf prevalent communities where those found to have mf on skin snip microscopy were offered doxycycline 100mg daily for 35 days. The other two components were biannual ivermectin distribution (for those not taking doxycycline in high prevalent areas and their surrounding communities) and larviciding of known simulium damnosium (blackfly vector) breeding sites. During the implementation of the ATS, the presence and the challenges in reaching the semi-nomadic population came to light. A post-MDA treatment coverage survey in 2014 showed that this group had the lowest coverage, with the majority of respondents stating that they were not offered treatment by drug distributors (Senyonjo et al., 2016). Furthermore, preliminary results of the ATS suggested that up to 70% of the semi-nomadic population, compared to 40% of the settled population, were not reached by TTd interventions that used existing strategies, even though they live at the frontline of transmission near blackfly breeding sites.

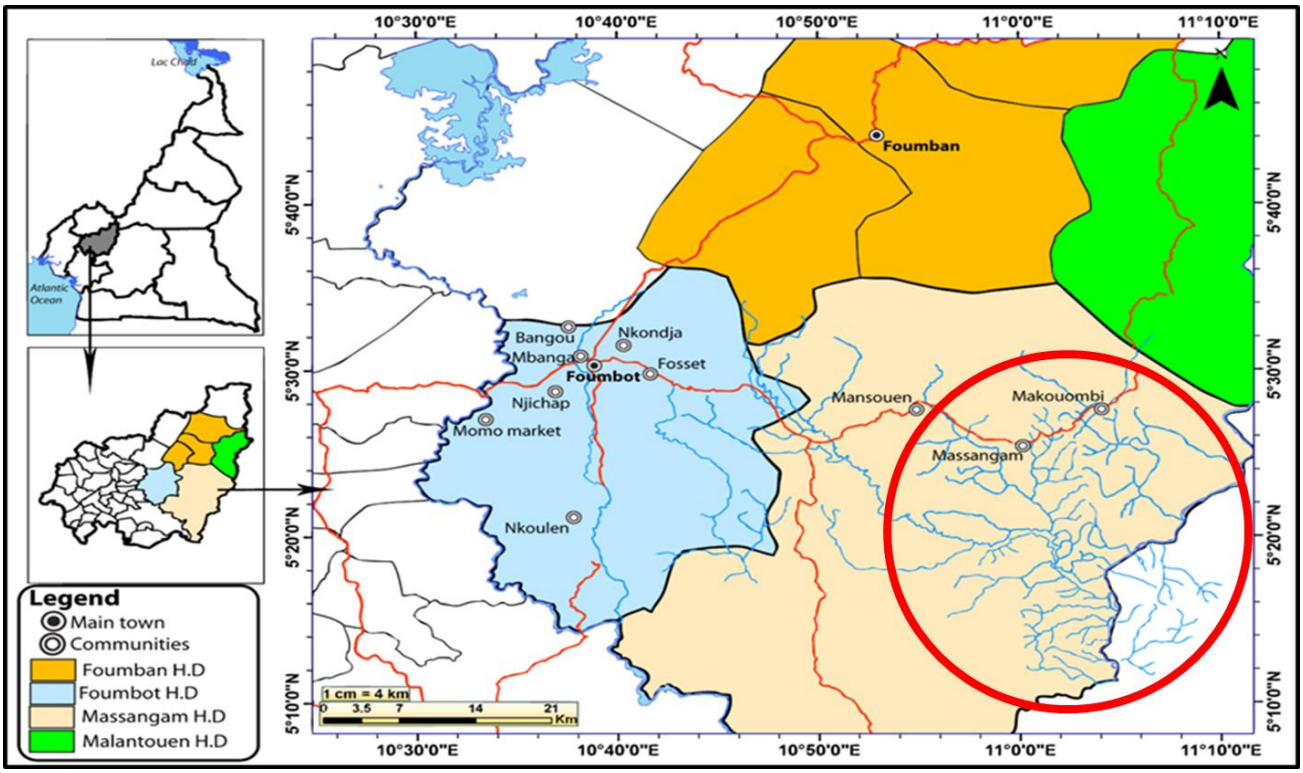
A qualitative assessment of the ATS in the MHA revealed barriers in reaching the semi-nomadic population (Nditanchou et al, 2021 in press). These included (1) the remote, dispersed and small settlements of the nomadic population; (2) their high mobility (seasonal and daily migration) which means they were often missed during MDA campaigns; (3) the community-directed distributors (CDDs) used for routine MDA efforts are from outside the nomadic community which creates challenges around acceptance due to linguistic and cultural differences; (4) the limited information and many preconceptions about the semi-nomads (low awareness and low education/literacy) who are not systematically included in health system programme planning including routine MDA.

As well as the implicit equity concerns with the exclusion of this group from both TTd and ivermectin MDA, there is a risk that they constitute a roaming reservoir of transmission which will impede elimination efforts. This research explores the level of infection in this population and, based on the previously identified challenges, further develops and tests an optimised TTd and ivermectin MDA delivery strategy for the semi-nomadic population in Massangam Health District.

The health district, located in the West Region of Cameroon, is situated in a savannah-forest transition zone and is characterised by mountainous terrain (altitude between 500 and 1000 metres). It also constitutes a watershed where many tributaries of the River Mbam, one of the main rivers in this area, rise. The two main tributaries rivers are the Noun which lies to the west and the Nja which cuts through Massangam. These rivers provide perennial breeding sites to blackflies, the vector of onchocerciasis (Bakajika et al., 2018). The inhabitants of this area are mainly the Bamouns but there are other minority groups such as the Bamilikes and Peuls (Bororo Fulani) who constitute almost all of the semi-nomadic and

hard-to-reach populations. The main economic activities of the habitants include farming, cattle rearing and petty trading. Figure 1 shows the area where this study was implemented (found within the red circle).

Figure 1: Map of Massangam Health District highlighting intervention area (red circle)



Objectives of study

The study's primary objective was to:

1. Establish whether mobile outreach that delivers a TTd strategy is effective in reducing onchocerciasis prevalence and the intensity of infection among hard-to-reach nomadic groups in Massangam Health Area

And secondarily to:

1. Increase the understanding about the nomadic population. This includes exploring the variation in the prevalence of onchocerciasis and the intensity of infection (community microfilaria load (CML)) in different age and sex groups of the hard-to-reach semi-nomadic community in the Massangam Health Area
2. Establish the coverage of ivermectin MDA in the semi-nomad population with respect to the last round of ivermectin MDA
3. Establish the cost of the mobile outreach strategy in this context with a focus on per person screened and treated

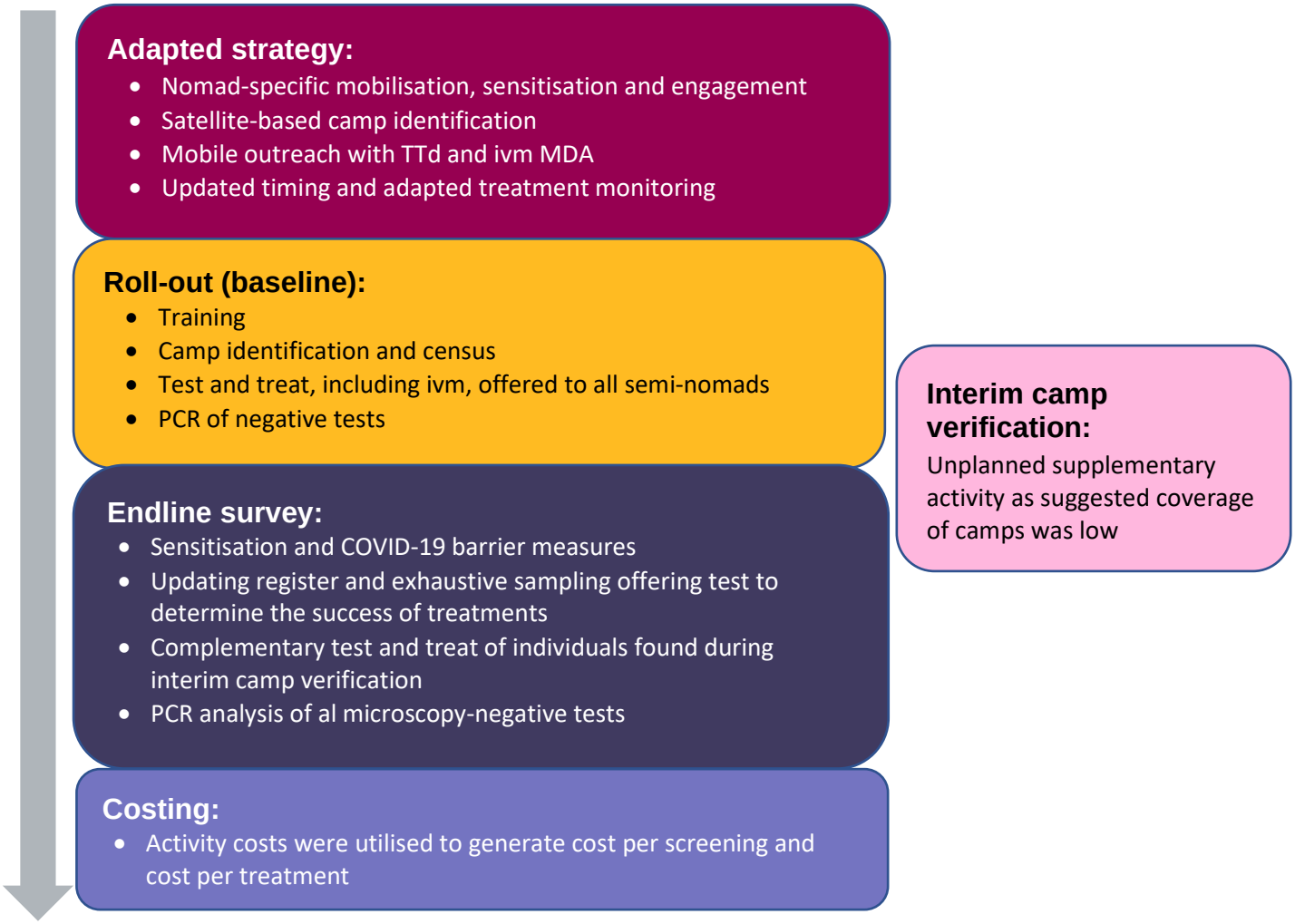
Methods

Overview of implementation phases

Based on the challenges faced in reaching the semi-nomadic communities identified in previous work, we adapted strategies to better reach semi-nomads. These included nomad-specific mobilisation, sensitisation and engagement, satellite-based identification of camps, mobile outreach to camps, updated timing and adapted treatment monitoring. These adaptions were then rolled out in the field. All eligible individuals within semi-nomadic communities were targeted for TTd and ivm treatment, with the testing undertaken at roll-out constituting the baseline. The impact was measured through an exhaustive sampling endline survey.

With the result of the roll-out showing an unsatisfactory reach of satellite-identified camps, an interim verification of the camps was undertaken alongside the endline survey. Activity costs were tracked and categorised into specific project activities. The diagram below outlines the steps of implementation.

Figure 2: Implementation phases



Adapted strategy

Nomad specific sensitisation and engagement

Nomad-specific sensitisation materials were developed together with the MoH and CRFilMT. The materials included banners, flyers, posters (adapted to include photographs of semi-nomads and altered text) and video and audio tapes in four local languages (Pidgin English, French, Bamoun and Fulfulde). These were used for reinforced mobilisation and sensitisation activities at three levels:

- District-level involving national, regional and district programme staff, local administrative authorities and community leaders
- Community-level involving community members
- Camp level involving camp-to-camp sensitisation alongside collecting census data

Satellite-based camp identification and census

By looking at satellite maps of where previous camps were located, we were able to identify some camp 'markers' which included bare earth, regular structures that look like huts and marks that look like paths or cattle tracks coming in and out. Based on these camp markers, camps were identified using satellite images of the area from 2016 and 2019. Satellite maps were then produced to indicate the 64 very probable and potential camps.

Mobile outreach with TTd and ivm MDA

We went to semi-nomadic camps to offer TTd instead of asking them to come to us. CDDs from the settled community were 'buddied up' with semi-nomadic CDDs and they travelled together to visit camps (overnighting where necessary). They conducted all activities in the camps, rather than nearby as this would have relied on the semi-nomads travelling to settled communities.

Updated timing and adapted treatment monitoring

Screening lagged the census by one to three days and people found to be infected with mf were immediately (within a week) placed on doxycycline treatment. CDDs were trained to provide medicines for self-treatment and money for a light breakfast every week (rather than daily). Pictorial treatment diaries were provided to the individuals being treated to record taking their medicine and their treatment experience. Empty packets of medicine and the diaries were collected weekly. These adaptations were designed to better fit with the nomadic population's movement patterns.

Roll-out (baseline)

The roll-out of the activities and show in **table 1** and **figure 2** and detailed below.

Training

Twelve CDDs, four from each of the three communities, were trained on the study process, sensitisation, camp identification and census, screening and treatment. Due to the nature of the work which required physical strength and considering the culture of the semi-nomads where women are not as exposed; women were not as much involved as men. However, we succeeded in including one woman. Refresher training was provided at the beginning of each intervention activity (see the steps in figure 2).

Table 1: Timeline

Activity	Date (2019)
Meeting and briefing with the regional and district team	15 - 16 October
Training and piloting	17 - 19 October
Community mobilisation/sensitisation and camp identification	19 - 20 October
Camp sensitisation and census	21 - 30 October
Mobile outreach screening and treatment	23 October - 15 December

Camp verification and census

Following the deployment of the sensitisation materials, meetings with community heads and settled and semi-nomadic CDDs were held. During these meetings, the satellite maps were consulted and viewed and a list of all known camps was made. With this list, the field team, guided by local researchers, reached out to all the listed camps and the census was conducted and recorded by the CDD pairs in the ivermectin treatment register. Accompanying researchers recorded the information in the CommCare app installed on smartphones acquired for the research. Researchers also used the app to record information relating to individual movements; ivm treatment histories; the duration of camps; and the GPS coordinates of all visited camps, households and individuals in the community. While in the camps, further efforts (snowballing) were made to identify new camps that hadn't been found through the initial mapping process.

Test and treat offered to all semi-nomads

The screening (testing) team consisted of two people from the CRFilMT and one pair of CDDs. The CDDs visited every identified camp and where necessary stayed overnight to reach every camp member. The screening test targeted all eligible individuals and involved registration, physical examination and a skin snip (biopsies) collection at the two posterior iliac crests for all individuals aged nine years and above using a 2mm Holth-type corneoscleral punch. After 24 hours incubation of the biopsies in saline, all emerged mf were counted under an optical microscope (Moreau, Prost, & Prod'Hon, 1978) and the presence (positive) or absence (negative) of mf was noted. Screening lagged behind the camp

identification and census process by one to three days. All negative snips were preserved for a later second test by PCR in Yaoundé. After testing, all eligible individuals including those not eligible for skin snip or who refused testing were offered ivm. Data was recorded on paper by the screening team and ivm treatment data was recorded by CDDs in ivm registers that they managed. Individuals found to be mf positive on microscopy in the field were immediately put on doxycycline treatment 100mg per day for 35 days.

Doxycycline treatment for each individual was initially provided by the CDD. The researcher closely monitored the first two days before handing over to the CDD for weekly monitoring. Treatment diaries were offered to each individual and they were asked to record whether they had taken the treatment medication, the time at which they took the treatment and how they felt following treatment. The CDDs reviewed the treatment diaries with the individuals at each weekly visit and then transferred the information to a paper treatment register. Additional information was collected on the reasons for not taking the medicine (when required) and any side effects they experienced. During these weekly reviews, the CDDs also collected old medicine packets and unused medicines and provided the individuals with treatment supplies for the following week. Furthermore, the CDDs made twice-weekly check-ins to monitor progress via phone, when and where possible. All treatment registers and diaries were collected at the end of treatment by the researchers.

Interim camp verification

Upon review of the baseline data, it became clear that the teams had not visited all the sites identified by the satellite and presented to them on the maps. 94 satellite-identified camps within 20km from Makouopsap, the focus of high transmission, had not been visited. On consultation, it transpired that teams struggled to transition between the lists and the satellite maps and faced issues when using the satellite maps in practice. Sketch maps were made based on local knowledge and these were used for camp identification and census. As such there were two important conclusions: (1) the adaptation had been unsuccessful in its current form and needed modification to be useful to programmes and (2) we still did not have a verified estimate of the nomadic population. The tools were redeveloped and re-deployed immediately before the endline as an interim camp verification.

For verification, we reduced our area of focus from a 20km radius to 16km and included the understood settled community ‘catchment area’ boundaries on the satellite image. In doing so, we were left with 83 camps to verify. It was thought that these 83 camps could be (1) camps but there were no semi-nomads there or (2) camps but the settled community was unaware of them or (3) not settlement areas at all. These unidentified camps were verified during the interim verification exercise to establish if one or both hypotheses were correct.

First, an office-based exercise was undertaken using ArcGIS PRO, a geographical information system (GIS) software, and satellite imagery. Together these were used as a reference base map to draw access routes to the 83 potential camps identified on the satellite that are within the transmission focus but were not visited by the teams. Then the 83 verification points were divided into 11 areas based on proximity and accessibility. Route maps were established to clarify and optimise methodical step-by-step access routes to all the potential camps and to identify the means of transport (car, motorbike or walking). Potential difficulties on the routes like streams or bushes and distance information of all

segmented roads were included in the roadmap navigation (see suppl. 1 and 2). The roadmaps created on the GIS software were linked to ArcGIS online platform and then installed on the field smartphone via the ArcGIS Explorer app. All the data downloaded on the app was to be accessible and used offline as the study area does not have internet signal. To help navigation, the location option of the phones was activated to track the actual location of the phone on the map. The location uses the satellite-based navigation system, GPS (Global Positioning System) and is independent of the phone signal in the area. As it was the first attempt, the team also had printed backup maps and had copies of these saved on the app but with the inclusion of a latitude and longitude grid (see suppl. 2). There was also a GPS and compass device in each team's backpack in case of technology failure. Along with the ArcGIS Explorer app, a CommCare app previously developed at baseline was revised and installed on the smartphones to collect verification and census information. The CommCare app also has site validation features that estimated how close the team was to their target site. Distances of less than 100m to targeted sites were considered satisfactory. Paper forms were also developed as a backup to capture essential camp verification and census information. Prior to the actual fieldwork, a pilot activity in a small community near Yaoundé was conducted to train in-country researchers and test and refine the tools.

Two verification teams of three people each - two data collectors including one semi-nomad community CDD and one settled-community CDD who is familiar with the camps, were trained to use the app, map and the procedure of camp verification using a previously developed guide. The CDDs also serve as bike riders who transported the team. Each team had a verification (V) sub-team guiding them to the sites using the GIS app previously installed on smartphones and loaded with maps. They collected information on whether the camp was (1) found (unoccupied) or (2) in current use (occupied) and (3) unfound (no indication of past or current camp) as well as pictures and a short video of the sites after obtaining consent where occupied. A census sub-team collected census information in occupied camps (see **table 2**). The roadmaps in the three communities were partitioned between the two teams. However, the two teams started together as field pilots verifying one route map before separating.

Table 2: Team structure and tasks

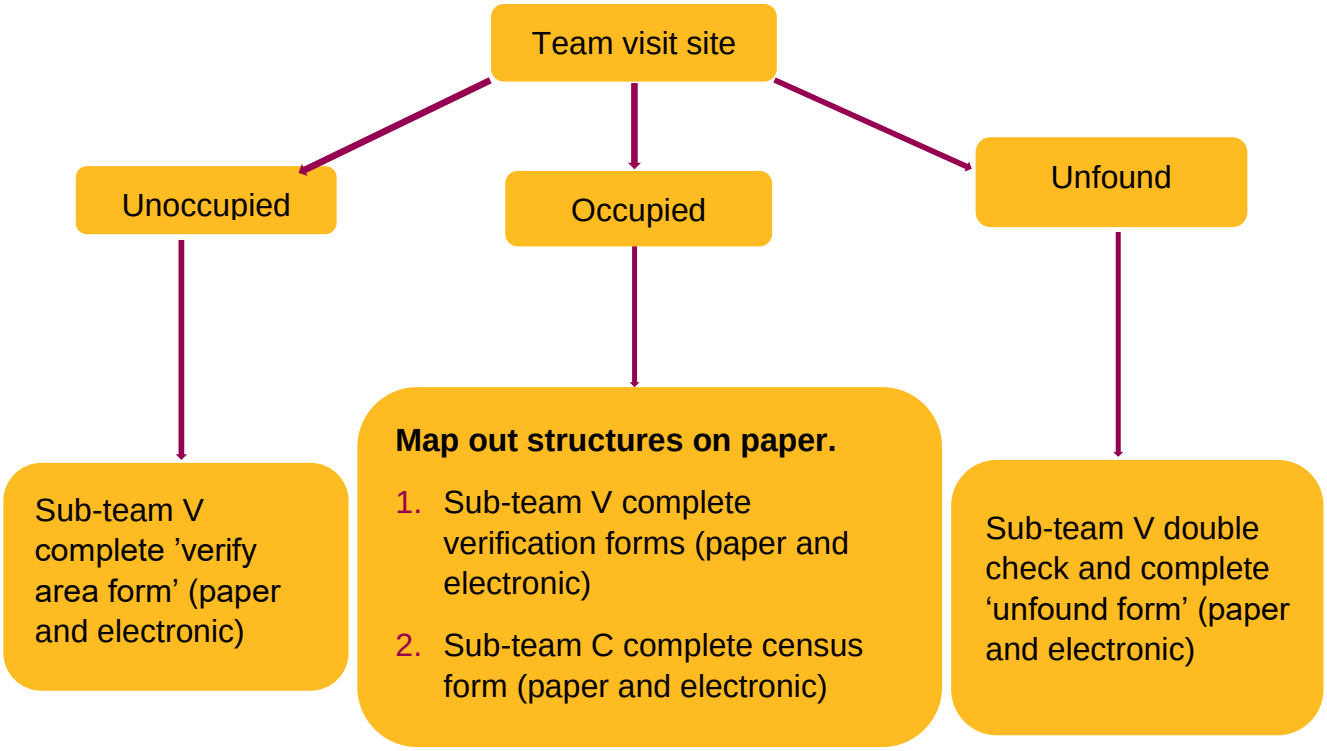
Teams	Sub-teams	Composition	Tasks
Team 1	Sub-team 1V	Camp registrar 1V, community guides	Verified and registered all structures in the camp and filled in the paper form as the census is being done
	Sub-team 1C	Census surveyor 1C, 1CDD	Registered camp and household, completed census and CDD filled in the MDA register
Team 2	Sub-team 2V	Camp registrar 2V, community guides	Verified and registered all structures in the camp and filled in the paper form as the census is being done

Teams	Sub-teams	Composition	Tasks
	Sub-team 2C	Census surveyor 1C, 1CDD	Registered camp and household, completed census and CDD filled in the MDA register

*V= verification; C= census

The field verification process began with community entry when the activities were explained to settled community and semi-nomadic camp members and their permission was obtained. With the CDD guiding with the help of the GIS app, the team navigated their way to all 83 locations. An excerpt of field navigation can be found **here**. Figure 3 below illustrates possible outcomes at each site and for each action taken.

Figure 3: Information flow diagram during camp verification



Once at the site, the team used a pre-developed pictorial guide to remind and guide them of the process (see suppl. 3). This included mapping camp structures and members of the camp, as well as their relation to who they regard as the head of the camp before proceeding onto the skin snip and ivm treatment.

Endline survey

Endline activities included camp sensitisation and COVID-19 mitigations, reviewing and updating the register, a skin snip test of all eligible individuals, ivermectin administration to those eligible and treatment of infected individuals with doxycycline.

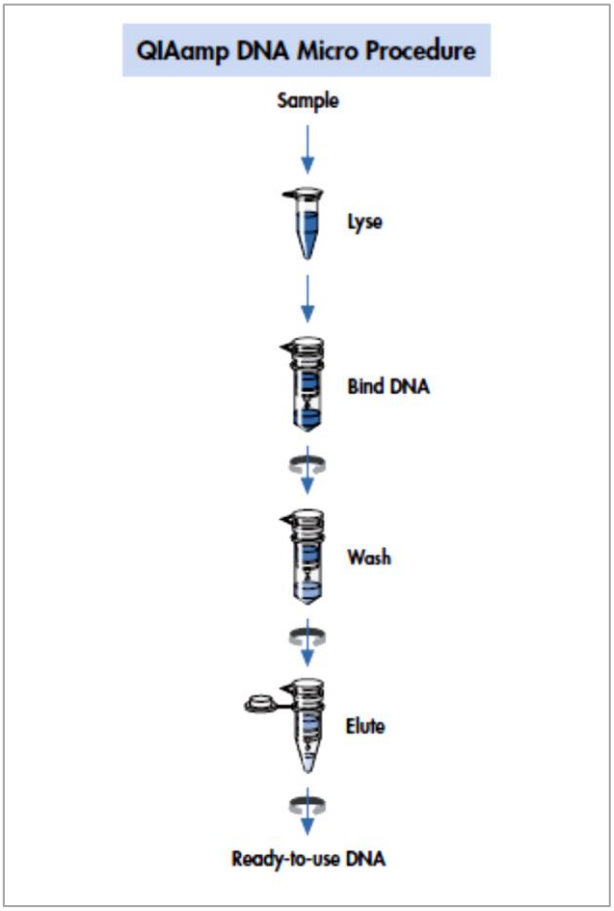
Sensitisation and COVID-19 barrier measures: Two weeks before the field activity, settled and nomadic community chiefs and religious leaders were informed of the second skin snip activities. The reasoning was explained to them and their buy-in, collaboration and permission were obtained. Using the sensitisation tools developed during baseline, the district team further sensitised the semi-nomadic communities via associations, religious and other social gatherings targeting semi-nomads. The research team organised further community sensitisation meetings with the semi-nomads to explain the activities. The camp verification and endline occurred after authorisation from the Ministry of Health which stated that field activities could be undertaken provided that prescribed COVID-19 barrier measures were adopted. Prior to all field activities, a COVID-19 risk assessment, mitigation and action tool (RAMA) were undertaken, and the resultant risk level was judged as acceptable. The communities were sensitised and offered COVID-19 protective materials for use during field activities which included face masks, alcohol gel and the provision of hand washing stations with soap. Similarly, all research team members were tested and certified as negative for COVID-19 before taking part in field activities. Individuals were monitored for COVID-19 symptoms throughout the field implementation. All government prescribed measures, including social distancing, were strictly observed. A specific aspect of mitigation measures for semi-nomads was identified and reinforced in a qualitative assessment which we conducted at the beginning of endline field implementation (Atekem et al, 2021 in press).

Updating register and exhaustive sampling to determine the success of treatments: The baseline census was downloaded from the CommCare platform and was cleaned, organised by the community, camps and households and then printed as a register. Using the register, the CDD guided the screening team to the camp where they obtained consent from the camp occupiers after an explanation of the activities had been provided. Following this, the names of every individual in the register for each camp was verified and individuals were noted as absent, present, moved away or died and any new person in the encampment was included. In doing this, the camps were further sensitised for the test and treat with doxycycline and those who were eligible and consented were tested. The test procedure was the same as for the baseline. Following testing, all eligible individuals including those refusing or ineligible for doxycycline were offered ivermectin. Information on testing, ivermectin treatment and test results were recorded in the register which was later entered into an Excel database. Those infected with mf were offered doxycycline treatment for 35 days. Negative snips were preserved for later PCR analysis in Yaoundé. Screened individuals were tracked using barcodes from testing to treatment. This treatment data was not included in the endline analysis since it was undertaken for ethical reasons and not as part of the evaluation itself.

PCR analysis: Due to delays in obtaining PCR reagents, both baseline and endline negative skin snips were tested at the same time after endline and those found positive were given doxycycline treatment by the Health District.

PCR analysis was conducted as described by Lloyd and colleagues (2015). Prior to deoxyribonucleic acid (DNA) amplification, the purification of skin biopsies negative to microscopy and optimisation was performed to identify a suitable approach for the efficient extraction of DNA from samples. Ten samples of skin biopsies positive to microscopy with

known microfilarial density were processed for DNA extraction using two methods: (1) mechanical approach (precellys) in which skin biopsies were transferred directly into standard precellys microcentrifuge tubes containing beads for processing; and (2) physicochemical approach using QIAamp DNA tissue kits (Qiagen) in which samples were processed directly into field sampling microcentrifuge tubes. DNA obtained from the two techniques was then amplified through qPCR for the detection of O. volvulus DNA. The results obtained led to the choice of the physicochemical approach as it performed better. Subsequently, all microcentrifuge tubes containing skin snip negative samples were placed in 1.5mL buffer solution and incubated for 3-5 hours at room temperature to allow excess ethanol to evaporate. DNA extracted following the manufacturer recommendations. The DNA extraction process was organised into two main stages:



- Tissue/cell lysis of skin snip samples, based on enzymatic activity of proteinase K and chaotropic effects of lysis buffers (AL and ATL buffers) and high temperature on cells and nuclei membranes
- DNA purification, based on exchange ions chromatography using QIAamp Mini spin column

Once the DNA purification was completed by the elution step (final elution volume was 200 µL), the purified DNA samples were stored in the -20°C freezer for further use. Detection of O. volvulus DNA was done by singleplex species-specific qPCR targeting the ND5 genes. Reactions were carried out using StepOnePlus PCR system (Applied Biosystems, Foster City, CA) in 10µL total volume containing 2 µL template DNA (sample DNA, plasmid with inserted ND5 target sequence as positive control and nuclease-free water as negative control), 10X Taq polymerase Buffer, 4.5 mM MgSO4, 40 mM dNTP, 2.5 units Taq polymerase, 300nM of each primer (OvOo ND5 forward: GCTATTGGTAGGGGTTTGCAT and OvOo ND5 reverse: CCACGATAATCCTGTTGACCA), and 50nM of the respective hybridisation probes (Ov Taqman probe: FAM-TAAGAGGTTAAGATGG-BHQ1). Cycling conditions involved Taq polymerase activation at 95°C for 15 min, followed by 45 cycles at 95°C for 10 secs and 61°C for 30 secs, with fluorescence acquisition on the FAM dyes that were excited at a wavelength of 488 nm and emit at 518 nm (With E=68,000 at a max wavelength of 494nm).

Interpretation of the sample amplification results (Figures 4a and 4b) was conditioned by the analysis of positive and negative controls. Two parameters: curve threshold (Ct) values and

the shape of amplification plot were considered for interpretation according to the following scheme:

Interpretation of standards' results

- A Ct value of less than 40 in three replicates of four positive controls associated with the suitable shape of amplification plots, and the absence of Ct value in the two replicates of negative controls were a prerequisite for interpretation of sample results. In the case of an absence of positive controls' amplification plot and/or the presence of a Ct value and/or amplification plot for negative controls, the experiment was systematically repeated

Interpretation of samples' results

- If two replicates for a sample were positive and had a Ct value of less than 40, the sample was considered positive for Onchocerca volvulus DNA
- If one replicate for a sample was positive and had a Ct value of less than 40, the sample was retested
- If no replicate for a sample was positive and had a Ct value of less than 40, the sample was considered negative for detectable Onchocerca volvulus DNA

Figure 4a: Amplification plot of sample negative to *O.* volvulus (red plots indicate positive controls' plots and green/blue plots correspond to samples)

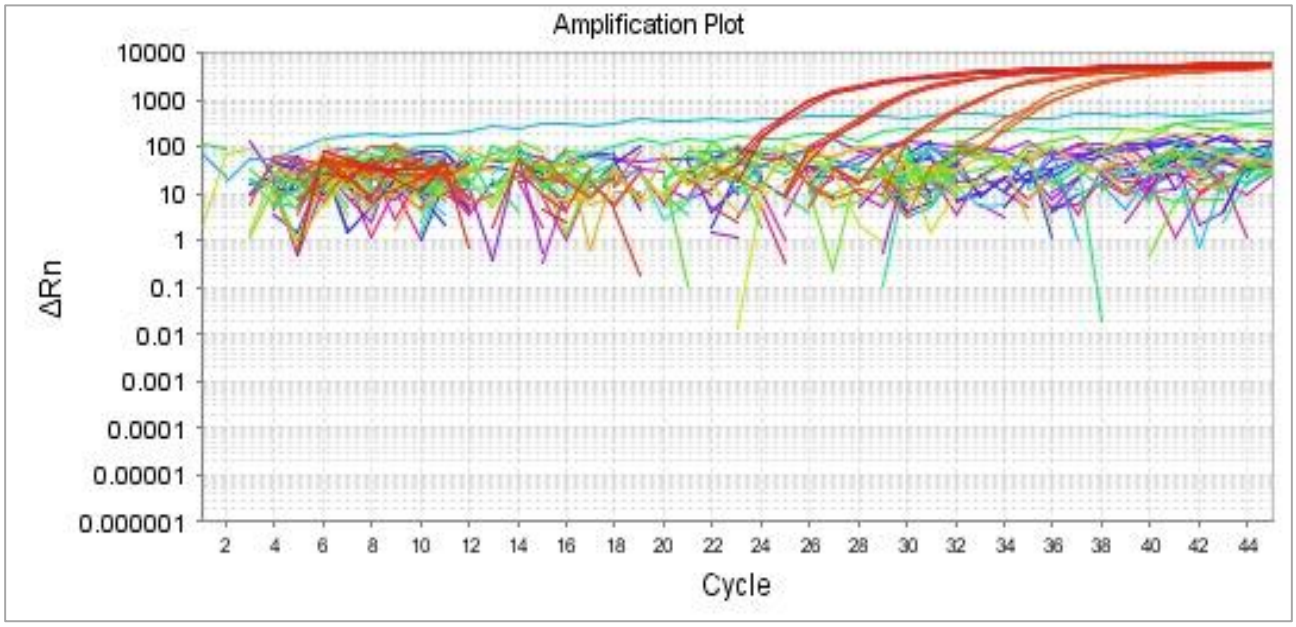
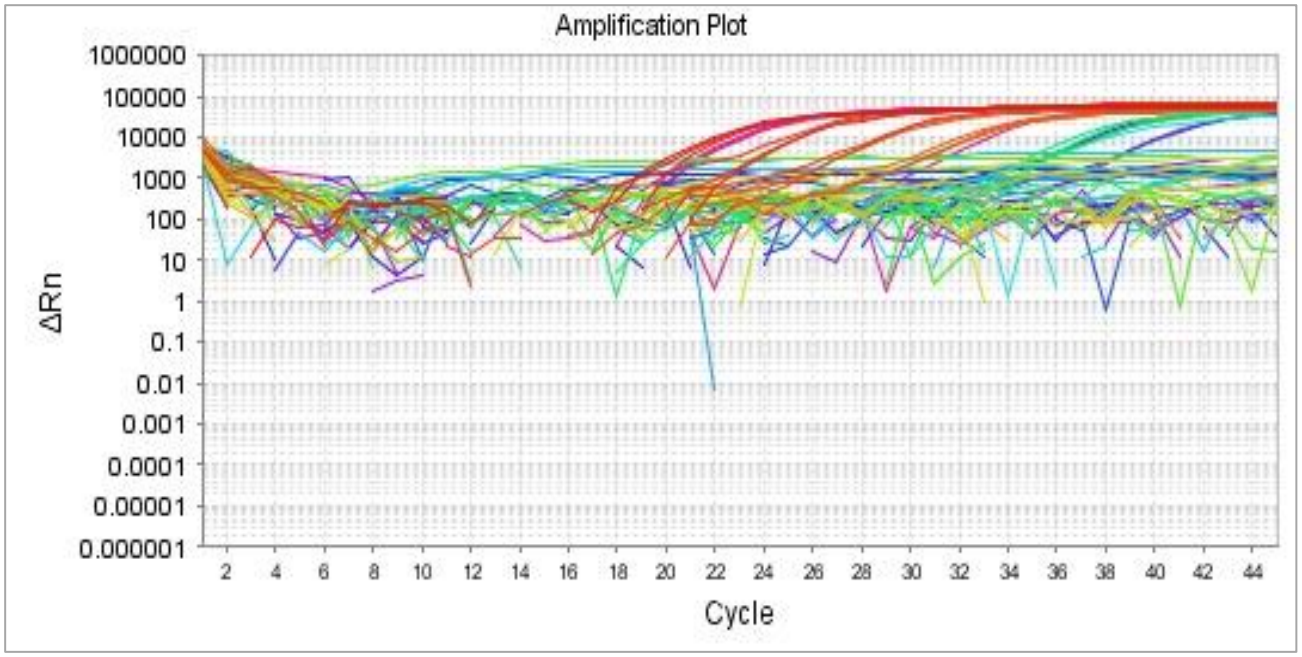


Figure 4b: Amplification plot of samples positives to O. volvulus (Red plots correspond to positive controls and green/blue plots correspond to samples)



Costing

Cost per screening and treatment

To estimate the standard cost of the test and treat strategy among semi-nomadic groups, a mixed methodology of costing was used. Top-down or bottom-up micro-costing or gross-costing approaches were adopted to estimate the cost of all activities (see supplementary information S4).

Project costs were collected or valued and then categorised into specific project activities and cost categories identified cost drivers and unit cost (see supplementary information S5). Financial data was collected from Sightsavers, implementing partners and ministries where appropriate and when available.

The total costs for undertaking one phase of ivermectin MDA and a TTd strategy was estimated, along with estimates of the cost per person screened and cost per person treated. The total standard cost of implementing a TTd strategy has been calculated based on the outcome (see supplementary information S6).

All costs were converted to US dollars of 2020 (USD) from Francs CFA (XAF) or UK pounds (GBP) using the average monthly exchange rate for the year 2020, respectively 570.7633 and 1.2920 (https://www.ft.com/currencies; access 26th August 2021).

Data analysis

Data recorded on paper was entered into Excel and data recorded on the CommCare app was downloaded in an Excel format. Data in the Excel format was then imported into Stata statistical software (StataCorp LLC 4905 Lakeway Drive, College Station, Texas 77845 USA http://www.stata.com), cleaned and analysed. The final Excel version was also linked to the project on the GIS software. Data was compared with the targeted camps. Pictures and

videos were also linked to their location on the map to obtain feedback of what looked like huts but were not. This also linked the pictures of the huts with their current location.

The participation rate of the test was calculated as the percentage of eligible individuals who took part. The participation rate for ivm MDA was calculated as a percentage of the total population who swallowed the medicine. Multiple logistic regression was performed to estimate the odds ratio of infection at endline compared to baseline after the data was reshaped data to account for individuals tested at both endline and baseline, and p values <0.05 were considered statistically significant. Community microfilarial load (CMFL) was calculated as the geometric mean in people over 20 years using a log+1 transformation. Average mf intensity was calculated using the arithmetic mean to include intensity measures of all skin snipped for mf (including those with zero intensity counts) so, analysis could be done on original (non-transformed) data.

All related financial data was downloaded from Sightsavers finance system in an Excel format and then reviewed, allocated and analysed in Microsoft Excel.

Treatment records of PCR-positive individuals, as well as complementary test and treat data, are not included in the data analysis.

Ethics

Ethical clearance was obtained from the Ethics Review and Consultancy Committee (ERCC), Cameroon Bioethics Initiative (CAMBIN) (clearance number CBI/445/ERCC/CAMBIN) and the National Ethics Committee for Human Research in Cameroon (clearance number 2020/0/1203/CE/CNERSH/SP). All participants underwent an informed consent process and consented before their registration and participation.

Description of results and outcomes

The test and treat intervention

Camp identification: Combining findings of baseline camp identification and interim verification, 62 camps were found giving a baseline coverage of 94% (58 camps). Four camps (6%) within a 16km radius of the focus of transmission (Makoussap) were identified only by satellite imagery. 15 camps (eight within and seven outside of the study's communities) were unoccupied (identified only by satellite imagery). Details are found in **table 3** and **figure 5** below.

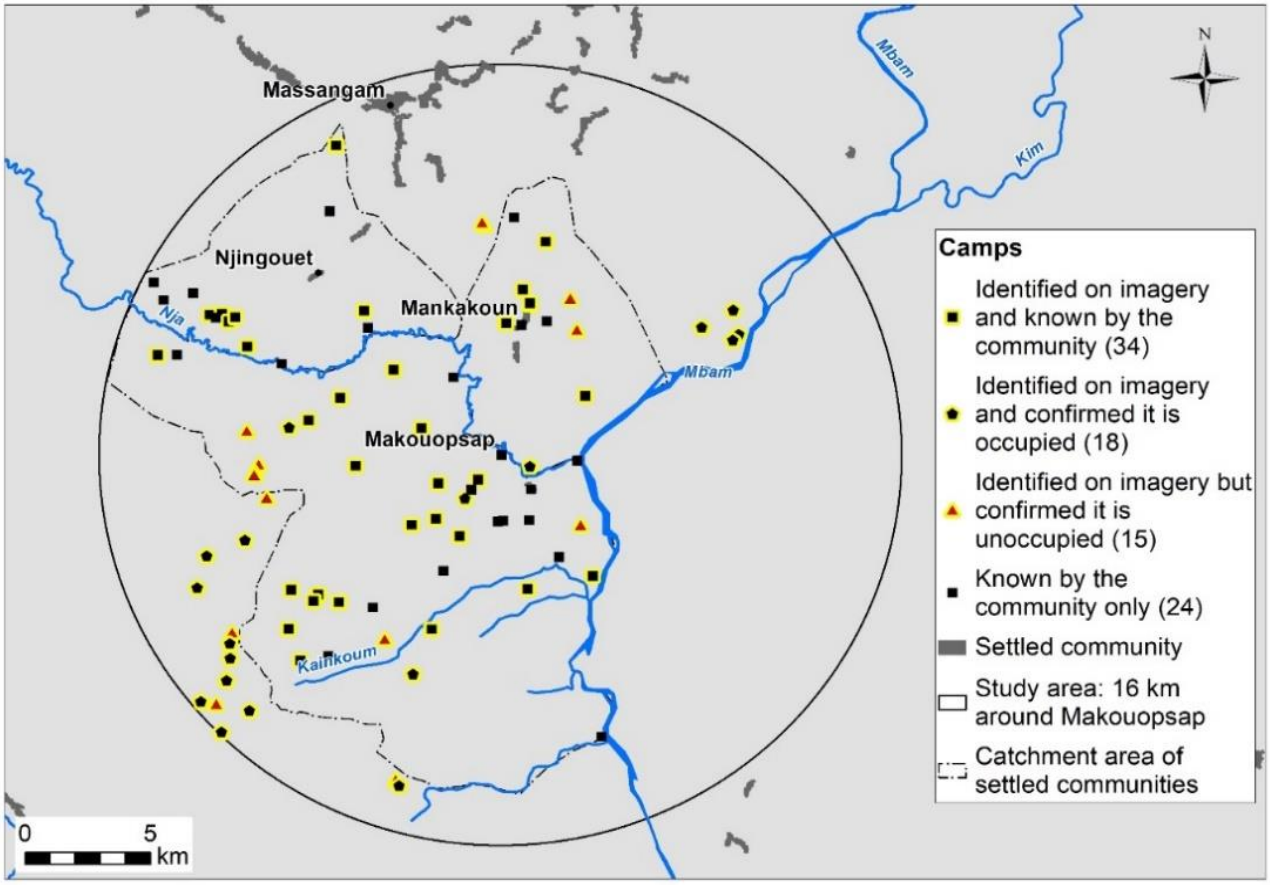
Table 3: Findings of interim camp identification

	# Potential on satellite image	# Potential camps visited	# Real camps within study community boundary	Real camps outside study community boundaries	Unoccupied camps
Interim	83	76 (92%)	4	14[1]	15[2]

	# Potential on satellite image	# Potential camps visited	# Real camps within study community boundary	Real camps outside study community boundaries	Unoccupied camps
	# Potential on satellite image	# Potential camps visited	# Real camps within study community boundary	Real camps outside study community boundaries	Unoccupied camps
Overall	128	110	62	14[1]	15[2]

[1]8 within and 7 outside study communities. [2]Camps outside the study community are not considered further in this analysis although they were offered test and treat with doxycycline.

Figure 5: Occupied and unoccupied camps within 16km of the focal community (Makouopsap)



The community approach to camp identification was 85% sensitive and 100% specific. The satellite approach was 65% sensitive and only 32% specific. However, the satellite image was not up-to-date and was aimed at validating community knowledge (**table 4**).

Table 4: Community and satellite sensitivity and specificity of identification of camps

Methods	Sensitivity	Specificity
Community	85%*	100% (58)
Satellite	65%	32% (38)
Both	100% (62)	58% (68)

*Include unoccupied camps

Participation in test and treat: At baseline, 47% of the eligible (aged over 9 and above, not pregnant) population were tested. Those aged 26-40 years were significantly more likely to be tested than those aged 9-15 years when controlled for length of stay in the community (OR=1.64; (CI: 0.99-2.72; p=0.05; see **table).**

Table 5: Test coverage at baseline across sex and age categories

Categories		# Eligible	# Tested	Percentage tested (CI)	Odd Ratio (CI)
Overall	Overall	479	225	46.9% (42.5-51.5)	-
Sex	Female	228	104	45.6% (39.2-52.1)	Ref
	Male	251	121	48.2% (42.1-54.4)	1.13 (CI: 0.79-1.63; p=0.49)
Age group	9-15 years	130	52	40.0% (31.9-48.7)	Ref
	16-25 years	133	66	49.6% (41.2-58.1)	1.51 (0.91-2.47; p=0.10)
	26-40 years	126	66	52.4% (43.7-61.0)	**1.64 (0.99-2.72; p=0.05)**
	>40 years	89	41	46.1% (36.0-56.5)	1.29 (0.74-2.23; p=0.36

*Odd ratios controlled for length of stay in the community

20 people (8.9%) were found to harbour mf by microscopy. Based on these microscopy exam results, community microfilaria load (CMFL) was computed to be 0.053 mf/ss. Out of the 161 microscopy-negative snips tested by PCR, 14 (9%) were positive, giving a microscopy sensitivity rate of 59% and overall mf prevalence of 15.1% (CI: 1.0-20.4) on both tests at baseline.

Among those positive on microscopy, all of them completed the 35 day course of doxycycline 100mg treatment.

Impact on prevalence and intensity: Out of 246 tested at endline, 4% were positive on microscopy and 12.2% positive on both microscopy and PCR examine (**table 6**). 9% of microscopy negative samples became positive on PCR, resulting in a microscope sensitivity of 30%. There was a significant reduction of mf prevalence (chi2=04.58, p=.0.032) on microscopy exam from baseline (9.3%) to endline (4.1%). Meanwhile, the combined results from microscopy and PCR on negative microscopy snips were not significant (see **table 6**).

Based on these microscopy exam results, community microfilaria load (CMFL) was computed to be 0.062 mf/ss, which is higher than 0.053 mf/ss found at baseline. However, the average intensity significant (p=0.013) reduced from baseline (0.18) to endline (0.01).

Table 6: Comparison of baseline and endline mf prevalence

	Baseline mf Prevalence	Endline mf prevalence	Chi2
Microscopy	8.9% (95% CI: 5.8-13.4)	4.1% (95% CI: 2.2-7.4)	Pearson chi2 = 4.58 (p = 0.032)
Microscopy and PCR*	15.1% (95% CI: 11.0-20.4)	12.2% (95%CI: 8.7-16.9)	Pearson chi2 = 0.85 (P = 0.356)
Average intensity	0.18 (0.01, 0.35)	0.16 (0.00, 0.32)	Z=2.487 (p=0.013)

Of the 20 individuals found positive at baseline and treated, 10 were retested at endline and all were negative upon microscopy examination and upon a further PCR examination, one was found positive.

The nomadic population

Population descriptors and turnover

Of the population recorded in the camps at baseline 48% (359) were females and 52% (389) males. People aged eight and underrepresented 36% (269) of the population while those older than 40 years represented 12% (89). Most males aged 16 years and above are herders (32%, 110) and most women aged 16 years and above are housewives (36%, 120). Most people (57%, 415) had lived in the area for between one to five years with 23% of the total population being born residents. Further details of the semi-nomadic demographic characteristics are shown in **table 7** below.

Table 7: Demographic characteristic of the semi-nomadic population (baseline)

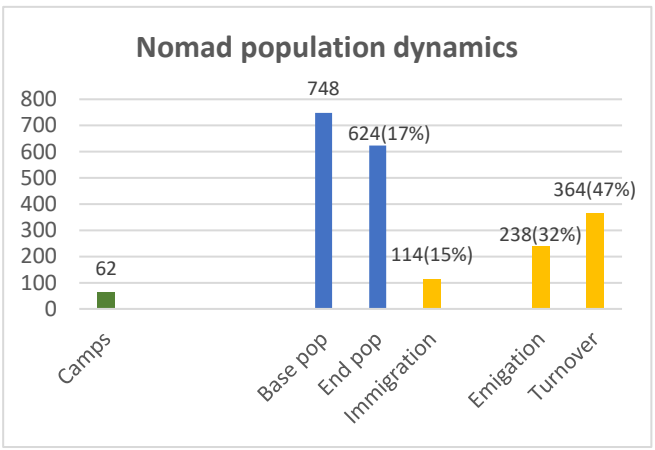
Categories	Overall	Female	Male			
n (%)	748 (100%)	359 (48%)	389 (52%)			
Communities	**Makouopsap**	**Makakoun**	**Njijia/Njigouet**			
n (%)	472 (63%)	106 (14%)	170 (23%)			

Categories	Overall	Female	Male			
Community stay	**< 1 years**	**1-5 years**	**> 5 years**	**Born here**		
n (%)	13 (2%)	415 (57%)	129 (18%)	169 (23%)		
Age group	**<9 years**	**9-15 years**	**16-25 years**	**26-40 years**	**>40 years**	
n (%)	269 (36%)	130 (17%)	133 (18%)	126 (17%)	89 (12%)	
Occupation	**Farming**	**Herding**	**Housewifery**	**Schooling**	**Others**	**None**
n (%)	91 (22%)	156 (37%)	132 (31%)	12 (3%)	15 (4%)	17 (4%)

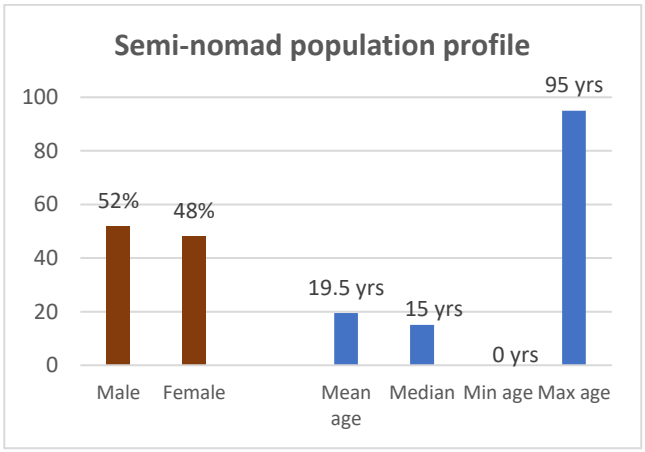
The overall resident population at endline was 622 which resulted in a net reduction of 17% (126) and an average of 686. From baseline to endline, the cumulative population (individuals who had passed through the area and were present at either baseline or endline (or both) is 862.

Since the baseline census, 114 (15% of baseline) individuals have immigrated into the communities. 238 (32%) have emigrated including those found in new camps identified during interim verification. Two individuals have died between the baseline and endline. This gives a population turnover rate of 47% (364) from baseline. Based on the cumulative population, the ages range from zero to 95 with a mean age of 19.5 (+/-17.3) years and a median of 15 years (**figure 6**).

Figure 6: Semi-nomadic population dynamic (a) and profile (b) of cumulative population



(a)



(b)

Overall, our survey population included those who were residents within the area of three settled communities – Makakoun, Njijia/Njigouet and Makouopsap. At baseline, the resident population was 748, reducing to 624 at the endline. 510 people were residents during both baseline and endline activities. Those outside of these community boundaries as defined by

the local programme implementers were not included in the analysis. The characteristics of the endline and baseline population are compared in **table 8**.

Table 8: Sample characteristics at base and endline by sex and age categories

		Baseline sample		Endline sample		Chi2 (between baseline and endline)
		#	%	#	%	
Overall	Overall	225	100%	246	100%	
Sex	Female	104	46%	116	47%	
	Male	121	54%	132	53%	0.04 (P= 0.839)
Age group	9-15 years	52	23%	89	36%	
	16-25 years	66	29%	60	24%	
	26-40 years	66	29%	67	27%	
	>40 years	**41**	**18%**	**30**	**12%**	**10.79 (P= 0.013)**

Variation in onchocerciasis prevalence within the nomad population

Within age categories, people aged 26-40 years were significantly less likely to be positive on microscopy than those aged 9-15 years (OR=0.19; CI: 0.04-0.93; p=0.04), controlling for the length of stay in the community. Combining microscopy and the PCR test, 18.2% of males were infected compared to 11.5% females though the difference was not significant statistically. See **table 9** below.

Table 9: Prevalence of mf at baseline across sex and age categories

Microscopy	Categories	# Tested	# Positive	Prevalence (CI)	Odd Ratio (CI)*
Overall	Overall	225	20	8.90% (5.8-13.4)	-
Sex	Female	104	7	6.7% (3.2-13.5)	Ref
	Male	121	13	10.7% (6.3-17.7)	1.58 (CI:0.59-4.20; p=0.36)
Age group	9-15 years	52	8	15.4 (7.9-27.9)	Ref
	16-25 years	66	5	7.6% (3.2-17.0)	0.47 (0.14-1.57; p=0.22)

Microscopy	Categories	# Tested	# Positive	Prevalence (CI)	Odd Ratio (CI)*
	26-40 years	**66**	**3**	**4.5% (1.5-13.2)**	**0.19 (0.04-0.93; p=0.04)**
	>40 years	41	4	9.8% (3.7-23.4)	0.58 (0.16-2.09; p=0.40)
Microscopy and PCR	**Categories**	**# Tested**	**# Positive**	**Prevalence (CI)**	**Odd Ratio (CI)***
Overall	Overall	225	34	15.1% (11.0-20.4)	-
Sex	Female	104	12	11.5% (6.7-19.3)	Ref
	Male	121	22	18.2% (12.3-26.1)	1.55 (0.72-3.35; p= 0.26)
Age group	9-15 years	52	10	19.2% (10.6-32.3)	Ref
	16-25 years	66	9	13.6% (7.2-24.3)	0.68 (0.25 -1.82; p =0.44)
	26-40 years	**66**	7	10.6% (5.1-20.7)	0.36 (0.12-1.14; p=0.08)
	>40 years	41	8	19.5% (10.0-34.5)	1.02 (0.36-2.86; p=0.98)

*Age group ORs adjusted for community stay

At endline (**table 10**), there was no significant variation in mf prevalence within various characterising groups. Among those tested at endline, 102 (45% at baseline) were repeaters (both exams) and only one was infected. The remaining 32 out of 33 infected were from a different population. 21 (12%) were from old residents and therefore, were present at baseline and 12 (15%) were from new arrivals.

For those tested during either or both rounds (373 being 65.3% of those eligible during either round), 8% (30) were positive on microscopy and 17.2% (64) positive by both microscopy and PCR.

Table 10: Prevalence of mf at endline across sex and age categories

	Categories	# Eligible	# Tested	# Positives	Rate (CI)	Odd ratio (CI)*
Microscopy		**n**			**Prevalence (CI)**	**Odd ratio (CI)**
Overall	Overall	416	246	10	4.0% (2.2-7.4)	
Sex	Female	197	116	6	5% (2.3-11.1)	ref
	Male	219	130	4	3% (1.1-7.9)	0.58 (0.16-2.12; p=0.41)
Age group	9-25 years	241	149	4	2.6% (1.0-7.0)	ref
	>25 years	173	97	6	6.2% (2.8-13.1)	0.44 (0.04 -4.38; p=0.49)
Microscopy and PCR		**n**			**Prevalence (CI)**	**Odd Ratio (CI)**
Overall	Overall	416	246	30	12.5% (8.9-17.2)	
Sex	Female	197	116	15	12.9% (7.9-20.4)	ref
	Male	219	130	15	11.5% (7.5-18.3)	0.89 (0.41-1.89; p=0.74)
Age group	9-15 years	124	89	7	7.9% (3.8-15.6)	ref
	16-2 5years	117	60	6	10% (4.5-20.6)	1.8 (0.41-7.7; p=0.43)
	26-40 years	104	67	11	16.4% (9.3-27.30	2.5 (0.68-9.14; p=0.17)
	>40 years	69	30	6	20.0% (9.2-38.1)	2.7 (0.61-11.7; p=0.19)

*Age group ORs adjusted for community stay

Ivermectin mass drug administration coverage estimates

From the census, 6% of people (38) at baseline stated that they have taken ivm during the previous MDA rounds. As shown in **table 11**, there were no significant variations of whether someone previously took ivm within sex and age groups. When asked whether they have

ever taken ivm, only 46% reported ever doing so. During the intervention, we integrated ivm treatment and recorded a 59% (CI:55.0-62.0) participation rate.

Table 11: Participation in the previous round of IVM distribution by sex and age categories

			Participation in previous ivm round	
		#	Rate	Odd ratio
Overall	Overall	289	38.6% (35.2-42.2)	
Sex	Female	146	40.0% (35.7-45.8)	ref
	Male	143	36.8% (32.1-41.7)	0.84 (0.63-1.13; p=0.27)
Age group	5-15 years	108	43.9% (37.8-50.1)	ref
	16-25 years	70	52.6% (44.4-61.0)	1.39 (0.90-2.14; p =0.14)
	26-40 years	66	52.3% (43.6-61.0)	1.42 (0.91-2.22; p=0.12)
	>40 years	45	50.6% (40.3-60.8)	1.32 (0.80-2.16; p=0.27)

*Odd ratio for age controlled for length of stay in the community

The cost of test and treat in the nomad population

Total standardised cost

Based on project experience and project financial data (S1-3), we estimated that the total standard cost of implementing a TTd strategy among the semi-nomadic group would amount to around USD 63,601 (table 8). Testing was the costliest activity due to the materials and supplies required for its implementation (USD 7,500).

Table 12: Estimated standard programmatic cost of TTd strategy among the semi-nomadic population by activity and cost categories (in USD 2020)

	Personnel	Materials and supplies	Transportation	Total	Percentage of total
Coordination and preparation	8,909	2,397	175	11,481	18%
Advocacy	1,034	2,853	385	4,272	7%
Training	867	448	263	1,578	2%
Sensitisation and census	7,551	1,105	4,727	13,383	21%

	Personnel	Materials and supplies	Transportation	Total	Percentage of total
Testing	4,906	7,500	4,709	17,115	27%
PCR analysis	2,628	6,302	-	8,931	14%
Treatment	4,751	82	1,307	6,140	10%
Supervision	526	-	175	701	1%
Total	31,171	20,687	11,742	63,601	100%
Percentage of total	49%	33%	18%	100%	

Cost per person screened and treated

Breaking down the standard cost by activities and person reached, sensitisation and census activities amounted to USD 13,383 or USD 231 per person censused. The cost of a single round of test and treat was USD 76 per person tested and USD 307 per positive individual treated fully with doxycycline. This excludes the cost of coordination, advocacy and overheads.

Key findings and recommendations

Satellite imagery and GIS tools: what did it add and how could it be used?

- In this setting in Massangam, the communities themselves proved to have very good knowledge of the community camps. They identified a high proportion of them and did not identify any places where there were no camps. However, there were a few camps that the community did not identify which were picked up by the satellite methodology. It could be recommended to use both methods at the same time at the beginning of the programme which would have the following advantages: (1) verifying community knowledge of camp identification; (2) finding the most hard-to-reach camps, the most marginalised and/or where equity is least; (3) improving and validating the denominator which increases the accuracy of coverage estimates; (4) increased integration and engagement of every section of the community into health intervention programmes; (5) using both methods is an effective way to discover unoccupied camps (that could be occupied in the future and should always be checked)
- There is often a need in the field to guide teams of researchers or programme implementers through very difficult and markerless terrain to specific locations. The GIS tools used in this project, which effectively translated between the GIS information and the ground and guided teams to accurate locations which do not have good landmarks, could be repurposed and developed for a number of other purposes. For example, locating vector breeding sites, selecting specific households for surveys or setting up monitoring sites, and extending the nomadic/hard-to-reach community mapping to other groups of semi-nomadic or remote living populations with distinctive settlements such as

the Maasai people in Tanzania and Kenya, Fulani in Nigeria and Cameroon or Karamojong in Uganda (Gammino V. M. et al, 2020).

- Satellite imagery and GIS tools found camps outside of community boundaries that would still be regarded as at-risk and within the transmission zone. It is important that searches for hard-to-reach semi-nomadic populations for health intervention are not restricted by administrative boundaries

The semi-nomadic population and onchocerciasis prevalence in this area

- The semi-nomadic population in this setting is young, dynamic and has a high turnover. Combining microscope and PCR, the prevalence of onchocerciasis has been shown to be as high as 17.2%. Infection was also found in new arrivals in the community and with a rate as high as 15%. This means that the semi-nomadic population can constitute a roaming reservoir of onchocerciasis transmission which makes achieving its elimination a daunting task. There is a need to develop a strategy to reach this group which also includes detecting and reaching newcomers or transiting people. This can be through routinely updating registers and checking previously unoccupied camps

The test and treat intervention was acceptable and impactful

- Almost half of the eligible population participated in the testing process and this was an improvement on the previous test and treat implemented by the settled community. In addition, newly identified camps that were previously not included due to not being known about, now had the opportunity to participate. Once tested, people were very likely to complete the treatment course. Thus, while programmes strive to improve participation in ATS, participation in the test itself requires the most work. Other research has shown that multiple rounds of test and treat and allowing for a longer testing participation window results in higher participation over time

- The test and treat strategy was impactful. Within a year, there was a substantive reduction of mf prevalence from baseline to endline. Annual ivermectin MDA would have required a much longer time to achieve this. Considering the youthfulness and dynamic characteristics of this group, a curative strategy conducted infrequently may be preferable to a 20 year commitment

Ivermectin MDA participation rate

- There is a low ivm MDA participation rate among semi-nomads. 46% of the semi-nomadic population reported having no previous participation and 38.6% reported as having participated in the previous round. This is compared to 82% for the four recent rounds and 69% in the previous round for the settled population

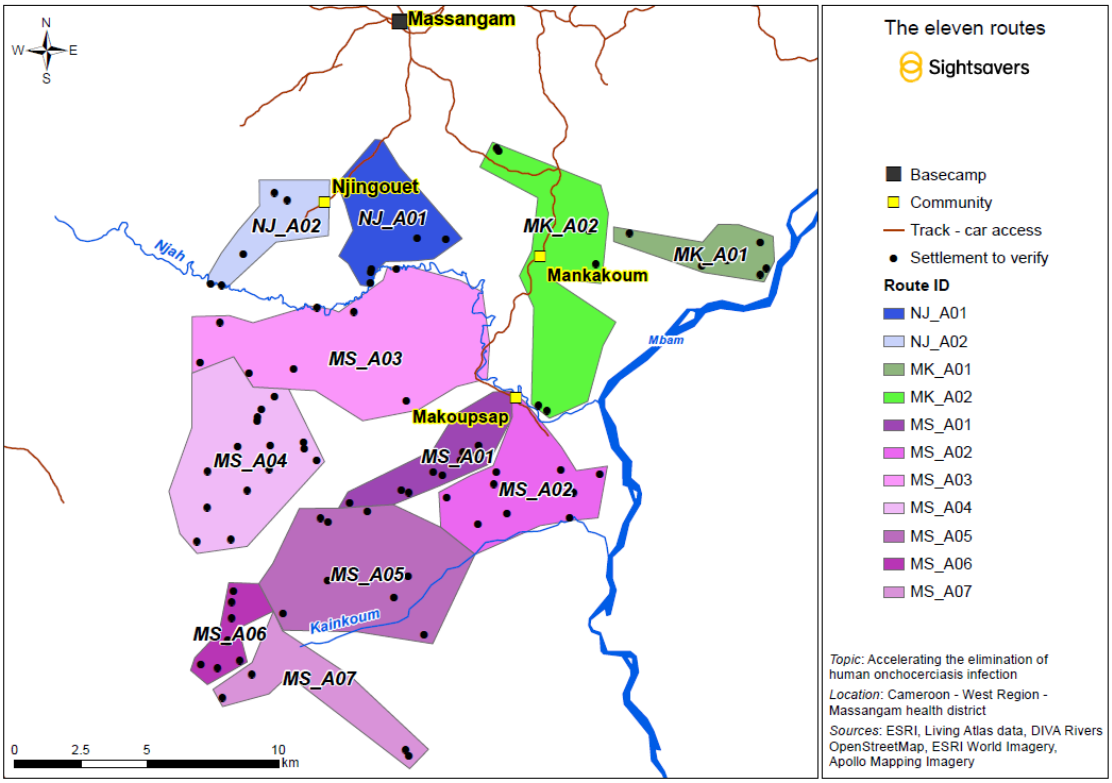
- Programmes should be encouraged to actively plan for nomadic or semi-nomadic population engagement. This includes adapting the programme sensitisation materials and integrating leaders and semi-nomadic drug distributors in the planning processes and treatment. This would involve extending it to them rather than just inviting their participation in the settled community focus/driven programme

Costing

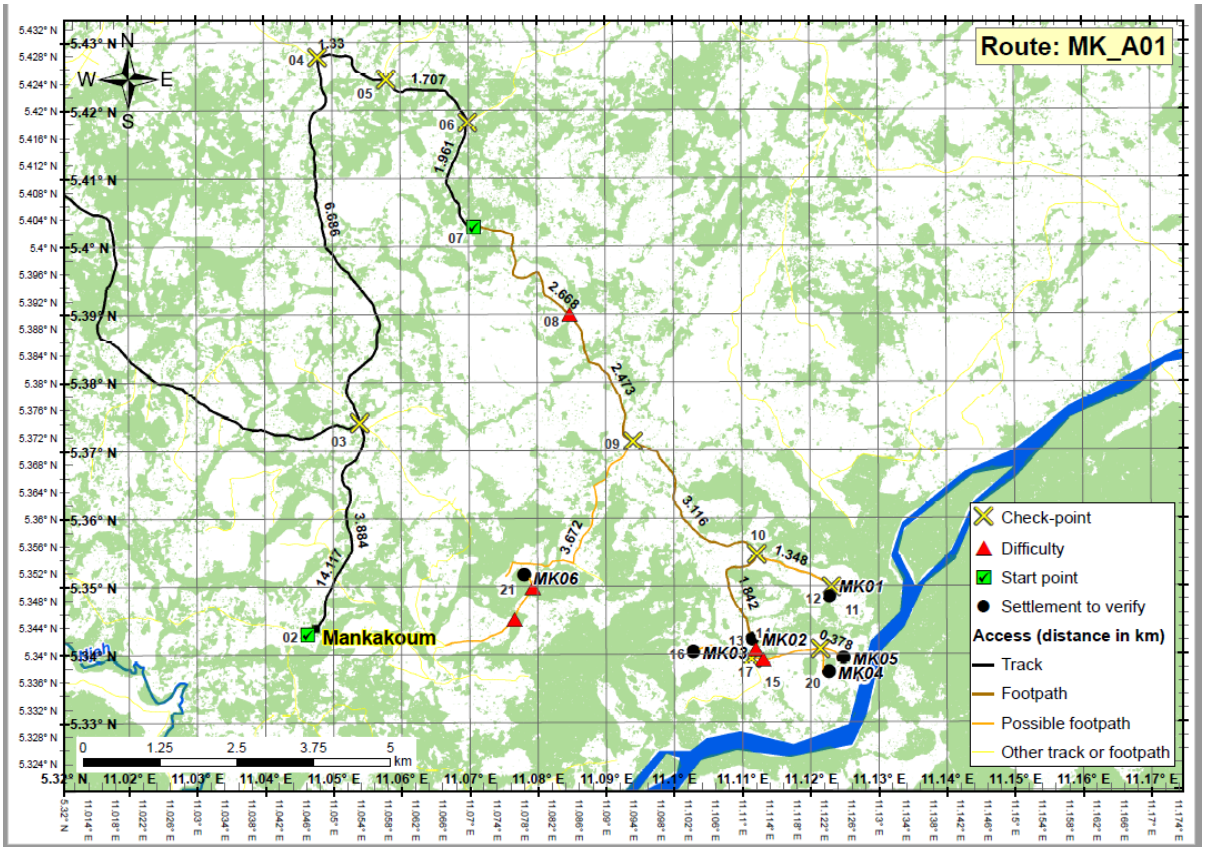
- The cost of a single round of test and treat was USD 76 per person tested and 307 USD per positive individual fully treated with doxycycline. This excludes the cost of coordination, advocacy and overheads. These costs are higher than the previous costs for settled community focus TTd. This is due to the significant cost of the outreach component. Also, due to the remote nature of this population and area, the 35 day treatment (compared to a single dose) with a purchased drug and the inclusion of a testing process, the cost was significantly higher per person reached and treated. Nevertheless, programmes should consider a curative strategy for hard-to-reach populations instead of a 20 year ivermectin MDA commitment

Supplementary information

S1: Overview of the 11 route maps



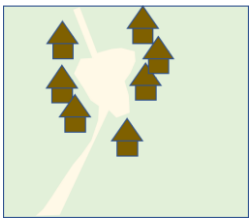
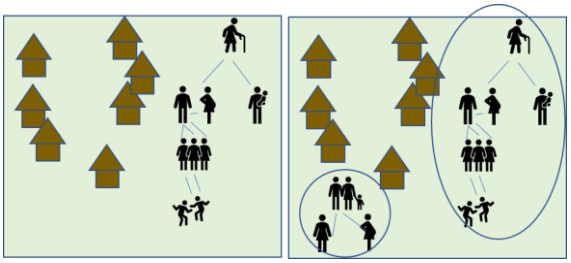
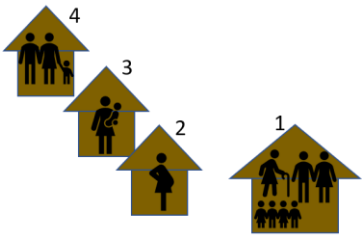
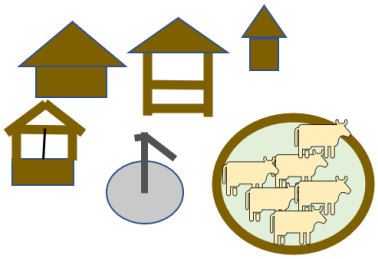
S2: Example route map (MK_A01)



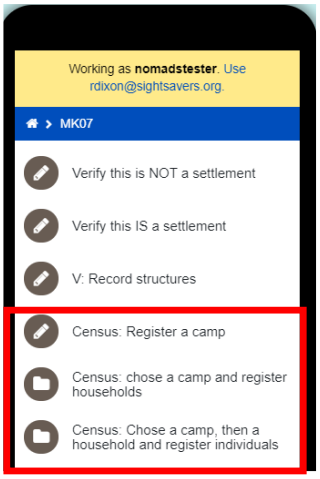
S3: Quick field guide

CENSUS (C)

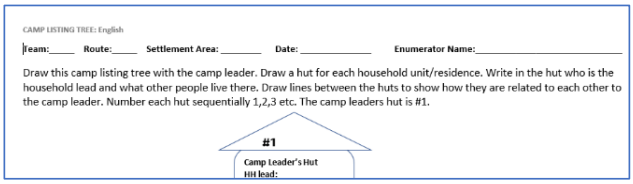
Definitions:

Settlement Area **(*Un site de campement*)**	Group of huts or structures that we see on the satellite	
Camp **(*Un groupe de nomades*)**	A group/extended family of nomadic people who move around together under the same camp lead/head and who are currently in this settlement area	
Household **(*Un Ménage*)**	1 living-structure (hut/house) and all the people who stay together there	
Structure **(*Un bâtiment*)**	Buildings or other man made things that we might see on a satellite image	

Your App Forms:



Your Paper Forms:


CAMP LISTING TREE: English

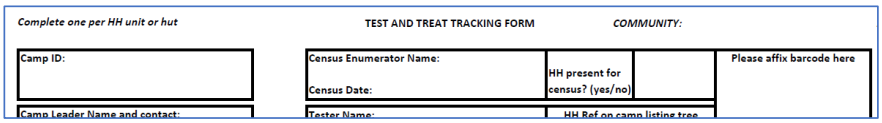
Team:____ Route:____ Settlement Area: _____ Date: _____ Enumerator Name:_____

Draw this camp listing tree with the camp leader. Draw a hut for each household unit/residence. Write in the hut who is the household lead and what other people live there. Draw lines between the huts to show how they are related to each other to the camp leader. Number each hut sequentially 1,2,3 etc. The camp leaders hut is #1.

#1

Camp Leader's Hut

HH lead:


Complete one per HH unit or hut TEST AND TREAT TRACKING FORM *COMMUNITY:*

Camp ID:	Census Enumerator Name: Census Date:	HH present for census? (yes/no)		Please affix barcode here
Camp Leader Name and contact:	Tester Name:	HH Ref on camp listing tree		


NON CONSENTING HOUSEHOLD LIST

Enumerator Name: _____

Each non consenting household should be listed here. Keep this safe and return to the team lead on the

Login: verif_1_com (team 1) **verif_2_com** (team 2)

S4: Methodologies by activity and sources used

Activities	Methodology	Source
Overheads	Mark-up	Partners' overhead percentage
Coordination, preparation	Top-down gross-costing	Project budget paid
Advocacy	Top-down gross-costing	Project budget paid
Training	Top-down gross-costing	Project budget paid
Sensitisation and census	Bottom-up micro-costing	Pilot financial data and output data
Testing	Bottom-up micro-costing	Pilot financial data and output data
PCR analysis	Top-down micro-costing	Pilot financial data and output data
Treatment	Bottom-up micro-costing	Pilot financial data and output data
Supervision	Top-down micro-costing	Project budget paid

S5: Table of activities included in standard cost

Activities	Included
Overheads	Mark-up assumed 15% of direct costs
Coordination, preparation	• Salaries, per diem and other personnel expenditures related to operational, management and coordination activities • Supplies and other equipment attributable
Advocacy	Expenditures directly attributable to advocacy meetings activities: Salaries, per diem and other personnel expenditures related to operational, management and coordination activities • Per diem and transportation expenses of attendees • Material and supplies
Training	Expenditure related to training activities: • Trainer and trainee per diem, accommodation, transportation etc • Venue rental • Material and supplies
Sensitisation and census	Expenditure related to community meetings, satellite maps verification and census of semi-nomadic population activities: • Coordinator, MoH staff, CDDs, drivers, per diem, accommodation, transportation etc • Material and supplies

Activities	Included
Testing	Expenditure related to testing, skin snip collection, skin biopsies, and recording activities: • Partner staff, CDDs, drivers, per diem, accommodation, transportation etc • Material and supplies
PCR analysis	Expenditure related to packing, shipping, and testing negative skin snips activities: • Bench fees for PCR tests • Material and supplies • Shipping fees
Treatment	Expenditure related to treatment distribution and monitoring activities (over 35 days): • Partner staff, CDDs, per diem, accommodation, transportation etc • Material and supplies (including Doxycycline, and patients' meal)
Supervision	Expenditure related to Ministry of Health supervision activities: • MoH staff, per diem, accommodation, transportation, etc.

S6: Output data used for the estimated standard cost

Unit	Baseline output
Communities	3
Camps	58
Number of persons censused	748
Number of persons tested	226
Number of persons fully treated	20
Number of persons receiving Ivermectin	438
Number of CDDs	12
Number of negative samples	161

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