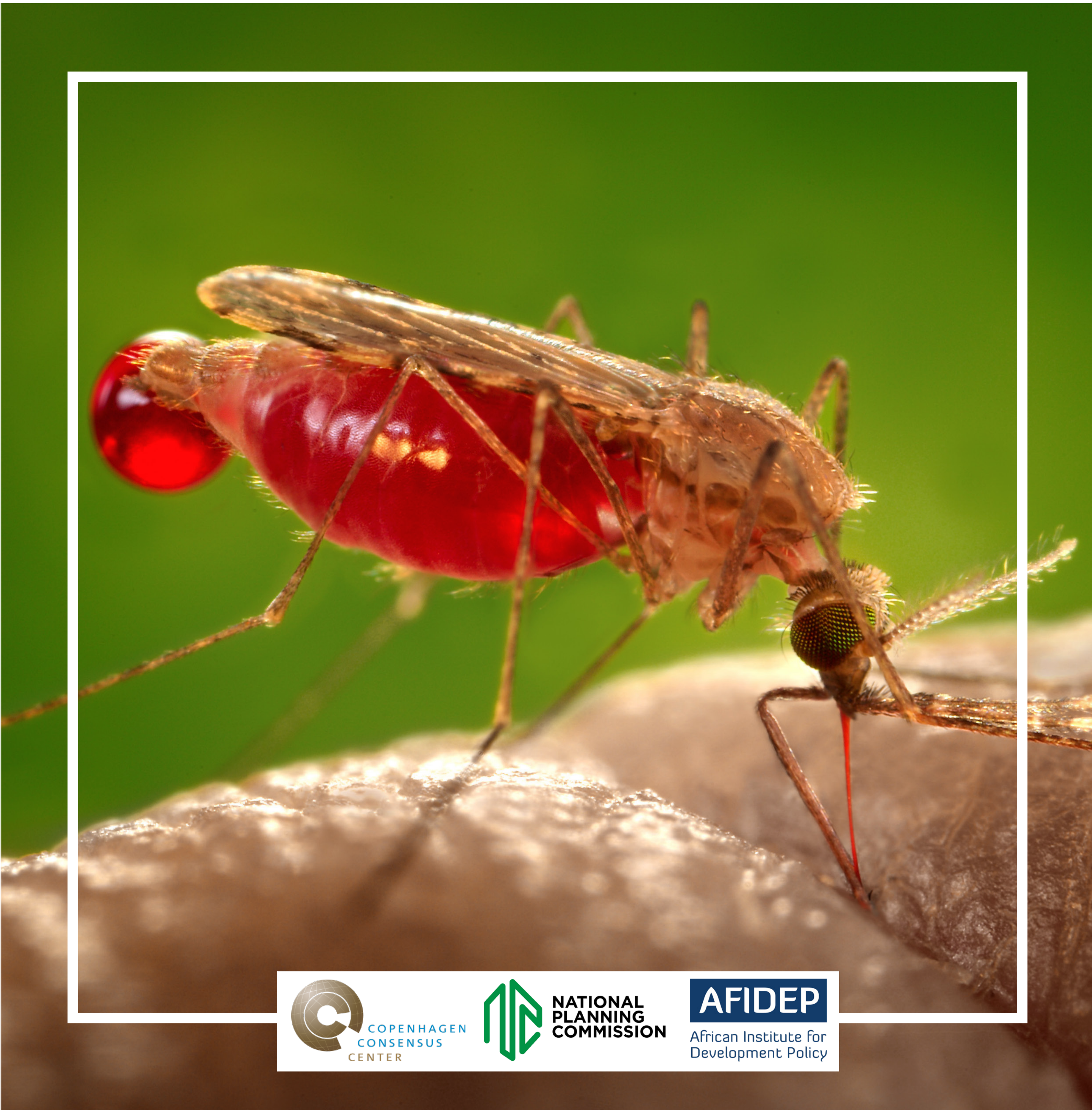
The Malawi Priorities Project

The Cost-Benefit Analysis of Malaria Control Strategies in Malawi: A Scenario Comparison using the Spectrum-Malaria Impact Modelling Tool - Technical Report

National Planning Commission Report with technical assistance from the Copenhagen Consensus Center and the African Institute for Development Policy



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Malawi Priorities: Background

Malawi Priorities is a research-based collaborative project implemented by the National Planning Commission (NPC) with technical assistance from the African Institute for Development Policy (AFIDEP), and the Copenhagen Consensus Center (CCC) to identify and promote the most effective interventions that address Malawi's development challenges and support the attainment of its development aspirations. The project seeks to provide the government with a systematic process to help prioritize the most effective policy solutions so as to maximize social, environmental and economic benefits on every kwacha invested. Cost-benefit analysis is the primary analytical tool adopted by the project. Cost-benefit analysis will be applied to 20-30 research questions of national importance. Research will take place over the course of 2020 and 2021.

Research questions were drawn from the NPC's existing research agenda, developed in September 2019 after extensive consultation with academics, think tanks, the private sector and government. This sub-set was then augmented, based on input from NPC, an Academic Advisory Group (AAG) of leading scholars within Malawi, and existing literature, particularly previous cost-benefit analyses conducted by the Copenhagen Consensus Center. The research agenda was validated and prioritized by a Reference Group of 25 prominent, senior stakeholders. The selection of interventions was informed by numerous consultations across the Malawian policy space, and one academic and two sector experts provide peer review on all analyses.

Cost-benefit analyses in Malawi Priorities consider the social, economic and environmental impacts that accrue to all of Malawian society. This represents a wider scope than financial cost-benefit analysis, which considers only the flow of money, or private cost-benefit analysis, which considers the perspective of only one party. All benefit-cost ratios (BCRs) reported within the Malawi Priorities project are comparable.

The cost-benefit analysis considered in the project is premised on an injection of new money available to decision makers, that can be spent on expanding existing programs (e.g. new beneficiaries, additional program features) or implementing new programs. Results should not be interpreted as reflections on past efforts or the benefits of reallocating existing funds.

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Contents

1. Introduction

Although Malaria is a largely preventable and treatable disease, it is responsible for an estimated 409,000 deaths globally, with the majority of morbidity and mortality occurring in young children in Sub-Saharan Africa (WHO, 2020). In addition to its impact on health, malaria imposes a heavy economic burden on households and economies at large (Chima et al. 2003; Sachs & Malaney, 2002). Malaria is a significant cause of mortality, morbidity, and productivity loss in Malawi. According to the Global Burden of Disease, malaria was Malawi's top ranked source of disability-adjusted-life-years (DALYs) in 2019, leading to 7,076 deaths – mostly in children under 5 – and 3.86 million cases (IHME, 2019). At any given time, approximately 15 percent of the Malawian population will have malaria (IHME, 2019). Malaria creates a large burden on the health system. According to the Malawi Health Management Information System (HMIS), malaria accounted for about 36 percent of all outpatient visits and 15 percent of all hospitalizations. Malaria takes people out of work or school for 5 to 11 days per episode depending on the severity of illness (Ewing et al. 2011; Hennessee et al. 2017). Based on these figures and the welfare losses outlined in Section 4 of this report, our estimates suggest that in 2019, malaria generated welfare loss equivalent to MWK 94,770 million – or 1.7 percent of GDP – when considering mortality, cost of illness, lost productivity and lost learning.

Over the years, the number of malaria cases have been showing a declining trend in Malawi. For example, in 2019 malaria accounted for 38 deaths per 100,000 population down from 65 per 100,000 in 2010 (IHME, 2019). Over the same period, annual incidence of symptomatic malaria episodes fell from 38 per person-year to 21 per person-year (IHME, 2019). The declines coincided with significant investment in vector control, testing and case management. Malawi has a continuous ITN distribution program that provides around one million long-lasting insecticide treated nets (ITNs) during antenatal care (ANC) and child immunization visits. These are supplemented by periodic mass distribution campaigns that provide more general coverage, delivering more than 10.7 million bed nets in the last mass distribution campaign which occurred in 2018 (Topazian et al., 2021).

As a complementary prevention measure, Malawi is rolling out intermittent preventative treatment for malaria during pregnancy (IPTp) in ANC, with a substantial proportion (78 percent) of pregnant women who receive at least two doses of IPTp (Ministry of Health National Malaria Control Programme Malawi et al., 2018). In terms of testing and case management, since 2018 more than 98 percent of fever cases who present at health facilities are parasitologically tested for malaria, and of those parasite-infected close to 100 percent receive ACT-based first-line treatment (DHIS2 data, cited as baseline in Global Fund 2020 Performance Framework).

All these interventions have proven to be effective repeatedly over many years, Having identified and scaled interventions with proven efficacy, now the challenge remains to identify further improvements that are sustainable, cost-effective and equitable. Decisions affecting the selection and coverage of additional interventions need to be taken in a rational, transparent manner using the best available evidence. Cost benefit analysis (CBA) is one useful decision tool that can shed light on which additional malaria control strategies should be prioritized for a given the reality of limited budgets and scarce resources.

Consultations with the National Malaria Control Program, Malawi noted several remaining challenges which, if unaddressed, could retard or even reverse the significant progress made thus far. The first challenge is emerging insecticide resistance particularly to pyrethroid (Riveron et al., 2015; Mzilahowa et al., 2016), leading to reduced ITN effectiveness (Topazian et al., 2021). Another challenge is suggestive evidence that a significant amount of ITNs in Malawi in practice only last for two years, leaving many people unprotected in the year before each triennial mass distribution campaign (Topazian et al., 2021). Lastly, while testing is near universal, only ~ 60 percent of people, or parents of children, seek care for fever (NSO, MDHS, 2015-2016)– meaning that a considerable proportion of malaria cases are not diagnosed and treated, which makes up a substantial part of the population-level burden of malaria morbidity, mortality, transmission and economic losses, even though not recorded in the DHIS2.

Against this backdrop, this report conducts cost-benefit analyses of several interventions that could reduce the burden of malaria, starting from the epidemic and programmatic situation as of 2020. These strategies were chosen based on discussions with the National Malaria Control Program and other experts, and evidence from academic literature. These interventions are:

- The universal (or: full transition to) use of only/exclusively piperonyl butoxide (PBO) ITNs, relative to a counterfactual of using pyrethroid-only ITNs
- Scaling-up Indoor residual spraying (IRS) in the districts that surround Lake Malawi, combined with pyrethroid-only ITN distribution
- Mass media for improved care seeking for fever, with vector control through pyrethroid-only or PBO ITNs
- Mass ITN campaigns every two years instead of every three

Epidemiological impacts of the interventions are modelled using Avenir Health's Spectrum-Malaria software (Korenromp et al., 2016, Hamilton et al., 2017), while costing was done on Spectrum outputs, applying cost assumptions from global scientific literature and national program data to modelled service needs and volumes. The results indicate that universal adoption of PBO nets and mass media for improved care seeking for fever are the most effective use of resources out of the interventions considered, with central benefit-cost ratios (BCR) of 6.0 and 7.4 respectively. An intervention that combines PBO nets with mass media for improved care seeking for fever (relative to pyrethroid-only ITNs, without improved fever care seeking) has a BCR of 6.6 and the largest absolute impact on malaria burden. The BCR for PBO nets are based on an assumed 50 percent effectiveness of pyrethroid-only ITNs relative to PBO nets based on national program data and community-trials in Nigeria and Tanzania (Topazian et al. 2021; Protopopoff et al. 2018; Shepard et al. 2020). In sensitivity analyses we furthermore show that BCRs are 2-3 times higher if pyrethroid effectiveness is assumed to be only 25 percent that of PBO nets, as suggested by officials at the National Malaria Control Program.

In contrast, IRS in the districts along the lake is likely a less cost-effective use of resources, with an estimated central BCR of 1.7. IRS is significantly more costly than ITN distribution, and has a more moderate impact on cases and deaths, according to Spectrum modelling results (and in line with other malaria dynamic transmission models, for Malawi and other countries in southern Africa, Lee et al. 2017). While Topazian et al. (2021) suggests a good impact of IRS in the Malawi context over 2018-2020, this observation was based on only one district of Malawi with an exceptionally high pre-intervention case load.

Lastly, while we have not conducted a formal cost-benefit analysis of increasing the frequency of mass campaigns due to lack of precise data on the deterioration rate of ITNs, a simple comparison of potential incremental costs versus incremental benefits suggests that this is also not likely to be an effective use of resources.

The primary policy implication of the analysis is that as far as NMCP resources permit, they should consider prioritizing the adoption of PBO ITNs and implementing mass media for improved care seeking for fever. This combined intervention would require an additional MWK 46,000 million, or USD 62 million, in (undiscounted) funding over 10 years, which equals ~ 8 percent of expected budget of an annual USD 80 million (NMCP, 2020). The combined intervention would reduce expected malaria deaths by around 45 percent and cases by 25 percent bringing Malawi closer to achieving impact targets of the 2017-2022 Malaria Strategic Plan. Additionally, we recommended more careful consideration and analysis of IRS and of increasing the frequency of mass ITN distribution campaigns, ideally with additional years of pilot field data, before institutionalizing these policy changes.

2. RESEARCH CONTEXT

The National Planning Commission (NPC), with technical support from the African Institute for Development Policy (AFIDEP) and the Copenhagen Consensus Center (CCC) are implementing the Malawi Priorities project over 2020 and 2021. Malawi Priorities is a research and advocacy exercise to identify the most cost-effective ways to address the nation's challenges, using the framework of cost-benefit analysis. The aim is to inform both short- and long-term development priorities for the country, acknowledging that there are insufficient resources to address all of Malawi's challenges and that maximizing outcomes requires careful, evidence-based consideration of the costs and benefits of all policies.

The starting point of all research is the NPC's existing research agenda, structured around the six thematic areas of Sustainable Agriculture, Sustainable Economic Development, Human Capital and Social Development, Sustainable Environment, Demography, Governance, Peace, and Security, and Human Capital and Social Development.

NPC's research agenda was developed by the commission in September 2019 after extensive consultation with academics, think tanks, the private sector and government. Consequently, the commission's research agenda, prima facie, contains questions of national importance. As a first step, Malawi Priorities drew questions from the NPC research agenda that could be answered by CBA. Then, additional research questions were added based on input from NPC, an Academic Advisory Group (AAG) of leading scholars within Malawi, and existing literature, particularly previous cost-benefit analyses conducted by the Copenhagen Consensus Center. This process of identifying research questions for investigation generated a total of 38 potential research questions across all 6 thematic areas.

The research agenda was validated and prioritized by a Reference Group of 25 prominent, senior stakeholders from government, civil society and the private sector. The outcomes of the Reference Group exercise were used to inform which research questions to prioritize and which interventions to focus on within those research questions. The validation process finished in July 2020. One of the questions that scored within the top 25 research questions was:

"What are the most cost-effective ways to address the burden of Malaria?"

This paper seeks to answer this research question. It is one of roughly 25 papers in the broader *Malawi Priorities* series.

A focused consultation and extensive literature review were conducted. The detailed research process including the intervention screening process is further explained in Annex 1. The process identified three programs as priority relevant interventions for further cost-benefit analysis. Additionally, one intervention was identified for additional consideration though data limitations precluded a formal cost-benefit analysis. These are:

- The universal (or: full transition to) use of only/exclusively piperonyl butoxide (PBO)-impregnated ITNs, relative to a counterfactual of using pyrethroid-only ITNs
- Scaling-up Indoor residual spraying (IRS) in the districts that surround Lake Malawi, combined with pyrethroid-only ITN distribution
- Mass media for improved care seeking for fever, with vector control through either pyrethroid-only or PBO ITNs
- Mass ITN distribution campaigns every two years instead of every three.

3. HEALTH IMPACT MODELLING

3.1 Spectrum-Malaria Model

The Spectrum-Malaria epidemiological projection model was used, in version 6.08 beta 5 of 29 April 2021. This model projects, dynamically over time, the impact of scaling-up the coverage of malaria interventions on, in turn: malaria cases, malaria-attributable deaths and the prevalence of Plasmodium falciparum parasite infection (Korenromp et al., 2016, Hamilton et al., 2017). Spectrum-Malaria statistically emulates the impact of malaria prevention and treatment intervention scale-up on malaria case, death, and infection load, as a function of baseline endemicity and seasonality in malaria, and of initial and target intervention coverage, as dynamically projected through the microsimulation model OpenMalaria.[1] This approach captures the short-term and long-term dynamics of how parasites, mosquitoes and humans interact, including saturation and synergy effects between interventions and effects of acquired immunity that individuals develop after their first childhood exposures, and the possible waning of that immunity in cohorts of individuals once control interventions lower endemicity.

Results are calculated in turn for all subnational Administrative 1-level units, and for 3 age groups (0-4 years, 5-14 years and 15+ years), and then summed up to produce national-level all-age results.

Calibration to Malawi: historic Malaria burden and intervention coverage trends

For Malawi, the projection started from annual national malaria case and death estimates over 2000-2019 from the World Health Organization (WHO), as published in the 2020 World Malaria Report (WMR) (World Health Organization, 2020). Allocation of these national-level burdens across the three modelled age groups and Malawi's four regions (Central, Lake Malawi, Northern and Southern) was done based on estimates by the Malaria Atlas Project, version of November 2020 ((Weiss et al., 2019) & https://malariaatlas.org/malaria-burden-data-download/) .

For ITNs, all-age usage, the indicator of effective protective coverage in Spectrum-Malaria, was anchored on results of the national household Malaria Indicator Survey (MIS) (Ministry of Health National Malaria Control Programme Malawi et al., 2018) conducted in 2017, being 63 percent of the all-age population having access to an ITN (defined as the household possessing ≥1 ITNs per 1.8 household members, thus allowing for varying household sizes and some wastage of ITNs stocked) and 55 percent usage.

The ITN coverage in 2018 and after, years without a national household survey yet available, were estimated based on ITN distributions and targets reported by the National Malaria Program (NMP), covering continuous routine distributions (through ANC and EPI clinics, to pregnant women, mothers and young children) and 3-yearly mass distribution campaigns (Table 1). Assuming a 3-year effective ITN lifespan and a 3-year interval between campaigns, the around 11.9 million ITN distributions of the 2018 campaign or the 12.4 million distributions envisioned for the 2021 campaign (according to the Presidential Malaria Initiative Malawi Malaria Operational Plan FY 2020 (U.S. Center for Disease Control & Prevention, 2020)), given Malawi's 17.6 million population in 2018, average household size of 4.4, annual population growth around 2.7 percent, should amply suffice to reach 100 percent household ownership and population access, as illustrated using the NetCALC tool (Vector Works, 2016).

As realistic assumption, and considering the steady but modest access and usage improvements seen across Malawi's recent household surveys (National Statistics Office Malawi and ICF, 2017, Ministry of Health National Malaria Control Programme Malawi et al., 2018), we assumed that access and usage would be 85 percent and 75 percent of the ITNs owned by households. The implied access-to-usage ratio of 1.13 is in line with that found in Malawi's 2017 MIS and in an Africa-wide analysis of ITN coverage (Bhatt et al., 2015), and with Malawi's target of 80 percent all-age usage by 2022 (Government of Malawi Ministry of Health National Malaria Control Programme, 2020b) and national coverage targets stipulated for the period 2021-2025 in the National Strategic Plans of National Malaria Programs (NMPs) in other falciparum-endemic African countries (République du Mali Ministère de la Santé et l'Hygiene Publique & Programme National de Lutte contre le Paludisme, 2018, République du Cameroun Ministère de la Santé Publique & Programme National de Lutte contre le Paludisme, 2019, République de la Côte d'Ivoire Ministère de la Santé et de l'Hygiène publique et al., 2020).

Effectiveness of ITNs was assumed to be 100% for PBO nets, throughout the projection period 2020-2030, regardless of Malawi's changing levels of insecticide resistance. For ITNs impregnated with pyrethroid only (abbreviated pyrethroid-only ITNs), the type most commonly distributed up to 2018, during the scenario projection period effectiveness was assumed to be half, in view of moderate levels of resistance observed in Malawi since 2011 (Mzilahowa et al., 2016, Government of Malawi Ministry of Health National Malaria Control Programme, 2020b), after which pyrethroid-only ITNs initially remained effective (Lindblade et al., 2015), but also in line with the lesser observed impact of pyrethroid-only nets on DHIS2-recorded confirmed cases over 2018-2020 in an evaluation that followed Malawi's 2018 distribution campaign (Topazian et al., 2021). The assumed relative effectiveness of the two ITN types is also in line with results a community-randomized trial in rural Tanzania, an area with high pyrethroid resistance, where PBO nets reduced child infection prevalence by 2- to 2.5-fold (over 9-21 months post-distribution, 2014-2016) compared to pyrethroid-only nets (Protopopoff et al., 2018), and with a community-randomized trial in Nigeria, another area of established high

[1] For more detail see: https://github.com/SwissTPH/OpenMalaria/wiki/UserGuide & (Smith et al., 2006)

pyrethroid resistance, over 2012-2014 (Shepard et al., 2020) and Uganda (Staedke et al. 2020).

In Malawi's 2018 campaign PBO nets constituted 28% of ITNs distributed, and effectiveness was therefore assumed to be 64 percent of the full effectiveness (= 28% * 100% effectiveness for PBO nets + 72% * 50% effectiveness for Pyrethroid-only nets). We therefore assumed 64 percent average ITN effectiveness over 2018-2020, after which effectiveness would evolve as a function of the mix of insecticide types used: 100 percent effectiveness with 100 percent PBO nets, or 50 percent effectiveness with 100 percent Pyrethroid-only nets (Table 1).

For other interventions, baseline coverages were set as follows:

- **Case management, uncomplicated cases:** Set at a time-constant 60 percent from 2011 onwards, based on DHIS2 data that indicate increased volumes and coverage of parasitological (RDT and/or microscopy) testing since 2014, reaching 99.7 percent of suspected cases by 2020 (DHIS2 data, cited as baseline in Global Fund 2020 Performance Framework; reported volumes of confirmed cases that equal or exceed Spectrum-estimated malaria cases from 2016 onwards, yet only 59 percent and 54 percent of fever patients reported to have sought treatment (in public, private or other sector) in the 2014 and 2017 MIS (Ministry of Health National Malaria Control Programme Malawi et al., 2018) and only 31.2 percent of caregivers reportedly sought appropriate malaria treatment within 24 hours of onset of their child's fever (Government of Malawi Ministry of Health National Malaria Control Programme, 2020b). In comparison, MAP estimated 64 percent ACT-based first-line treatment coverage (Malawi's recommended first-line ACT being Artemether Lumefantrine) in 2011-12, decreasing to 60 percent by 2016 (Bennett et al., 2017, Weiss et al., 2019).
- **Case management, severe cases:** The burden of severe cases at population level is not precisely known nor routinely measured in DHIS2 in a reliable way that is standardized and comparable across countries and over time. As in earlier Spectrum-Malaria country applications, severe malaria cases were estimated as a proportion of total malaria cases, separately for each province and year, as a dynamically modelled function of the province's endemicity and intervention coverage (Ross et al., 2006). The coverage of appropriate management of severe cases was estimated at 48 percent, a regional default value used by Spectrum-Malaria for all countries in sub-Saharan Africa, and held constant over time (Ross et al., 2006, McCombie, 1996, Goodman et al., 2001, Tediosi et al., 2006).
- **Indoor Residual Spraying:** Based on the data and targets summarized in Table 2 below, assumed to be a time-constant 5 percent of the nation-wide population protected, all within the Lake area, based on population coverage (targeted households) in that region of 39.36 percent.

Table 1: *ITN distribution, access, and effective usage/protection rates in two scenario variants for Malawi*

Indicator		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
ITN distributions	Routine	2.34M	9.59M	1.04M	1.14M	1.19M	1.43M	1.51M	1.51M	1.55M	1.60M
	Campaigns				10.9M			9.3M			10.02M
	Routine + Campaigns	2.34M	9.59M	1.04M	12.0M	1.19M	1.43M	10.7M	1.51M	1.55M	11.61M
% PBO nets	Scenario: Pyrethroid only				72 %	72 %	72 %	100 %	100 %	100 %	100 %
	Scenario: PBO only				28 %	28 %	28 %	100 %	100 %	100 %	100 %
Effectiveness, weighting ITN types	Scenario: Pyrethroid only	Not used (before start of impact projection)			64 %*	64 %	64 %	**50 %**	**50 %**	**50 %**	**50 %**
	Scenario: PBO only				Idem	Idem	idem	**100 %**	**100 %**	**100 %**	**100 %**
ITN population access	Either scenario	39 %	51 %	63 %	69 %	74 %	79 %	**85 %**	85 %	85 %	85 %
ITN effective/ protection usage*	Scenario: Pyrethroid only	28 %	28 %	28 %	39 %	42 %	45 %	**37.5 %**	**37.5%**	**37.5 %**	**37.5 %**
	Scenario: PBO only	Idem	Idem	Idem	Idem	Idem	idem	**75 %**	**75 %**	**75 %**	**75 %**

Notes to Table 1: The indicator inputted to Spectrum-Malaria, driving projected health impact, is ITN effective usage, averaged across all age groups. Population access is defined as the proportion of population living in a household possessing ≥1 ITNs per 1.8 household members. Distribution volumes shown apply to both scenarios, i.e. irrespective of the scenario of type of ITNs, the total distributions are the total of Routine distributions (through Antenatal care and child immunization clinics) plus 3-yearly mass distribution campaigns. Bold font indicates the yeas and parameter values for which the 2 ITN type scenarios differ.
** Calculated as: 28% * 100% effectiveness for PBO nets + 72% * 50% effectiveness for Pyrethroid-only nets*

Table 2: IRS spraying results and targets, Malawi, from different data sources

	2015	2018	2019	2018	2019	2020	2018
Population coverage, national	4.9 %		7.9 %				5.0 %
Population coverage, target area				94.9 %	≥85 %	≥85 %	39.36 %
Households/ houses sprayed		180,000	225,503 in 2 or 3 Global Fund-supported districts	112,264	118,000	118,000	
Persons protected			1.56 million (Government of Malawi Ministry of Health National Malaria Control Programme, 2020a)	501,324	500,000	500,000	907,565
Geographical area	National	7 high-burden districts	3 GF-supported & 1 PMI-supported district (Government of Malawi Ministry of Health National Malaria Control Programme, 2020a)	Nkhotakota District, part of Lake area			Lake area
Source	2015-16 DHS (National Statistics Office Malawi and ICF, 2017)	Private corresp-ondence, NMCP	NMP, via WMR 2020 (World Health Organization, 2020)	PMI MOP 2020, pages 36-38 (U.S. Center for Disease Control & Prevention, 2020)			Spectrum-Malaria

Notes to Table 2: For reference, the last column of the table also shows the population coverage in numbers and percentage of population as modelled in Spectrum-Malaria, for the year 2018 before intervention scale-up.

3.2 Intervention Scenarios (2021-2030)

1. <u>ITN distribution (routine + campaigns) adopt Pyrethroid-only nets</u>

   This scenario assumed that from 2021 onwards, Malawi would revert to using exclusively Pyrethroid-only nets, and no PBO nets. Table 1 shows the resulting effective protective coverage, assuming that Pyrethroid-only nets are half as effective as PBO nets.

   a. In a sensitivity analysis, the relative effectiveness of Pyrethroid-only nets was further lowered to 25 percent, as estimated by the NMP based on local field observations.

2. <u>ITN distribution (routine + campaigns), moving to 100 percent PBO nets from 2021 onwards</u>

   Both scenarios assumed that ITN campaigns would continue every 3 years, as projected by PMI (2021). These campaigns would be supplemented with continual routine distributions, whose annual number increases by 1.8 percent yearly, reflecting national population growth. Maintaining this pattern, population access and usage would increase to 85 percent and 75 percent from 2021 onwards.

   In the scenario with PBO nets, effective protective coverage in the population would equal population usage (75 percent). In the scenario with Pyrethroid-only nets, with halved effectiveness, effective protective coverage would be 37.5 percent from 2021 onwards, as detailed in Table 1.

3. <u>Scale-up IRS in Lake area – complementing pyrethroid-only nets only</u>

   This scenario scaled-up IRS coverage in the Lake area (4 districts) from 39.4 percent i.e. 907,565 people each year over 2013-2020 to 80 percent effective coverage i.e. 1.84 million people, from 2021 onwards (equivalent to a nation-wide coverage increase from 5 percent to 10 percent).

   The IRS scale-up is modelled against the background of ITN distribution reverting to 100 percent Pyrethroid-only nets, given that in the Tanzania community-randomized trial IRS conferred a benefit on top of pyrethroid-only nets but not when combined with PBO nets – whose pharmacological path of action may in fact be antagonistic with pirimiphos-methyl, the insecticide that Malawi used for IRS over 2018-2020 (Protopopoff et al., 2018).

4. <u>Mass media for improved care seeking for fever</u>, on top of ITNs, 100 percent Pyrethroid-only or 100 percent PBO, and with IRS unchanged from 2018-2020 (39 percent of Lake area). These scenarios assumed an increase in the coverage of fever care seeking and/or testing, spread via radio mass media, informed by community dialogues. Specifically, coverage of effective first-line treatment increased from 60 percent to 70 percent, from 2021 onwards, in line with an increase in the proportion of

fevers seeking care from 60 percent to 70 percent. This assumed increase was based on an impact evaluation of the impact of a community-driven mass media campaign in rural Malawi on maternal health care service utilization (Zamawe et al., 2016), as well as a meta-analysis of large-scale household Malaria Indicator Surveys from 8 sub-Sahara African countries of the effect of malaria-related communication via radio, on usage antimalarial drugs during pregnancy (Yaya et al., 2018).[2] The corresponding volumes of fevers, RDTs, ACT courses administered are detailed in Table 3.

Impact evaluation design

Across the scenarios, effective intervention coverages start to diverge in 2021 (Tables 1 and 3). This results in impact starting from 2022 onwards, as Spectrum-Malaria assumes a 1-year lag from coverage increase to health impact.

Comparisons of impact, cost and cost-benefit focused on the period 2022 to 2030, thus capturing both the immediate short-term effects and longer-term effects through changing transmission dynamics.

Outcome metrics considered in the cost-benefit analysis (CBA) included: malaria cases (combining uncomplicated and severe cases), severe malaria cases (a subset of total cases) and malaria-attributable deaths. All 3 were estimated by Spectrum-Malaria (Hamilton et al., 2017).

3.3 Epidemiological and Health impact Results

Figure 1 shows the calibration of Spectrum-Malaria to WHO and MAP historic burden trend estimates, and the forward projection for the alternative scale-up scenarios.

If ITN distribution reverts to Pyrethroid-impregnated nets, annual cases, deaths and infection prevalence all rise to well above the 2021 baseline level. This is the case if ITN effectiveness with pyrethroid impregnation is 50 percent of that with PBO (default) and even more so with the more extreme assumption of 25 percent effectiveness relative to PBO-impregnated nets (sensitivity analysis).

Conversely, a transition from the 2019-2020 ITN types mix to 100 percent PBO-impregnated nets would reduce malaria case and death rates, as a function of falling transmission and parasite infection prevalence (bottom panel of Figure 1). Absolute numbers of annual cases and deaths would still rise, but this simply reflects population growth.

IRS scale-up in the Lake area may marginally compensate for reversal to Pyrethroid-based ITNs (brown line, compared to red line) in line with empirical observations in the recent Tanzanian community-randomized trial (Protopopoff et al., 2018).

Improved fever case management, even at a modest increase from 60 percent to 70 percent, adds a marked health impact over and above ITN distribution, irrespective of ITN types.

Time pattern in impact

For all scale-up scenarios, for case parasite infection prevalence and case incidence, impact builds up and increases, from the initial impact (driven by Spectrum's short-term effectiveness assumptions (Korenromp et al., 2016, Hamilton et al., 2017) in 2022, to larger impact from 2023 onwards (Figure 2). For mortality, in contrast, the initial impact is followed by a slight (but partial) rebound from 2023 onwards. This pattern reflects that the reduction in malaria endemicity and population exposure entails a progressive slight reduction in acquired immunity, apparent especially for older age groups and after the initial years of scale-up (Hamilton et al., 2017), a feature that Spectrum-Malaria captures just like the more sophisticated dynamic transmission simulation model Open Malaria by the Swiss Tropical and Public Health institute (Smith et al., 2006)) on which Spectrum-Malaria was emulated.

Combining these epidemiological patterns with Malawi's strong population growth results in somewhat marked rebound for death numbers (Figure 1).

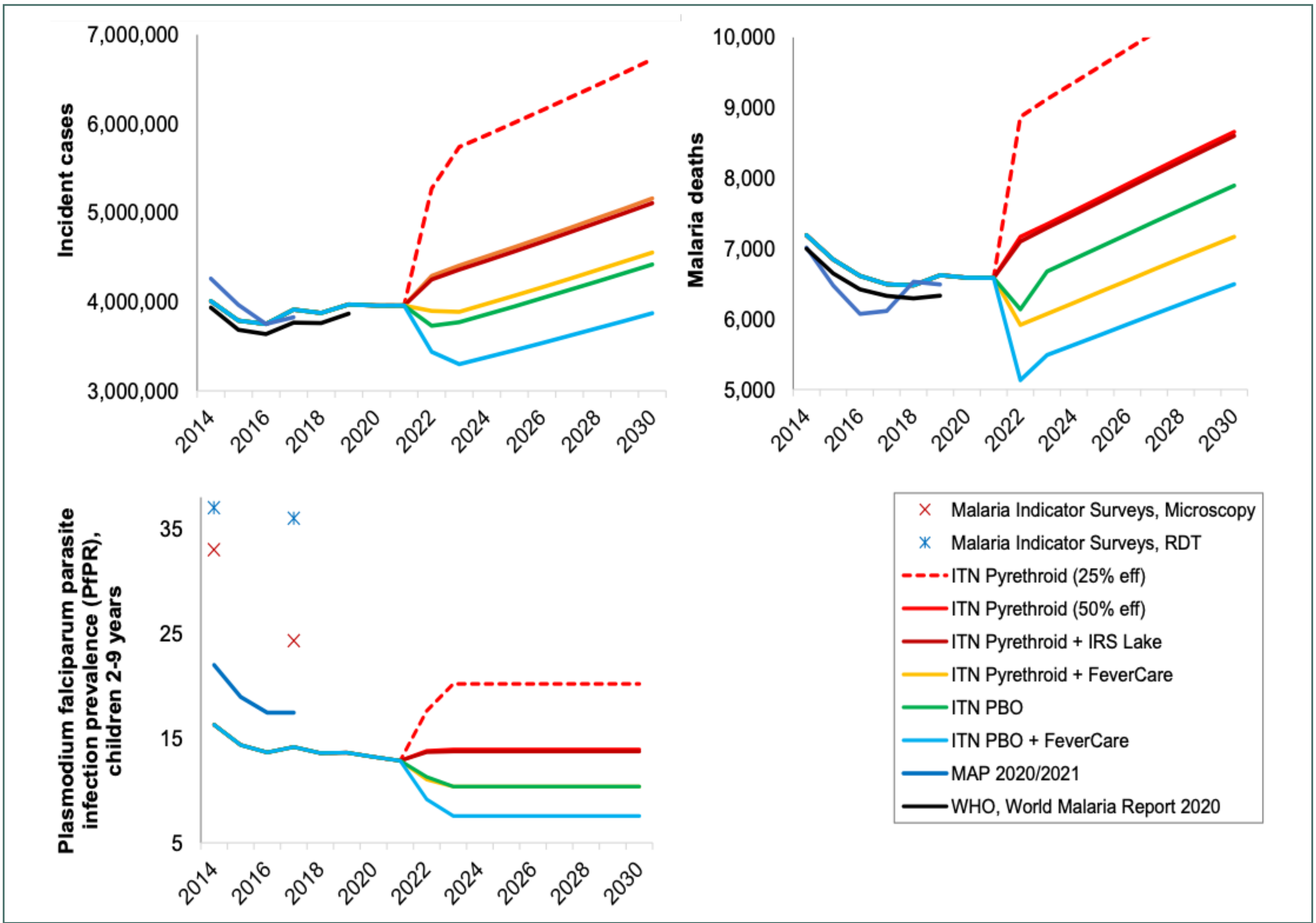
Table 3: Model parameters and scenarios for malaria case management, with and without improved fever case management

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Unchanged Fever Case management (scenario: PBO nets)										
Total incident fevers, including those not seeking care (millions)	12.40	12.73	13.08	13.43	13.80	14.16	14.54	14.92	15.31	15.70	16.10
% Fever cases that sought treatment and received RDT	60%	60%									
% Fever cases that sought treatment and received RDT	7.42	7.62	7.83	8.04	8.25	8.47	8.70	8.93	9.16	9.40	9.63
Fevers treated with a first-line ACT course* (millions)	6.75	6.87	6.73	6.75	6.81	6.86	6.91	6.97	7.02	7.08	7.14
ACT courses given to true, confirmed malaria cases (millions)	2.37	2.37	2.24	2.26	2.32	2.37	2.42	2.48	2.54	2.59	2.65
ACT courses given to non-malarial fevers (millions)	4.37	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.48	4.48
Proportion of ACTs given to real malaria cases	35%	35%	33%	34%	34%	35%	35%	36%	36%	37%	37%
Malaria cases given effective first-line treatment	60%	60%									
	Improved Fever Case management (scenario: PBO nets)										
Total incident fevers, including those not seeking care (millions)	12.40	12.73	12.79	12.96	13.31	13.67	14.04	14.41	14.78	15.17	15.56
% Fever cases that sought treatment and received RDT	60%	70%									
% Fever cases that sought treatment and received RDT	7.42	8.89	8.92	9.05	9.29	9.54	9.80	10.06	10.32	10.59	10.86
Fevers treated with a first-line ACT course* (millions)	6.75	8.01	6.80	6.74	6.85	6.91	6.96	7.02	7.08	7.14	7.19
ACT courses given to true, confirmed malaria cases (millions)	2.37	2.77	2.41	2.31	2.36	2.42	2.48	2.53	2.59	2.65	2.71
ACT courses given to non-malarial fevers (millions)	4.37	5.24	4.39	4.43	4.49	4.49	4.49	4.49	4.49	4.49	4.48
Proportion of ACTs given to real malaria cases	35%	35%	35%	34%	34%	35%	36%	36%	37%	37%	38%
Malaria cases given effective first-line treatment	60%	70%									
	Unchanged Fever Case management (scenario: Pyrethroid-only nets)										
Total incident fevers, including those not seeking care (millions)	12.40	12.73	13.64	14.07	14.45	14.83	15.22	15.62	16.02	16.43	16.84
% Fever cases that sought treatment and received RDT	60%	60%									
% Fever cases that sought treatment and received RDT	7.42	7.62	8.16	8.42	8.64	8.87	9.11	9.34	9.58	9.83	10.08
Fevers treated with a first-line ACT course* (millions)	6.75	6.87	7.26	7.15	7.19	7.26	7.32	7.38	7.45	7.51	7.58
ACT courses given to true, confirmed malaria cases (millions)	2.37	2.37	2.57	2.64	2.71	2.77	2.83	2.90	2.96	3.03	3.10
ACT courses given to non-malarial fevers (millions)	4.37	4.49	4.68	4.51	4.49	4.49	4.49	4.49	4.48	4.48	4.48
Proportion of ACTs given to real malaria cases	35%	35%	35%	37%	38%	38%	39%	39%	40%	40%	41%
Malaria cases given effective first-line treatment	60%	60%									

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Improved fever case management (scenario: Pyrethroid-only nets)										
Total incident fevers, including those not seeking care (millions)	12.40	12.73	13.25	13.55	13.91	14.28	14.66	15.05	15.44	15.83	16.24
% Fever cases that sought treatment and received RDT	60%	70%									
% Fever cases that sought treatment and received RDT	7.42	8.65	8.89	9.25	9.46	9.71	9.97	10.23	10.50	10.78	11.05
Fevers treated with a first-line ACT course* (millions)	6.75	7.87	7.22	7.27	7.26	7.34	7.40	7.47	7.54	7.60	7.67
ACT courses given to true, confirmed malaria cases (millions)	2.37	2.77	2.73	2.72	2.78	2.85	2.91	2.98	3.05	3.12	3.19
ACT courses given to non-malarial fevers (millions)	4.37	5.10	4.49	4.55	4.47	4.49	4.49	4.49	4.49	4.49	4.48
Proportion of ACTs given to real malaria cases	35%	35%	38%	37%	38%	39%	39%	40%	40%	41%	42%
Malaria cases given effective first-line treatment	60%	70%									

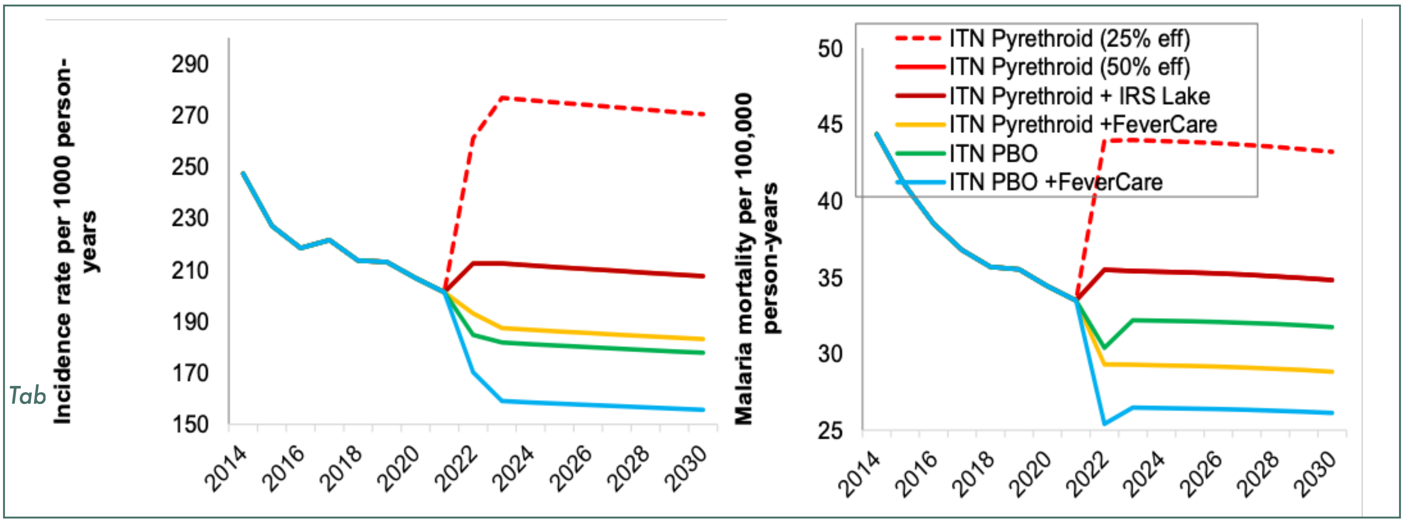
Sources: (U.S. Center for Disease Control & Prevention, 2020, World Health Organization, 2020); Malawi Performance Framework for the Global Fund, version 202.
Incidence of fevers presenting for outpatient care reflected assumed rates of 2.0, 0.60 and 0.33 per person-year, for the groups 0-4 years, 15-14 years and 15+ years, respectively (U.S. Center for Disease Control & Prevention, 2020), for the scenario without improved fever care; the scenarios with improved fever care lowered all-cause fever incidence by the reduction in malaria-attributable fevers.
The Fever management scale-up was ran in variants of ITN distribution with 100 percent Pyrethroid-only or 100 percent PBO nets, without IRS scale-up.
'ACT courses given to non-malarial fevers' reflect presumptive treatments for the 0.2 percent of clinical fevers that do not receive a parasitologically test, treatments given to patients whose fever concurred with malaria parasitology/RDT positivity but was really due to a concurrent other, non-malarial cause (Battle et al., 2016, Dalrymple et al., 2019, Johansson et al., 2015), treatments given by providers despite a negative RDT result, patient self-treatments of ACTs bought from pharmacies without a formal health care contact, and treatments following a false-positive RDT result (Chinkhumba et al., 2010).
The proportion of 'Malaria cases given effective first-line treatment' is expressed relative to (the numerator of) both cases presenting for care (at clinics or a community health worker) and cases not presenting for care.

Figure 1: Malaria cases, deaths and Plasmodium falciparum parasite infection prevalence in Malawi, projected by Spectrum-Malaria in scenarios varying in effective coverage of ITNs (as a function of insecticide type and assumed relative effectiveness of Pyrethroid impregnation relative to PBO), IRS (Lake area only), and/or improved fever case management, from 2021 onwards.



Notes to Figure 1: For comparison are also shown, the independent estimates for the same malaria burden indicators by the WHO (World Health Organization, 2020). and Malaria Atlas Project 2020 ((Weiss et al., 2019) & https://malariaatlas.org/malaria-burden-data-download/) .(see Sections 3.1 and 3.2 for detail).

Figure 2: Malaria cases incidence and mortality rates, for the same scale-up scenarios in Malawi's Spectrum-Malaria model



Tab

4. CBA general parameters & estimation approach

4.1 General Parameters

All analyses cover the period from 2021 to 2030. Actions occurring in a given year generate impacts in the following years, with the exception on increased use of RDTs and ACTs which generate impacts in the same year. Following Malawi Priorities standardized assumptions, we adopt annual discount rates of 5 per cent, 8 per cent and 14 per cent for the cost-benefit analyses. Costs are reported in 2020 Malawian Kwacha. Data from older years are inflated based on Malawi GDP deflators, provided by the World Bank's Economic Indicator database. (World Bank, 2020).

4.2 Valuing Mortality Avoided

These are based on Spectrum-estimated malaria-attributable deaths. The monetary value of malaria deaths avoided follows Malawi Priorities standardized assumptions and is based on guidance on income elasticity for value of statistical life (VSL) benefit transfer provided by Robinson et al. (2019). This is then divided by the life expectancy of the average adult to calculate the value of statistical life year (VSLY). In short, each life year lost is valued at 0.6 x GDP per capita in the initial year rising marginally to 0.7 x GDP per capita in 2030. For deaths in young children (0 to 4 years) we assume years of life lost avoided as 65.9 years, for older children (5 to 15 years) 60.8 years, and for adult death - 49.4 years, as per Malawian life tables (WHO, 2019).

4.3 Valuing Morbidity Avoided: Cost-of-Illness approach

Following Malawi Priorities standardized assumptions, avoided morbidity is valued using a cost-of-illness approach incorporating the full societal costs including health system, direct and indirect household costs. The benefit of an avoided case is simply the cost-of-illness avoided.

We assess costs for three different categories of morbidity from symptomatic malaria cases/episodes (as modelled by Spectrum-Malaria): uncomplicated cases that do not seek care from a formal health provider; uncomplicated cases that seek care from a formal health provider; and severe malaria cases that require hospitalization. Each outcome is estimated for each of the Spectrum-modelled three age groupings (0-4 years old; 5-14 years old and 15+ years old).

Three different types of costs associated with malaria episodes are considered:

Direct household costs – this includes costs paid directly by households including medication, travel, consultations, and hospitalization. Cost estimates for uncomplicated cases were sourced from Ewing et al., (2011), while severe cases were sourced from Hennessee et al., (2017).

Indirect household costs – this includes productivity loss associated with time spent out of work, time spent travelling and seeking care and caregiver time. As with direct costs, indirect costs were sourced from Ewing et al., (2011) and (Hennessee et al., 2017) and assume an average length of illness for uncomplicated and severe malaria equal to 5.0 and 10.6 days respectively.

For children aged 5-14 years we also measure the impact of missed school days. According to Turkson, Wong and Dubosse (2020), mean years of schooling in Malawi total 8 years. We take the difference between average income and income associated with no schooling, equal to roughly MWK 250,000 per year (Turkson, Wong and Dubosse, 2020). The present value of this wage premium across a working life from 15 to 60 is the value of eight years of schooling. An uncomplicated case of malaria lasts 5 days and therefore, each episode is associated with $5/(8*365) = 0.2$ percent schooling loss, which we assume translates to 0.2 percent loss of the schooling premium. A similar calculation is done for severe malaria episodes which last 10.6 days instead of 5.

Provider cost – provider costs include costs to the health system for an inpatient hospital stay or outpatient visit, and are estimated using WHO CHOICE data for Malawi (WHO-CHOICE, 2021).

Estimates for each type of outcome are presented below. Spectrum-Malaria projects totals of uncomplicated and severe cases; For uncomplicated cases, we applied a weighted average cost-of-illness, 60 percent get treated.

Table 4: Cost-of-illness estimates (2020 MWK)

	Young Children (0-5)	School Aged Children (5-15)	Adults (15+)
Uncomplicated episode not receiving formal health care			
Direct HH Cost	30	30	30
Indirect HH Cost	2,002	9,599	2,002
Provider Cost	0	0	0
Total Cost	**2,032**	**9,629**	**2,032**
Uncomplicated episode receiving formal health care			
Direct HH Cost	285	285	285
Indirect HH Cost	2,523	10,120	2,523
Provider Cost	1,214	1,214	1,214
Total Cost	**4,022**	**11,619**	**4,022**
Treated severe episode			
Direct HH Cost	3,935	7,001	7,001
Indirect HH Cost	3,512	18,678	16,852
Provider Cost	32,606	32,606	32,606
Total Cost	**40,052**	**58,285**	**56,459**

Notes to Table 4: All costs reported in 2020 Malawian Kwacha. Costs derived from Ewing et al. (2011), Hennessee et al. (2017), Turkson, Wong and Dubosse (2020) and WHO CHOICE data, inflated to 2020 figures. Treated severe episodes includes the costs of initial – but failing – first line care seeking and treatment.

5. Cost-benefit analysis results

5.1 Intervention 1: PBO distribution (relative to 100 percent pyrethroid-only ITN)

Description

In the impact projections and CBA presented here, the intervention scenario assumes transition to 100 percent PBO ITNs from 2021 onwards (compared to 28 percent in the 2018 campaign), which is compared to a counterfactual of the distribution and use of only (100 percent) pyrethroid-only ITNs.

Costs

The only relevant cost parameter for this intervention is the price differential between standard pyrethroid-only ITNs and PBO ITNs. All other costs, including planning, distribution, and monitoring, are assumed to be equal between the two types of ITNs. As of March 2020, the difference in price between the ITNs is USD 0.62 or MWK 462 (UNICEF, 2020). The time series of costs is depicted in Figure 3.

Benefits

As per the modelling results, the intervention results in the avoidance of 6,767 deaths, 277,600 severe cases and 5,785,000 uncomplicated cases over 10 years. These are monetized using the principles outlined in Section 4. Approximately two-thirds of the benefits are for avoided mortality. The monetized benefit stream is depicted in Figure 3.

5.2 Intervention 2: IRS in Districts around Lake Malawi (relative to 100 percent pyrethroid-only ITN)

Description

IRS spraying in districts around Lake Malawi.

Costs

The cost of IRS is assumed to be MWK 2,476 per household sprayed (White et al., 2011). For costing, we assumed that IRS is implemented using long-lasting insecticide pirimiphos-methyl, which requires 12-monthly spraying and was used in Malawi over 2018-2020 (Topazian et al., 2021), and not the (more conventional) bendiocarb, which requires 6-monthly spraying. The time series of costs is depicted in Figure 3.

Benefits

As per the modelling results, the intervention results in the avoidance of 507 deaths, 18,200 severe cases and 413,500 uncomplicated cases over 10 years. Approximately 60 percent of the benefits are mortality avoided. The monetized benefit stream is depicted in Figure 3.

5.3 Intervention 3a: Mass media for improving care seeking for fever (complementing 100 percent pyrethroid-only ITN)

Description

The NMCP noted a desire to investigate community engagement interventions to reduce the malaria burden. Based on findings in literature, this intervention combines community dialogues with mass media. Specifically, the intervention envisions community consultations with 10,000 participants in each of the 28 districts of Malawi in the first half of year 1. This is to identify context-specific constraints to increased care seeking for fever and design mass media messages appropriately. Then from the second half of year 1 onwards the messages gleaned from the community dialogues are used to craft a mass media promotion (radio) specific to each district. We expect this intervention to increase care seeking for fever from 60 percent of those with fever, to 70 percent.

Costs

To arrive at the initial message design cost we assume community dialogues will include 10,000 people in each of the 28 districts. The per person cost of community led program for malaria control strategies in Malawi is estimated at MWK 18,625 or $25 (USD 2020) (Phiri et al., 2020, Colbourn et al. 2015). The total cost of this component is therefore 10,000 people * 28 districts * 18,625 = MWK 5,215 million.

(Kasteng et al., 2018) assess the cost-effectiveness of a mass radio campaign on health-seeking behaviours for child survival. They estimate the cost of mass media per capita in Malawi as 7 cents per capita (USD 2015), which we rounded off to 10 cents per capita (USD $2020) or MWK 75. The cost of this component is estimated by the product of the population of Malawi in a given year and the cost per capita, 75 MWK. This investment averages MWK 1,761 million per year until 2029.

This intervention furthermore changes the usage of RDT and ACT, due to increased care seeking. The cost of RDT is set at MWK 335 (PMI, 2018), while the cost of a course of first-line ACT is MWK 2,235 (Khuluza and Heide, 2017). The time series of costs is presented in Figure 3. Community engagement and mass media comprise most of the cost. Additional RDT and ACT costs are minimal in comparison.

Benefits

As per the modelling results, the intervention results in the avoidance of 12,312 deaths, 210,200 severe cases and 4,692,300 uncomplicated cases over 10 years. Approximately 80 percent of the benefits are mortality avoided. Mortality avoided benefits are a higher proportion of benefits than the other interventions because it focuses on improving treatment once someone already has malaria. To be clear, improved treatment also has some transmission benefits, but not as much as ITN and IRS which are solely vector control interventions. The monetized benefit stream is depicted in Figure 3.

5.4 Intervention 3b: Mass media for improving care seeking for fever plus PBO ITN (relative to 100 percent pyrethroid-only ITN)

This intervention combines the mass media intervention improving fever care seeking with the transition to PBO ITNs. The stream of costs and benefits are presented in Figure 3. This intervention has the largest absolute impact of interventions considered, avoiding 18,129 deaths, 456,370 severe cases and 9,977,000 uncomplicated cases over 2022-2030. Three-quarters of the benefits are from mortality avoided.

5.5 Intervention 4: ITN distribution every 2 years instead of every 3

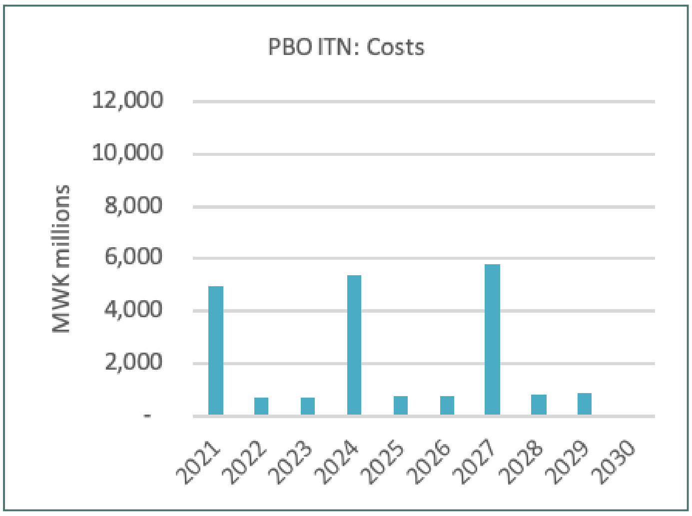
Description

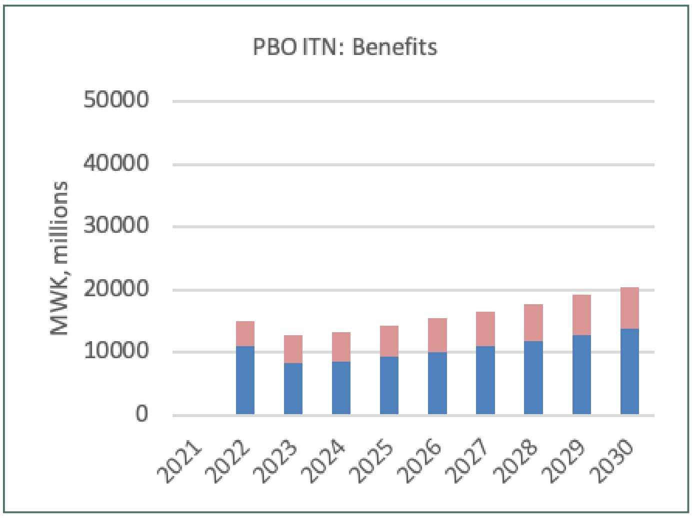
Increasing frequency of mass ITN distribution campaigns from once every three years to once every two years was raised as an intervention under consideration by the NMCP. The justification was further highlighted during a webinar of draft results, where NMCP indicated that by the third year only 50 percent of the nets were functional. Therefore, the NMCP is considering increasing the frequency of mass net distribution to once every two years to address this issue. However, the relevance and impact of this potential policy change would depend on the exact pathway of ITN effectiveness decline post-distribution, a combination of insecticide retention, physical ITN integrity, and ownership (as opposed to selling/giving away) and usage for personal night-time protection – a cascade for which empirical data are lacking. Impact modelling results in our scenarios are anyways based on assumed high usage, at 75 percent close to the targets of the MSP – and do not explicitly reflect the timing and quantity of distributions needed to arrive at the stipulated usage rate.

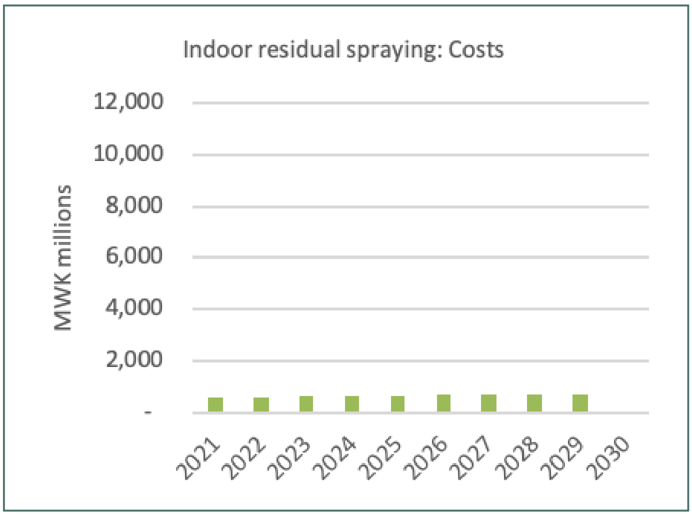
Costs & Benefits

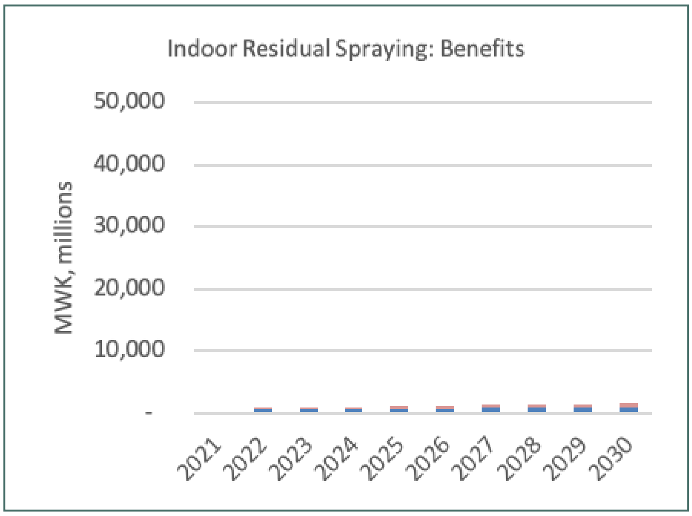
We estimated the cost-benefit effects of increasing distribution campaign frequency increases from 3 years to 2 years, independent from Spectrum-Malaria by simplistically applying Malawi's observed national usage rate of 50 percent in the 3rd year after the 2018 distribution campaign, and assuming that health impact linearly and immediately reflects usage. Per 6-year cycle, costs increase by approximately 40 percent, since there would be three mass campaigns instead of only two (while routine distribution remains unchanged). If increased frequency mitigates a 50 percent drop in malaria benefits in the third year, then the improvement in benefits is only 20 percent over the 6-year cycle (i.e. in years 3 and 6 ITN effectiveness are 100 percent, instead of 50 percent). In other words, increasing the frequency of distribution would increase costs by 40 percent but would only increase benefits by 20 percent. Of course, this is an over-simplification and does not account for transmission impacts, which may mean a less favourable cost-benefit relation given that long-term dynamic population-level impact reflects the cumulative benefits of community protection and acquired immunity. Nevertheless, the interpretation is that relative to a 3-year cycle, a 2-year cycle is unlikely to be as cost-effective.

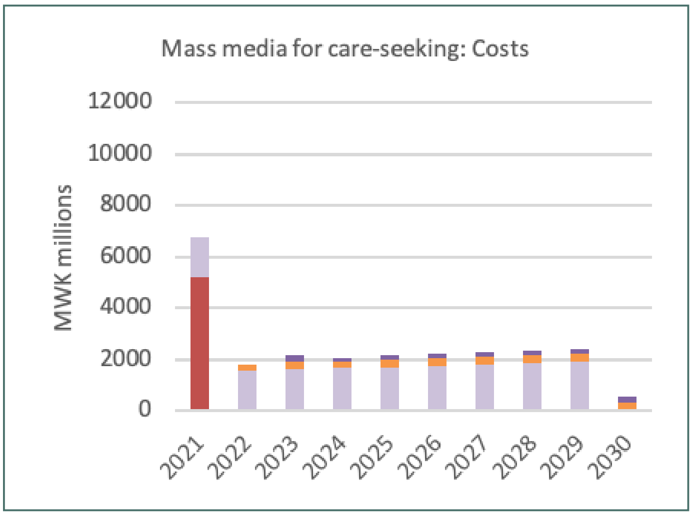
Figure 2: *Malaria cases incidence and mortality rates, for the same scale-up scenarios in Malawi's Spectrum-Malaria model*

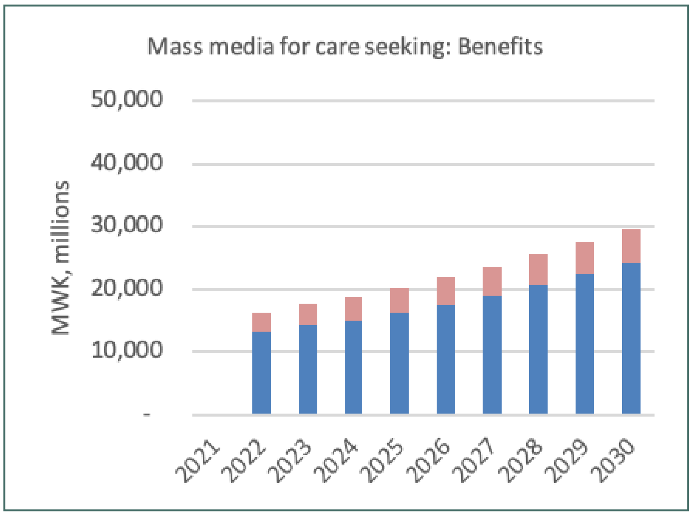


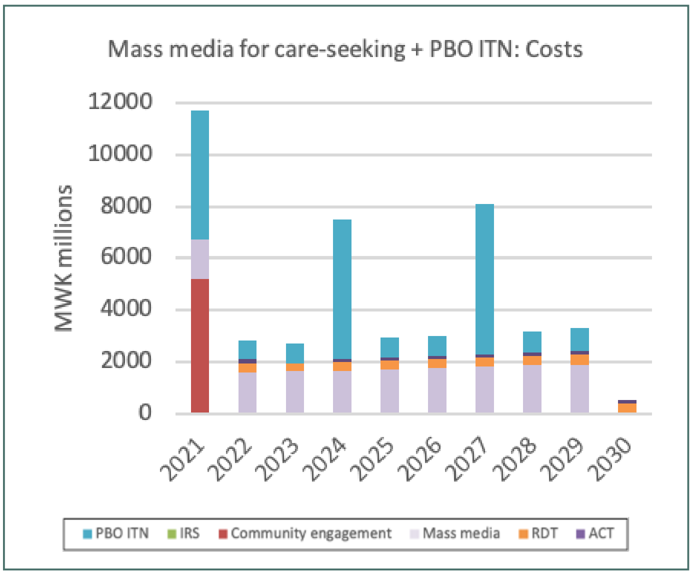


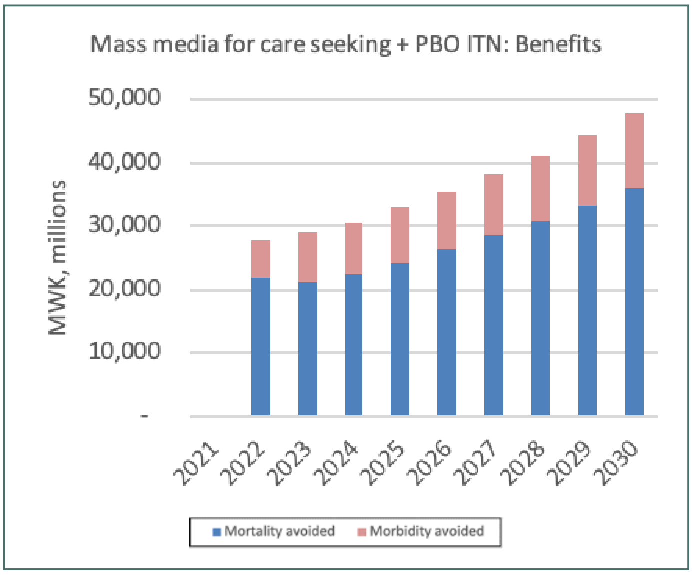












5.6 Sensitivity Analysis

To assess the sensitivity of results to assumed parameters, we vary several parameter estimates and report the resulting BCRs.

In a webinar presentation of draft results, officials at the NMCP noted that pyrethroid-only ITNs may have an effectiveness of 25 percent, instead of the 50 percent assumed in this study. Therefore, we re-estimate results varying this parameter. Additional assumptions altered include the costs of each intervention (+/-25 percent) and the VSLY (assumed 1x GDP per capita for every life year saved). The results are presented in Table 5.

The results of the sensitivity analysis support the primary policy implication of the analysis – i.e. mass media for fever care and PBO ITNs remain the likely most cost-effective interventions for consideration by the NMCP, irrespective of variations in costs, benefits valuation and assumed insecticide resistance. Additionally, it appears unlikely that IRS would be a superior intervention from a cost-effectiveness perspective. Perhaps the most interesting result is the impact of changing the assumed effectiveness of pyrethroid-only ITNs from 50 percent to 25 percent. The BCRs are substantially higher than the base case, confirming the significant potential advantage of switching to PBO ITN, the more so as pyrethroid resistance spreads. This adds further support to the notion that the NMCP should change to PBO ITNs which is already under consideration.

Table 5: Sensitivity Analysis – Benefit Cost Ratios

	Base Case	Pyrethroid-only Effectiveness = 25 percent	Costs +25 percent	Costs -25 percent	VSLY 1x GDP per capita
PBO ITN	6.0	19.4	4.8	8.1	8.9
IRS	1.7	Not modelled	1.4	2.3	2.5
Mass media for improved care seeking for fever care	7.4	Not modelled	5.9	9.8	11.2
Mass media for improved care seeking for fever + PBO ITNs	6.6	13.2	5.3	8.8	9.8

6. Conclusion & Policy Implications

This study conducted cost-benefit analyses on several interventions. The results indicate that PBO ITNs and mass media for improving fever care seeking are likely the most efficient use of additional resources for the NMCP (Table 6). The combination of the two interventions would have the largest absolute impact on malaria burden in the country. We do not overemphasize differences in the point estimates of the respective BCRs, since each comes with substantial uncertainty. This combined intervention would require an additional MWK 46,000 million, or USD 62 million, in (undiscounted) funding over 10 years, which equals ~ 8 percent of the typical average national program budget of an annual USD 80 million (NMCP, 2020). The combined intervention would reduce malaria deaths by around 45 percent and cases by 25 percent, bringing Malawi much closer to achieving MSP impact goals (reducing malaria case incidence and death rates in 2030 by 90 percent, compared to a 2015 baseline (and by 40 percent and 75 percent in 2020 and 2025, respectively (Government of Malawi Ministry of Health National Malaria Control Programme, 2020b)).

In contrast, IRS in the districts around the Lake as well as increasing the frequency of mass ITN distribution campaigns are likely less effective use of resources than the other two interventions, whether individually or combined. We recommended more careful consideration and analysis of IRS strategies and of the optimal frequency of mass campaigns, ideally with more context-specific data, before implementing these possible policy changes.

Table 6: Summary of costs, benefits and benefit-cost ratios across three discount rates

Intervention	Discount Rate	Cost (MWK, millions)	Benefit (MWK, millions)	BCR
100 percent PBO ITN distribution	5 %	17,616	122,933	7.0
	8 %	16,148	97,684	6.0
	14 %	13,858	71,478	5.2
Scale-up IRS in districts around Lake Malawi	5 %	4,790	9,930	2.1
	8 %	4,308	7,414	1.7
	14 %	3,567	5,161	1.4
Mass media for improved care seeking for fever	5 %	21,064	164,350	7.8
	8 %	19,370	142,451	7.4
	14 %	16,781	109,874	6.5
Mass media for improved care seeking for fever + 100 percent PBO ITN distribution	5 %	38,898	271,963	7.0
	8 %	35,730	235,927	6.6
	14 %	30,839	182,289	5.9
Increasing frequency of mass ITN campaigns from once every 3 years to once every 2 (PBO or pyrethroid-only)	n/a	Approx. 40 percent increase in costs	Approximate (up to) 20 percent increase in benefits	<1

Notes to Table 6: Intervention costs and benefits reported in 2020 MWK and represent present values over a 10-year period from 2021-2030.

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8. Annexures

8.1 ANNEX 1

Research Process: The project team completed a scan of all potential interventions which could improve malaria control and reduce the burden of the disease in Malawi. Strategies used by the Malawi Ministry of Health and Population include fever case management, mass distribution of long lasting insecticide treated nets; indoor residual spraying and larviciding; malaria prevention during pregnancy with IPTp; social and behavioural change communication to promote positive behaviours and treatment adherence, and monitoring and evaluation. All were considered as part of the process of narrowing down on interventions for cost-benefit analysis.

We then interviewed several experts with experience in malaria, whether in Malawi or elsewhere, including:

- Dr. Michael Kayange, Director, National Malaria Control Programme, Malawi.
- Dr. Joshua Yukich, School of Public Health & Tropical Medicine, Tulane University, Canada.
- Prof Don Mathanga, Malaria Alert Centre, of the University of Malawi and the Kamuzu University of Health Sciences.

The results of the consultation were then considered with other factors. The criteria for intervention selection included:

1. **Sector expert priority –** An intervention is accorded higher priority if sector experts note that it is important. In this case, the discussion with Dr. Kayange was particularly informative as it highlighted some of the key concerns that were affecting the Malaria Control Program currently, the interventions under consideration, and the interventions that were not.
2. **High benefit-cost ratio or cost-effectiveness in similar previous research –** The purpose of the Malawi Priorities project is ultimately to identify interventions of outsized benefits relative to costs. Input into this factor is determined from the economics literature, particularly previous research conducted by the Copenhagen Consensus Center. In the Center's experience, BCRs above 15 are among the highest across all interventions. Due consideration is given to contextual differences between previous research and the current situation in Malawi in determining the effect of this criterion.
3. **Sufficient potential public health impact –** some interventions could be considered highly effective yet only address a small percentage of a given problem, limiting the overall net benefits of the approach. To avoid focusing on solutions that are too small, each intervention considered must have the potential to provide an impact of public health significance and population-level significance.
4. **Significant gap in current coverage levels of intervention –** all analysis conducted in Malawi Priorities focuses on marginal benefits and costs. Therefore if an intervention already has high coverage rates, then additional resources provided towards that intervention are unlikely to be effective, or will suffer from the 'small-size' problem.
5. **Availability of crucial data or credible knowledge of impact –** due to time and resource constraints, all analyses conducted by Malawi Priorities are based on secondary data. No new primary research is conducted, such as field experiments or trials. Therefore, the selection of interventions explored was conditional on the availability of effectiveness data in the public domain, either from the national program or from relevant published studies relevant to the national setting. In many cases, one key constraint is knowledge concerning the impact of a given intervention. It is typical to formally deal with uncertainty here via sensitivity analyses, examining alternative higher and lower effectiveness. However, in some cases the uncertainty is so great that it precludes even researching the intervention at all.

The process of screening and prioritizing interventions is summarized in Table A-1, drawing on the factors described above.

Table A-1: Intervention Screening Process

Intervention considered	Sector expert priority	High BCR or cost-effectiveness	Addresses a problem of sufficient size	Significant gap in current coverage of intervention	Effectiveness data available	Overall
Distribution of PBO ITNs	Yes - NMCP priority	Research in Nigeria notes a BCR of over 200 for distribution of PBO ITN (Shepard et al., 2020)	Yes, resistance to pyrethroid has been documented in Malawi and evidence indicates pyrethroid ITN has lower effectiveness than PBO ITNs	Yes, in the 2018 campaign only 28 percent of nets were PBO nets, with the remainder pyrethroid	Yes	High
IRS in high burden districts	Yes – NMCP priority	Literature review indicates targeted spraying yields an ICER of $ 41.70 (Stelmach et al. 2018)	Yes, resistance to pyrethroid has been documented in Malawi and evidence indicates pyrethroid ITN has lower effectiveness than PBO ITNs. IRS is being considered to supplement increasing resistance	Only 4.9 percent of Malawi's households have had IRS done, according to DHS 2015-16	Yes	High
Community engagement through mass media for improved behaviours around care seeking for fever.	Yes - NMCP priority	Unknown	Yes – there is ample scope for improved malaria control behaviours e.g. only 55-67 percent of children with fever sought care (2015-16 DHS & 2017 MIS)	Yes	Yes	High
Increase frequency of mass ITN campaigns from 3 years to 2 years	Yes – NMCP priority	Unknown	Malawi's national program evaluation over 2018-2020 suggests ITN effectiveness may fall in the 3rd year post-distribution	Potentially ((mass campaigns are currently held every three years))	National field evaluation, but no formal randomized trial	High
Malaria RTS,S Vaccine	Sector experts did not give the vaccine high priority.	Literature review suggest RTS,S vaccine implementation would be highly cost effective with an ICER of $115 per DALY averted (Ndeketa et al. 2020)	Malawi is one of three countries participating in a large-scale pilot implementation programme of the RTS S malaria vaccine.	RTS,S is the first vaccine against malaria to undergo pilot implementation, begun in 2019 and vaccinating 360,000 children per year in Malawi. Still in the pilot stage	Yes	Medium
IPTp	Yes	Literature review suggests an ICER of $7.28 per DALY averted for IPTp3 using Sulphadoxine-Pyrimethamine (Fernandes et al, 2015).	Pregnant women, besides children below the age of five, make up a significant part of Malawi's high malaria burden and are a target group for the MSP (MIS, 2017)	According to MIS (2017) the coverage of pregnant women is 41 percent for IPTp3, 76 percent for IPTp2, and 92 percent for IPTp1	Yes	Medium

Intervention considered	Sector expert priority	High BCR or cost-effectiveness	Addresses a problem of sufficient size	Significant gap in current coverage of intervention	Effectiveness data available	Overall
Improving parasitological testing capability and coverage	Yes	Literature review indicates BCR of 6.7 for test-based malaria treatment in Nigeria (Ezennia et al. 2017).	Universal testing is critical to reduce mis-use and over-use of ACTs for presumptive treatment, and thus spare ACTs and minimize the development of parasitological resistance	Since 2018, test coverage among clinical cases is already >98 percent but this does not cover cases not presenting for clinical (or CHW care: only 55-67 percent of children under five years old with fever sought advice or treatment (DHS 2015-16 & 2017 MIS).	Yes	Low

The Malawi Priorities Project

2021

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