

Impact of mass distribution of long-lasting insecticidal nets (LLINs) in Mozambique, 2011 to 2025: Retrospective and prospective modeling of child mortality and lives saved

Erica A Wetzler

World Vision US

Jorge A.H. Arroz

World Vision Mozambique

Chulwoo Park

San Jose State University

Marta Chande (✉ marta_chande@wvi.org)

World Vision Mozambique

Figueiredo Mussambala

World Vision Mozambique

Baltazar Candrinho

National Malaria Control Program

Research

Keywords: Long-lasting insecticidal net (LLIN), Mozambique, Lives Saved Tool (LiST), NetCALC

Posted Date: December 16th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-126233/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Background

Malaria was the leading cause of post-neonatal deaths in Mozambique in 2017. The use of long-lasting insecticidal nets (LLINs) is recognized as one of the most effective ways to reduce malaria morbidity and mortality, especially in children. In 2015, Mozambique committed to the expansion of LLIN coverage nationwide, culminating in the first countrywide campaign in 2017, reaching 95% of registered households. Between 2012 and 2019, more than 34 million LLINs were distributed. No previous analyses have estimated changes in mortality attributable to the scale-up of LLINs, accounting for provincial differences in mortality rates and coverage of health interventions.

Methods

From 2012 to 2020, the population-based model NetCALC was used to predict provincial household LLIN coverage based upon the number of LLINs distributed annually. NetCALC also projected how many LLINs are needed to maintain universal coverage in 10 provinces from 2021 to 2025. Based upon the annual provincial coverage of LLINs, the Lives Saved Tool (LiST), a multi-cause mathematical model, estimated under-5 lives saved, and reductions in under-5 mortality attributable to LLIN expansion in 10 provinces of Mozambique between 2012 and 2020, and projected lives saved from 2021 to 2025 if universal coverage of LLINs is sustained.

Results

Results from the LiST models estimate that 64,470 child deaths were averted between 2012 and 2019. If currently planned quantities of LLINs are distributed in 2020, and universal coverage is maintained from 2021 to 2025, an additional 68,695 child deaths could be averted. From 2011 to 2020, the percent reduction in all-cause child mortality was 19.2%, from 114.5 per 1,000 to 93.2 per 1000 in the LLIN distribution model compared to 9.5% in the baseline model. If universal coverage continues through 2025, this reduction will be sustained.

Conclusions

LiST and NetCALC used together are useful in estimating lives saved and mortality in countries such as Mozambique where vital registration data to measure changes in mortality are not consistently available. Universal coverage of LLINs can save a substantial number of child lives and reduce child mortality in Mozambique but will require resource mobilization. Without continued investment, thousands of avoidable child deaths will occur.

Background

Malaria burden in Mozambique: Mozambique has the fourth highest burden of malaria worldwide, with an estimated 9 million cases in 2018 [1]. There were 10,132 deaths due to malaria in children under 5 years in Mozambique in 2017, with malaria as the top cause of post-neonatal deaths [2]. The prevalence of malaria has historically been higher in the northern provinces of the country, where there are more humid climates and higher populations (Figure 1).

There is substantial evidence linking long lasting in long-lasting insecticidal nets (LLINs) with reduced child mortality and morbidity. Universal coverage of LLINs is a core malaria prevention tool, and part of the first pillar of World Health Organization's (WHO) Global Technical Strategy for Malaria 2016–2030 [3–5]. Globally, LLINs have become a core intervention of national control strategies with over 2.2 billion nets distributed worldwide as of the second quarter of 2020 [6].

Mozambique's National Strategic Plan for Malaria (2017–2022) focuses on reducing the burden in high endemic areas while sustaining gains in low transmission areas to accelerate elimination. The plan emphasizes strengthening case management, universal access to diagnosis and treatment, strengthening malaria surveillance systems, and the continuation of universal coverage of LLINs as the main vector control strategy, with the use of indoor residual spraying (IRS) as a mitigation method. The National Malaria Control Program's (NMCP) objectives relevant to LLIN distribution are to ensure that: 1) at least 90% of registered households have sufficient LLINs (at least one for every two people), and 2) at least 80% of LLIN owners sleep under their LLINs. The NMCP's goal is to distribute one LLIN for every 1.8 people in the household every 3 years.

In Mozambique, the NMCP rolled out a national insecticide-treated nets (ITN) household ownership strategy in 2011, aiming to achieve universal coverage of LLINs throughout the country. Subsequently, through funding from the U.S. government's President's Malaria Initiative, and later from the Global Fund for Malaria Tuberculosis and AIDS, the NMCP worked with partners to organize mass distributions in all provinces. Between 2011 and 2019, 36,862,845 LLINs were distributed nationwide, starting in six provinces, culminating in the first countrywide campaign that delivered over 16 million LLINs to 95% of registered households in 2017 [7]. The 2020 campaign plans to deliver over 12 million LLINs to seven provinces but has been delayed by the COVID-19 pandemic.

Vital registration data to measure changes in mortality are not available in Mozambique and in most sub-Saharan Africa countries. Birth histories from national surveys are useful in measuring trends in all-cause child mortality, but they do not typically assess cause of death. There have been no provincial level mortality estimates in Mozambique since 2011. The Lives Saved Tool (LiST), developed by Johns Hopkins University, is a modeling application available through the Spectrum software package that estimates child mortality and "lives saved" for children under 5 years of age retrospectively and prospectively using the age structure of the population, fertility rates, under-5 mortality rates, cause of death structure, and changing coverage estimates of key child survival and maternal interventions [8].

The LiST child health intervention indicator related to LLINs is household ownership of an ITN and/or protected by Indoor Residual Spraying (IRS).

In Mozambique, previous LiST analyses have modeled the direct effect of the scale-up of malaria interventions (IRS, ITN household ownership, ITN use by pregnant women and IPTp during pregnancy) on reducing malaria-specific mortality from 2007 to 2011, and between 1997 and 2011 [9, 10]. These analyses linearly interpolated coverage between survey years to estimate ITN coverage while also increasing coverage of other maternal and child health interventions.

Junior et al. used historical coverage data and mathematical modeling to project future coverage levels for 22 interventions for 2015 to 2030, and then used LiST to estimate additional lives saved and changes in the child mortality rate over time [11]. However, the estimates did not take into account the actual number of LLINs distributed. Even so, the two interventions projected to save the most under-5 lives between 2015 and 2030 are increased coverage of artemisinin-based combination therapies (ACTs) and ITN ownership, contributing to an estimated 40.9% of the total lives saved if historical trends continue.

NetCALC is a tool that estimates how many bed nets are needed to reach a specified target for LLIN or ITN household coverage, or conversely, estimates ITN or LLIN coverage based on distribution of nets each year. The principal design of the NetCALC tool is a simple, compartmental model, and requires core population information, including: 1) the starting year, 2) the target population size during that year, 3) the average household size of the population, and 4) the average population growth rate [12-14]. The tool includes parameters on timing and size of actual net distributions, population and household size population growth, intra-household net accumulation, and net decay to project LLIN coverage at a given point in time based on the number of nets available for use for the specified target population. The tool has been used in previously published work [15-18].

In 2013, Paintain et al. used NetCALC and LiST together to estimate that the LLINs distributed between 2010 and 2012 in 40 countries in sub-Saharan Africa prevented about 350,000 malaria-attributable under-5 deaths compared to the baseline in 2009.

No previous analyses have estimated changes in mortality attributable to the distribution and scale-up of LLINs in Mozambique, accounting for heterogeneous mortality rates, differences in disease patterns, and coverage of maternal and child health interventions between provinces. Most reporting and analysis on LLIN distribution has focused on outputs, such as the number of ITNs distributed by province or district. However, data on outcomes including mortality and lives saved can help stakeholders advocate for continued investment in LLINs as a cornerstone for driving and maintaining reductions in under-5 child mortality in Mozambique.

Further, the Mozambique NMCP usually calculates the number of LLINs needed annually, comparing the current method of calculating LLIN needs with provincial level evidence-based projections from NetCALC can help planners and policy makers to anticipate investments needed in LLINs, in order to more efficiently and effectively distribute them where most needed.

Methods

This study seeks to estimate deaths averted in children under-5 due to LLIN distributions in 10 provinces of Mozambique between 2012 and 2020 and to project the number of lives that can be saved in children under 5 from 2021 to 2025 if universal coverage is maintained. The study population is the population of Mozambique, excluding the city of Maputo, estimated at about 22 million people in 2011 [19]. Maputo City was excluded because LLIN distribution is not the primary malaria prevention effort there and no LLIN has been distributed since 2017.

Additional outcomes are percent reductions in under-5 mortality nationally and by province for the same time periods, and estimated number of LLINs needed by province from 2021 to 2025 to maintain universal coverage.

Predicting LLIN coverage using NetCALC

Data from the 2011 Demographic and Health Survey (DHS) were used for baseline bed net coverage in each province [20]. The provincial baseline population in NetCALC (version 3.2) was the total population for that province in 2011, according to 2007 Mozambique census projections. For the core population information required by NetCALC, household size was set using the 2011 DHS. The average population growth rate was fixed at 2.86% for all provinces [21]. Median LLIN survival time was set to three years, in line with NMCP guidance for the LLIN brands used in Mozambique.

To estimate trends in ITN and LLIN ownership coverage between 2012 and 2020, we entered the number of LLINs distributed during that time, and NetCALC estimated coverage for each year. To create a counterfactual to estimate the trend in ownership coverage had no LLINs been distributed, 2011 baseline coverage from the DHS was used as a starting point, NetCALC modeled the rate at which coverage would decline if no LLINs were distributed after 2011. Annual net replacement needs from 2021 to 2025 were modeled using the 'sustain uc' function in NetCALC, assuming 100% as the target to be sustained.

Predicting deaths averted and percent reduction in all-cause under-5 mortality

The LiST model (Version 5.761) and accompanying documentation used in this analysis [22]. LiST models were created for each of the 10 provinces in Mozambique using Spectrum's Sub-National Wizard, and then summed to estimate the total lives saved as a result of LLIN distribution. Separate models for each province were needed because provinces have different cause of death structures and varying coverage levels of the MCHN interventions that LiST uses to make projections. Using countrywide estimates would have diluted the effect of these regional variations and the corresponding accuracy of mortality and lives saved estimates. LiST requires a parameter on the "first-year" population, in this case 2011. We estimated the first-year population for each province using census projections for 2011, the same population values entered in NetCALC [20]. With the exception of Inhambane and Nampula provinces, provincial neonatal, infant, and under-5 mortality rates were based on the 2011 DHS. Under-5

mortality rates for Nampula and Inhambane provinces from the DHS were less than half of neighboring provinces, so for these two provinces LiST estimates were deemed more realistic.

The intervention coverage indicator of interest in LiST is “ITN/IRS – household ownership of insecticide treated bed net (ITN) and/or protected by indoor residual spraying (IRS)” [23]. This is the indicator for which coverage estimates were changed in LiST based upon NetCALC projections. Coverage levels for all other LiST interventions remained constant. For each province, we created three sets of models in LiST. The first was the baseline or counterfactual, which assumed no distribution of LLINs after 2011, and therefore a decline in ownership coverage. The second set of models used coverage estimates from NetCALC based upon actual LLINs distributed through 2020 (and no LLINs after 2020). The third set of models assumed universal coverage is maintained through 2025. For each model, LiST estimated lives saved for children under 5.

For each province, all-cause under-5 mortality rates were projected in the baseline model (no LLIN distribution) and in the LLIN distribution model. For each province and nationally, we estimated the percent reduction in under-5 mortality between 2011 and 2020 and percent reduction in under-5 mortality if universal coverage is sustained between 2021 and 2025 in the baseline and LLIN distribution models.

Results

Number of nets distributed by province

Between 2012 and 2019, 34,513,379 LLINs were distributed in 10 provinces of Mozambique. During the initial years of distribution, LLINs were distributed in selected districts in each province. Nearly half of the LLINs (16,558,818) were distributed during 2017. The program planned to distribute 12,014,149 LLINs in 2020. Distribution has been delayed due to the COVID-19 pandemic, but door-to-door distribution is now planned in seven provinces during the latter part of the year.

Predictions in LLIN coverage (median and IQRs) by province

In 2017, estimated LLIN coverage reached 100% in all 10 provinces, coinciding with the mass countrywide LLIN distribution that year (Table 1). Universal coverage was sustained through 2019 in all provinces except Zambezia, Sofala, Inhambane, Gaza, and Maputo. If LLINs are distributed as planned in 2020, all provinces except Maputo will be at 100% coverage. For the period from 2011 to 2019, median coverage for each province was lowest in Gaza and Maputo province at 69.56% (IQR: 46.06%, 83.22%) and 69.12% (IQR: 37.66%, 83.88%) respectively. These provinces have a lower burden of malaria. Median coverage was highest in Nampula and Manica provinces at 83.70% (IQR: 60.56%, 100%) and 83.14% (IQR: 53.96%, 100%) respectively.

Table 1. Estimated household coverage (%) of LLINs in 10 provinces of Mozambique, 2011

to 2020

Province	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Coverage Trend 2011-2019	IQR
Nampula	60.6	48.5	85.3	83.7	72.6	50.1	100.0	100.0	100.0	100.0		60.6, 100.0
Niassa	47.3	29.9	17.2	85.2	76.9	58.6	100.0	100.0	100.0	100.0		47.3, 100.0
Cabo Delgado	61.4	39.0	35.2	98.1	81.3	60.0	100.0	100.0	100.0	100.0		60.0, 100.0
Zambezia	46.6	60.2	60.4	53.4	73.7	55.8	100.0	100.0	89.7	100.0		55.8, 89.7
Tete	47.4	29.6	17.0	22.0	80.9	69.5	100.0	100.0	100.0	100.0		29.6, 99.8
Manica	54.0	70.8	52.9	45.7	100.0	83.1	100.0	100.0	100.0	100.0		54.0, 100.0
Sofala	56.9	54.4	37.4	82.1	93.0	71.8	100.0	100.0	95.3	100.0		56.9, 95.3
Inhambane	54.0	39.5	24.8	43.5	89.1	73.9	100.0	100.0	81.1	100.0		43.5, 89.1
Gaza	46.1	29.2	27.3	83.2	69.6	51.6	100.0	100.0	75.3	100.0		46.1, 83.2
Maputo Province	37.7	22.0	12.6	69.1	70.3	54.8	100.0	100.0	83.9	52.1		37.7, 83.9

Lives saved in children 0–59 months by province, 2012 to 2020

In total, LiST estimated that 64,470 lives of children under 5 were saved due to ownership of LLINs between 2012 and 2019. If nets are distributed as planned in 2020, an additional 12,721 deaths will be averted this year. The estimated number of under-5 lives saved nationwide increased every year starting from 1,608 in 2012 to 8,981 in 2015, even as modest numbers of LLINs were distributed throughout the country. There were no LLINs distributed in 2016 and 2018. However, after the mass distribution in 2017, the estimated number of lives saved increased to 12,211 per year and is projected to remain stable at about 12,000 per year until 2021 (Fig. 2).

Figure 2. Total LLINs distributed and estimated lives saved of children under-5 in Mozambique from 2012–2020

Key for Fig. 2. Between 2012 and 2020, the number of estimated under-5 lives saved increased as the number of LLINs distributed increased, with a total of 64,470 lives saved between 2012 and 2019, and an additional 12,721 projected for 2020 if the planned number of LLINs are distributed in the country. The countrywide mass distribution of LLINs in 2017 helped to elevate household coverage to 100% in all provinces in both 2017 and 2018, which in turn, resulted in a over 12,000 under-5 lives saved starting in 2017 and continuing in subsequent years.

If no nets are distributed in 2021, 10,769 child deaths will still be averted. Between 2020 and 2025, a total of 20,322,378 LLINs are needed to achieve and maintain universal coverage, with 697,868 nets projected in 2021 and 5,309,734 in 2025 (**Additional Table 1 and Fig. 3**). NetCALC projects that 81,942 LLINs are

needed in Maputo province in 2020, but no LLINs are scheduled for distribution there. If universal coverage is maintained between 2021 and 2025, then an estimated 68,695 under-5 deaths will be prevented (Fig. 3).

Figure 3. Total LLINs needed to maintain 100% coverage and projected under-5 lives saved, Mozambique, 2021–2025

Key for Fig. 3. To maintain universal household coverage at 100%, 697,868 LLINs are needed for distribution in 2021, peaking at 5,596,708 in 2023 and decreasing slightly until 2025. During the same time period, the estimated under-5 lives saved increased in a linear manner starting at 13,160 in 2021 and reaching 14,333 by 2025.

At the provincial level, most lives saved were in the more populous provinces of Nampula and Zambezia, which also correspond to the provinces with a higher malaria burden. From 2012 to 2019, we estimated that 15,438 under-5 deaths were averted in Zambezia province alone, or about 23.95%.

Estimated percent reductions in under-5 mortality by province

Overall, after scale-up of LLINs through mass distribution, estimated all-cause under-5 mortality decreased from 114.51 per 1000 in 2011 to 93.24 per 1,000, a 18.58% reduction. This compares to a 7.84% reduction over the same period in the baseline model where no LLINs were distributed (Fig. 4). If universal coverage is sustained through 2025, under-5 mortality is projected to be 92.48 per 1000. LiST also projected changes in under-5 mortality by province attributable to the distribution of LLINs.

Figure 4. Estimated under-5 mortality rates (per 1,000) with and without LLIN distribution, and universal coverage after 2020

Key to Fig. 4. Estimated reductions in all-cause under-5 mortality assuming no LLIN distribution and assuming actual distribution of LLINs from 2011 to 2020 and sustaining universal coverage of LLINs from 2021 to 2025. In 2011, the under-5 mortality rate was estimated at 114.51 per 1,000 live births in both models. However, by 2020, the estimated under-5 mortality rate had dropped to 105.53 per 1,000 in the baseline model (no LLINs), and to 93.24 per 1,000 in the LLIN distribution model. If universal coverage is sustained until 2025, the mortality rate drops marginally to 91.95 per 1,000 by 2025. If no LLINs are distributed, the mortality rate decreases from 105.53 per 1,000 in 2020 to a projected 104.45 per 1,000 in 2025.

Comparing baseline projections to those including actual mass scale-up of LLINs from 2011 to 2020, reductions in under-5 mortality were lowest in Maputo province (from 96.06 per 1000 to 80.86 per 1000), a 12.55% reduction, and greatest in Manica province (113.99 per 1000 to 91.49 per 1000), where it was 20.55% lower than 2011 (**Additional Table 2**). Under-5 mortality was also projected between 2021 and 2025 if universal coverage is sustained, dropping slightly from 93.23 per 1000 in 2020 to 92.48 per 1000 in 2025. In the baseline model, under-5 mortality is estimated at 105.53 per 1000 in 2020, dropping to

103.65 per 1000 in 2025. These mortality rate estimates do not reflect coverage changes in any other maternal and child health interventions, so actual rates in 2020 and 2025 would likely be lower.

Discussion

The scale up of LLINs in Mozambique saved an additional 64,470 lives from 2012 to 2019, with an estimated 12,721 more in 2020 if planned distributions are completed. Expanded coverage of LLINs has contributed to reductions in all-cause child mortality, supported by under-5 mortality rate projections that estimate a net reduction of about 10 per 1,000 deaths in each province between 2011 and 2020. To sustain universal coverage, an estimated 20,420,436 LLINs are needed in Mozambique between 2021 and 2025. The NMCP has not yet made projections for the LLINs needed in 2021 through 2025, so these projections can provide useful comparison points when projections are made and can assist with budgeting and projections as Mozambique applies for funding for LLINs from the Global Fund in 2021.

If universal coverage is maintained through 2025, progress toward preventing deaths will continue with over 66,000 lives saved. However, the COVID-19 pandemic and uncertainty regarding continued investment in LLINs threaten sustained coverage, especially those in the north and central provinces of the country.

Our results show greater number of lives saved due to LLIN distribution than other studies that used the LiST model to estimate lives saved attributable to LLIN ownership in Mozambique. This is for a couple of reasons: Because of the objective to determine the role of LLINs in preventing death and reducing mortality, coverage levels for other interventions remained static. Secondly, coverage levels of LLIN ownership steadily increased starting in 2012, while previous studies focused on time periods when LLIN coverage had not yet been expanded through mass campaigns. Finally, to align with our research question, the baseline model did not keep LLIN coverage constant, but modeled how coverage would decrease over time had no LLINs been distributed after 2011.

This research adds to the body of evidence showing the relative importance of LLINs to prevent under-5 deaths in Mozambique. Though other studies have used slightly different approaches and did not measure the effects of LLINs only, their findings also demonstrate the importance of LLINs in preventing deaths of children in Mozambique. The President's Malaria Initiative conducted an analysis estimating deaths prevented due to the scale-up of malaria control interventions from 2007 to 2011 and estimated that 13,198 (range: 9,231 to 17,231) deaths were prevented in children ages 1 to 59 months, due to the scale-up of ITN and IRS [9]. In an analysis of 11 interventions, Macicame et al. estimated that 55,757 under-5 child lives were saved between 1997 and 2011 (15 years) through ITN and IRS. Compared to LLIN ownership, wasting prevalence was the only intervention that saved more lives [10].

Junior et al. used historical coverage data and mathematical modeling to project future coverage for 22 child and maternal health interventions from 2015 to 2030, estimating 29,302 child lives saved nationwide for the same period, second only to treatment with ACTs [11]. This was lower than projections from our models because estimated LLIN coverage was lower than actual and other interventions were

not held constant. In 2019, Pothin and Winkel modeled the impact of various vector control and drug-based interventions and the prevalence at the district level throughout the country, including the distribution of piperonyl butoxide treated nets in 2020 and every three years through 2030 at 80% coverage [24]. On their own, ITNs were the most impactful intervention at reducing prevalence compared to IRS, case management, mass drug administration, seasonal malaria chemotherapy, and larval source management.

The LiST and NetCALC tools used together are useful to estimate lives saved and mortality in countries such as Mozambique where vital registration data to measure changes in mortality are not consistently available. Both NetCALC and LiST models have been validated by their authors against observed field data [25–27]. A strength of LiST is that it incorporates a comprehensive approach to mortality modeling, calculating the increases in LLINs in this case against the backdrop of other intervention coverage remaining static, while using evidence-based effectiveness values for each of the interventions it incorporates.

However, this study had a few limitations. NetCALC is designed to predict the number of LLINs needed annually to maintain a defined coverage level, based on population size, existing coverage from previous LLIN or ITN distributions and median LLIN lifespan. When NetCALC calculates replacement need, it assumes LLINs will reach those not covered in an equitable manner and does not consider how they will be distributed. If there are additional nets planned for distribution beyond the replacement need, NetCALC considers these “excess.” However, when the NMCP plans for distributions, it considers both mass campaign mechanisms and continuous distribution channels, which results in double distribution for some recipients and therefore a greater projected need for LLINs than the replacement need modeled in NetCALC.

In addition, coverage by IRS was not included in this analysis. In 2019, the IRS program covered five provinces, including an estimated 780,597 people in Maputo Province, where LLIN coverage was lower than other provinces, which contributed to further reductions in mortality not included in this analysis. The remaining provinces covered by IRS were also covered by LLINs. Furthermore, other malaria interventions such as case management with ACTs and chemoprophylaxis for pregnant women were considered static for this analysis. This analysis focused only on children under 5 years of age, underestimating the full impact of LLIN distribution on the population of Mozambique, and not including deaths where malaria may have been a secondary cause.

Conclusions

Multiple analyses have shown that continued investment in interventions to prevent childhood malaria, especially LLINs, can result in substantial reductions in child mortality and an increase in saved lives. The total estimated cost per LLIN in Mozambique was \$1.22 (including procurement, logistics, training, transport) in 2017, a relatively small investment given the number of lives that can be saved [7]. Sustaining universal coverage of LLINs may be more feasible than scaling and maintaining coverage of

other key child health interventions such as malaria treatment with ACTs and oral rehydration solution for diarrhea. In an analysis of 69 countries, Walker et al. predicted that by 2035, the coverage of four interventions all related to malaria prevention, including household ownership of insecticide treated nets, will increase rapidly, while another 24 interventions will not see substantial scale-up by 2035, bolstering the case for continued investment in mass distribution of LLINs [8].

Gaps in coverage of maternal and child health interventions need to be viewed through an equity lens, which acknowledges the need for a multi-intervention approach, while strategically focusing on those interventions known to be effective at reducing mortality, and whose distribution and delivery mechanisms facilitate or promote equity (lower cost, less time for distribution and training). Mass LLINs campaigns are last-mile solutions to help close the equity gap. In Mozambique, LLINs only need to be delivered every three years, reaching the most remote areas, which are often the most vulnerable. In contrast to other maternal and child health interventions, LLINs benefit the entire household. Logistical burdens surrounding transport and handling are also less complex, depending on fewer intermediaries. Mass distributions are one-off events rather than continuous, reducing the number of trips needed for delivery. Over time, this makes mass distribution events less vulnerable to the effects of external events such as emergencies and political instability that undermine sustaining or increasing coverage of other maternal and child health interventions. However, there are challenges associated with distribution, access, and use of LLINs at the household level that should be considered during allocation of scarce financial resources for child health. This analysis shows that child deaths are concentrated in provinces in the north and central regions. If funding gaps continue, targeted selection of high burden, more populous provinces and districts should be prioritized.

In 2019, an estimated 81,507 children under-5 died in Mozambique [28]. Maintaining universal coverage of LLINs is clearly a strategic opportunity for maximizing the number of child lives saved; however, sustaining universal coverage of LLINs will require substantial resource mobilization. Without continued investment in sustaining coverage, thousands of avoidable child deaths will occur.

Abbreviations

ACTs: Artemisinin-based combination therapies, DHS: Demographic and Health Survey, IRS: Indoor residual spraying, ITN: Insecticide-treated net, LiST: Lives Saved Tool, LLIN: Long-lasting insecticidal net, NMCP: National Malaria Control Program

Declarations

Ethics approval and consent to participate

Not applicable. Human participants were not involved in the study. This research uses secondary data and is not subject to ethics approval.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

Funding

The LLIN mass distribution campaigns in Mozambique were supported through a financial contribution from the Global Fund to Fight AIDS, Tuberculosis, and Malaria.

Authors' contributions

EAW led the study design, conducted the modeling and analysis, drafted the manuscript. JAHA contributed to the study design and drafted the manuscript. CP advised on the modeling and analysis and contributed to the manuscript. MC and FM provided baseline or initial data and contributed to the manuscript. BC reviewed and contributed to the manuscript.

Acknowledgements

Doctor Jorge A.H. Arroz, who was instrumental in designing this study, passed away while the manuscript and final analysis were underway. Dr. Arroz dedicated his life and career to improving the health of the people of Mozambique. The authors would also like to acknowledge the contributions of communities in Mozambique who help make the distribution of LLINs possible throughout the country, and the contributions and dedication of the district and provincial health authorities, and the National Malaria Control Program. The Director of the National Malaria Control program reviewed the manuscript prior to submission.

Author's information

This information is on the title page.

References

1. World Health Organization: World malaria report 2019. <https://www.who.int/publications/i/item/world-malaria-report-2019> (2019). Accessed 20 November 2020.
2. World Health Organization. MCEE-WHO methods and data sources for child causes of death 2000-2017. Geneva: WHO. 2018.

3. Lengeler C. Insecticide-treated bed nets and curtains for preventing malaria. Cochrane database of systematic reviews. 2004(2).
4. Pryce J, Richardson M, Lengeler C. Insecticide-treated nets for preventing malaria. Cochrane Database of Systematic Reviews. 2018(11).
5. World Health Organization. Global technical strategy for malaria 2016-2030. World Health Organization; 2015. Report No.: 9241564997.
6. The Alliance for Malaria Prevention: Net Mapping Project. <https://netmappingproject.allianceformalariaprevention.com/> (2020). Accessed 23 October 2020.
7. Arroz JA, Candrinho B, Pedro S, Mathe G, da Silva M, Tsabete S, et al. Planning and implementation of a countrywide campaign to deliver over 16 million long-lasting insecticidal nets in Mozambique. *Malaria Journal*. 2018;17(1):254.
8. Walker N, Tam Y, Friberg IK. Overview of the lives saved tool (LiST). Springer; 2013.
9. USAID. Evaluation of the Impact of Malaria Control Interventions on All-Cause Mortality in Children under Five Years of Age in Mozambique 2016.
10. Macicame I, Magaço A, Cassocera M, Amado C, Feriano A, Chicumbe S, et al. Intervention heroes of Mozambique from 1997 to 2015: estimates of maternal and child lives saved using the Lives Saved Tool. *Journal of Global Health*. 2018;8(2).
11. Júnior JM, Cane RM, Gonçalves MP, Sambo J, Konikoff J, Fernandes Q, et al. Projecting the lives saved by continuing the historical scale-up of child and maternal health interventions in Mozambique until 2030. *Journal of global health*. 2019;9(1).
12. Kilian A, Boulay M, Koenker H, Lynch M. How many mosquito nets are needed to achieve universal coverage? Recommendations for the quantification and allocation of long-lasting insecticidal nets for mass campaigns. *Malaria Journal*. 2010;9(1):330.
13. Briët OJ, Hardy D, Smith TA. Importance of factors determining the effective lifetime of a mass, long-lasting, insecticidal net distribution: a sensitivity analysis. *Malaria Journal*. 2012;11(1):20.
14. Kilian A, Byamukama W, Pigeon O, Atieli F, Duchon S, Phan C. Long-term field performance of a polyester-based long-lasting insecticidal mosquito net in rural Uganda. *Malaria Journal*. 2008;7(1):49.
15. Paintain LS, Kolaczinski J, Renshaw M, Filler S, Kilian A, Webster J, et al. Sustaining fragile gains: the need to maintain coverage with long-lasting insecticidal nets for malaria control and likely implications of not doing so. *PloS one*. 2013;8(12):e83816.
16. Koenker HM, Yukich JO, Mkindi A, Mandike R, Brown N, Kilian A, et al. Analysing and recommending options for maintaining universal coverage with long-lasting insecticidal nets: the case of Tanzania in 2011. *Malaria Journal*. 2013;12(1):1-16.
17. Ahogni IB, Salako AS, Akinro B, Sovi A, Gnanguenon V, Azondekon R, et al. Physical integrity and survivorship of long-lasting insecticidal nets distributed to households of the same socio-cultural community in Benin, West Africa. *Malaria Journal*. 2020;19(1):58.

18. Yukich J, Bennett A, Keating J, Yukich RK, Lynch M, Eisele TP, et al. Planning long lasting insecticide treated net campaigns: should households' existing nets be taken into account? *Parasites & vectors*. 2013;6(1):174.
19. Instituto Nacional de Estatística: Recenseamento Geral da População e Habitação [General Census of Population and Housing]. Accessed 1 January 2019.
20. Ministerio da Saude - MISAU/Moçambique, Instituto Nacional de Estatística - INE/Moçambique, ICF International. Moçambique Inquérito Demográfico e de Saúde 2011. Calverton, Maryland, USA: MISA/Moçambique, INE/Moçambique and ICF International; 2013.
21. United Nations: World Population Prospects. <https://population.un.org/wpp/Download/Standard/Population/> (2020). Accessed 12 January 2020.
22. Johns Hopkins Bloomberg School of Public Health: The Lives Saved Tool. <https://www.livessavedtool.org/listspectrum> (2020). Accessed 20 November 2020.
23. Avenir Health, Johns Hopkins Bloomberg School of Public Health, Programs Ifl. The Lives Saved Tool: Spectrum Manual.
24. Winkel M dCE, Chico AR, Colborn J, Didier B, Lucero D, Guidon M, Roca-Feltrer A, Zulliger R, Candrinho, B, Pothin E, editor Supporting strategic planning with malaria modelling in Mozambique. American Society of Tropical Medicine and Hygiene Annual Meeting; 2020.
25. Friberg IK, Bhutta ZA, Darmstadt GL, Bang A, Cousens S, Baqui AH, et al. Comparing modelled predictions of neonatal mortality impacts using LiST with observed results of community-based intervention trials in South Asia. *International journal of epidemiology*. 2010;39(suppl_1):i11-i20.
26. Hazel E, Gilroy K, Friberg I, Black RE, Bryce J, Jones G. Comparing modelled to measured mortality reductions: applying the Lives Saved Tool to evaluation data from the Accelerated Child Survival Programme in West Africa. *International journal of epidemiology*. 2010;39(suppl_1):i32-i9.
27. Larsen DA, Friberg IK, Eisele TP. Comparison of Lives Saved Tool model child mortality estimates against measured data from vector control studies in sub-Saharan Africa. *BMC Public Health*. 2011;11(S3):S34.
28. UNICEF: Child Mortality. <https://data.unicef.org/topic/child-survival/under-five-mortality/> (2020). Accessed 12 October 2020.

Figures



Figure 1

Provincial map of Mozambique. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.



Figure 1

Provincial map of Mozambique. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

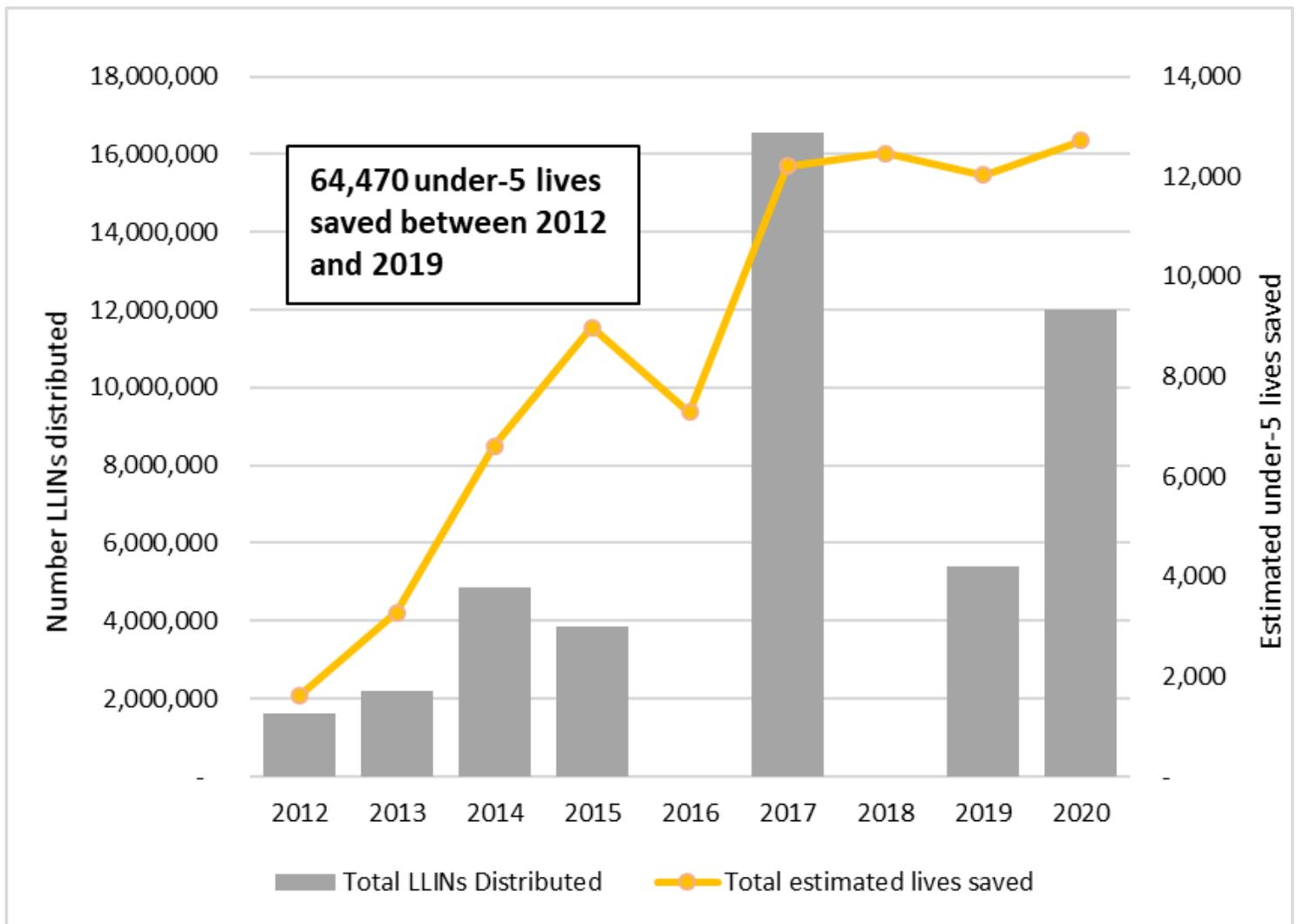


Figure 2

Total LLINs distributed and estimated lives saved of children under-5 in Mozambique from 2012–2020

Key for Figure 2. Between 2012 and 2020, the number of estimated under-5 lives saved increased as the number of LLINs distributed increased, with a total of 64,470 lives saved between 2012 and 2019, and an additional 12,721 projected for 2020 if the planned number of LLINs are distributed in the country. The countrywide mass distribution of LLINs in 2017 helped to elevate household coverage to 100% in all provinces in both 2017 and 2018, which in turn, resulted in a over 12,000 under-5 lives saved starting in 2017 and continuing in subsequent years.

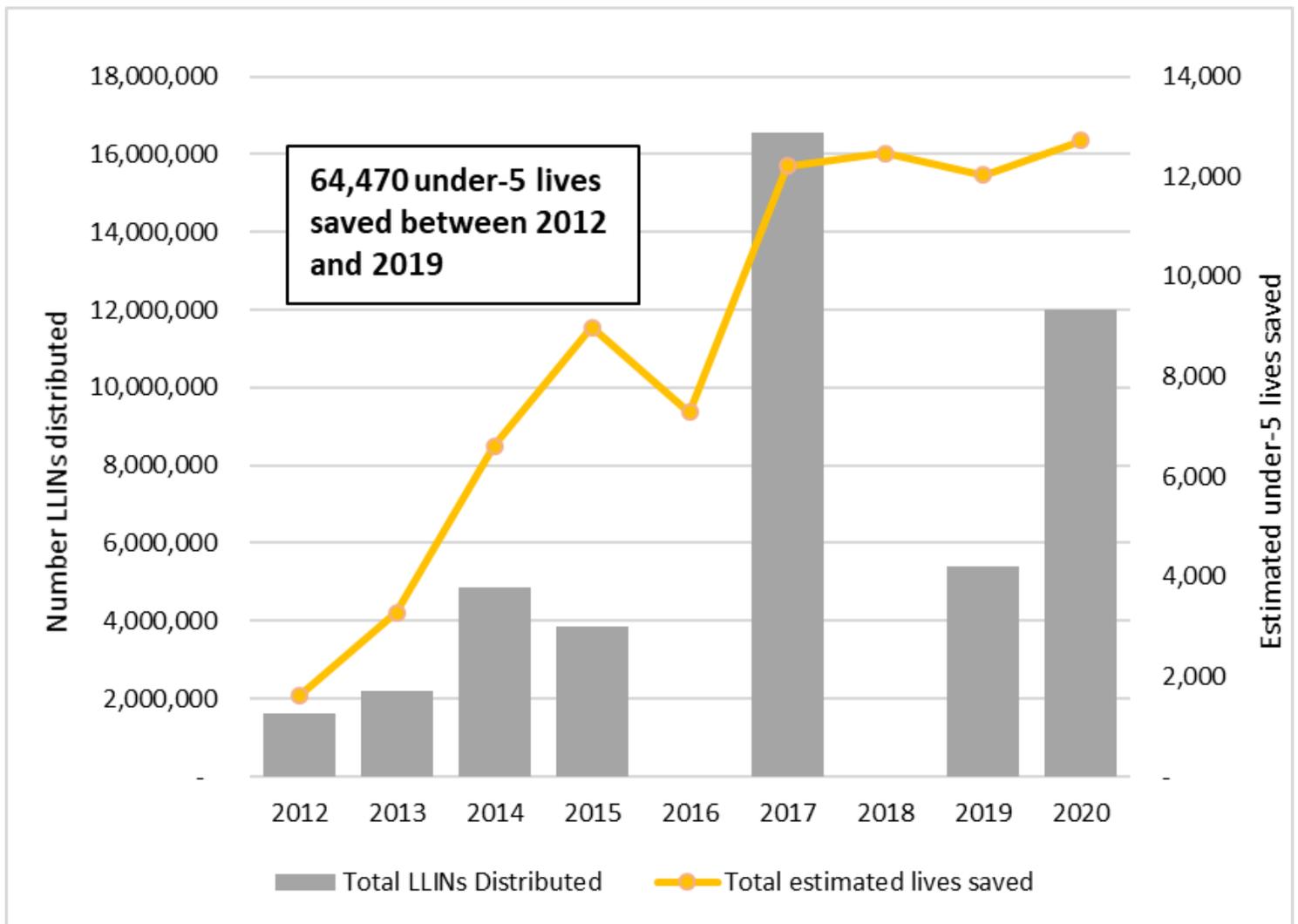


Figure 2

Total LLINs distributed and estimated lives saved of children under-5 in Mozambique from 2012–2020
 Key for Figure 2. Between 2012 and 2020, the number of estimated under-5 lives saved increased as the number of LLINs distributed increased, with a total of 64,470 lives saved between 2012 and 2019, and an additional 12,721 projected for 2020 if the planned number of LLINs are distributed in the country. The countrywide mass distribution of LLINs in 2017 helped to elevate household coverage to 100% in all provinces in both 2017 and 2018, which in turn, resulted in a over 12,000 under-5 lives saved starting in 2017 and continuing in subsequent years.

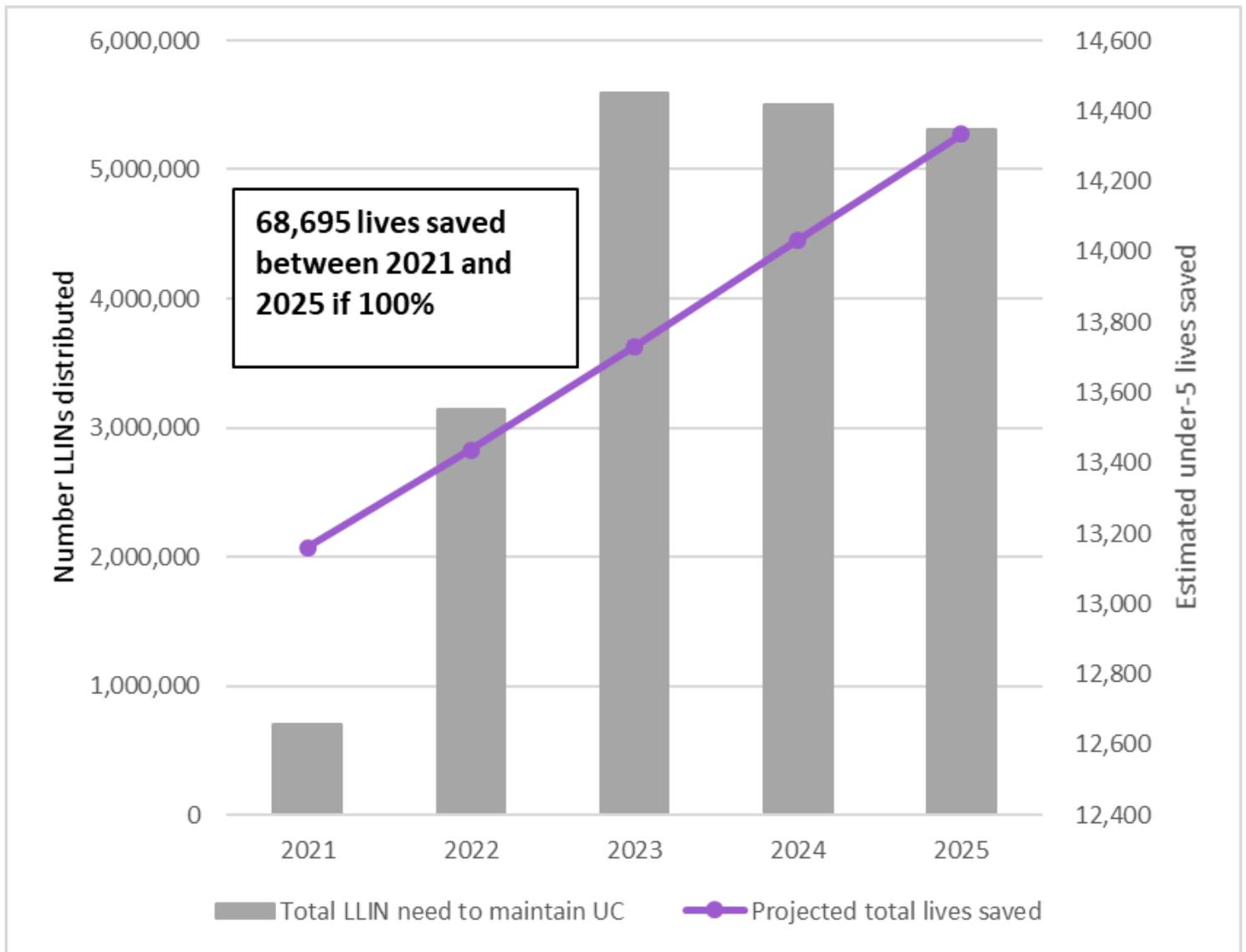


Figure 3

Total LLINs needed to maintain 100% coverage and projected under-5 lives saved, Mozambique, 2021–2025 Key for Figure 3. To maintain universal household coverage at 100%, 697,868 LLINs are needed for distribution in 2021, peaking at 5,596,708 in 2023 and decreasing slightly until 2025. During the same time period, the estimated under-5 lives saved increased in a linear manner starting at 13,160 in 2021 and reaching 14,333 by 2025.

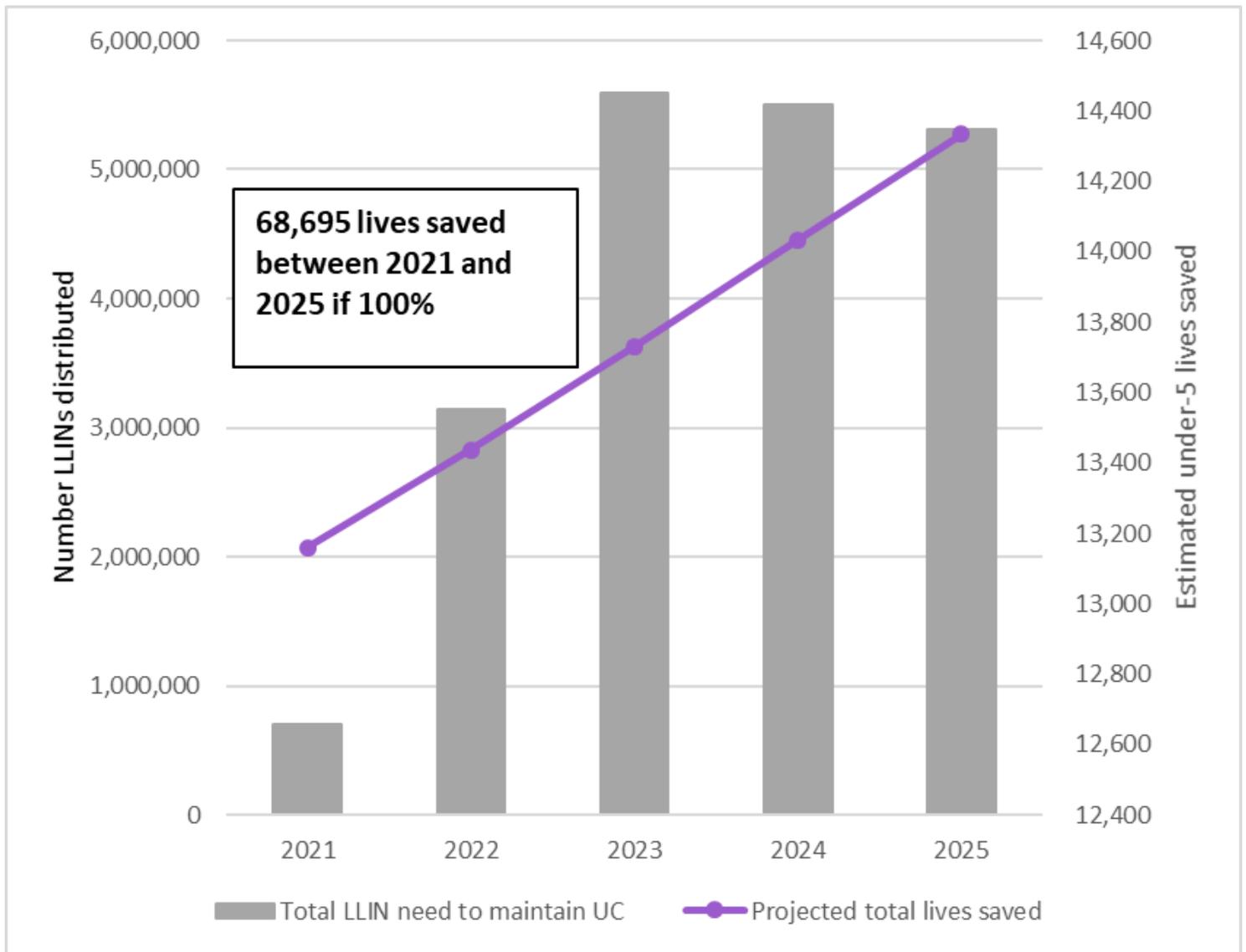


Figure 3

Total LLINs needed to maintain 100% coverage and projected under-5 lives saved, Mozambique, 2021–2025 Key for Figure 3. To maintain universal household coverage at 100%, 697,868 LLINs are needed for distribution in 2021, peaking at 5,596,708 in 2023 and decreasing slightly until 2025. During the same time period, the estimated under-5 lives saved increased in a linear manner starting at 13,160 in 2021 and reaching 14,333 by 2025.

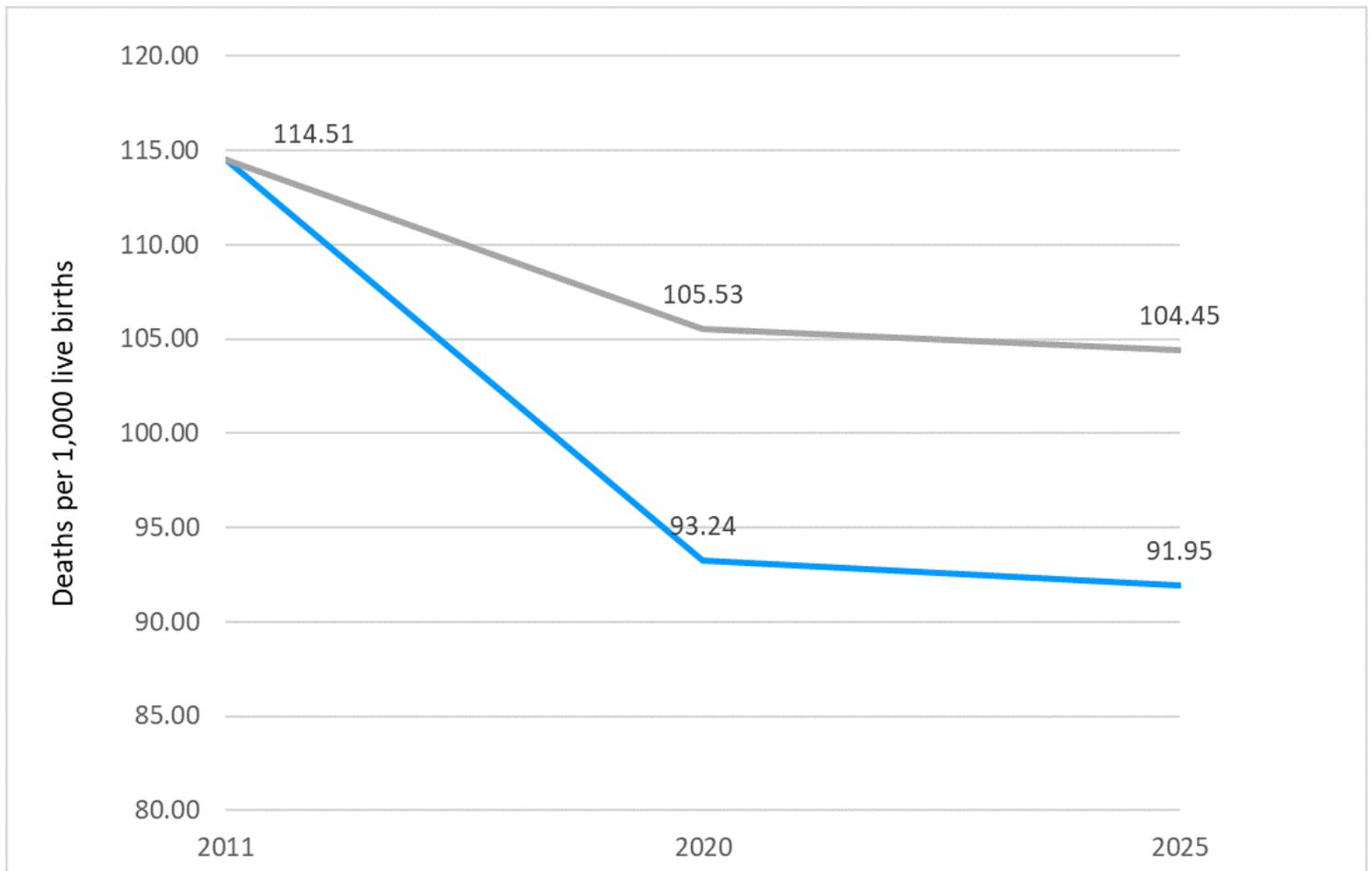


Figure 4

Estimated under-5 mortality rates (per 1,000) with and without LLIN distribution, and universal coverage after 2020 Key to Figure 4. Estimated reductions in all-cause under-5 mortality assuming no LLIN distribution and assuming actual distribution of LLINs from 2011 to 2020 and sustaining universal coverage of LLINs from 2021 to 2025. In 2011, the under-5 mortality rate was estimated at 114.51 per 1,000 live births in both models. However, by 2020, the estimated under-5 mortality rate had dropped to 105.53 per 1,000 in the baseline model (no LLINs), and to 93.24 per 1,000 in the LLIN distribution model. If universal coverage is sustained until 2025, the mortality rate drops marginally to 91.95 per 1,000 by 2025. If no LLINs are distributed, the mortality rate decreases from 105.53 per 1,000 in 2020 to a projected 104.45 per 1,000 in 2025.

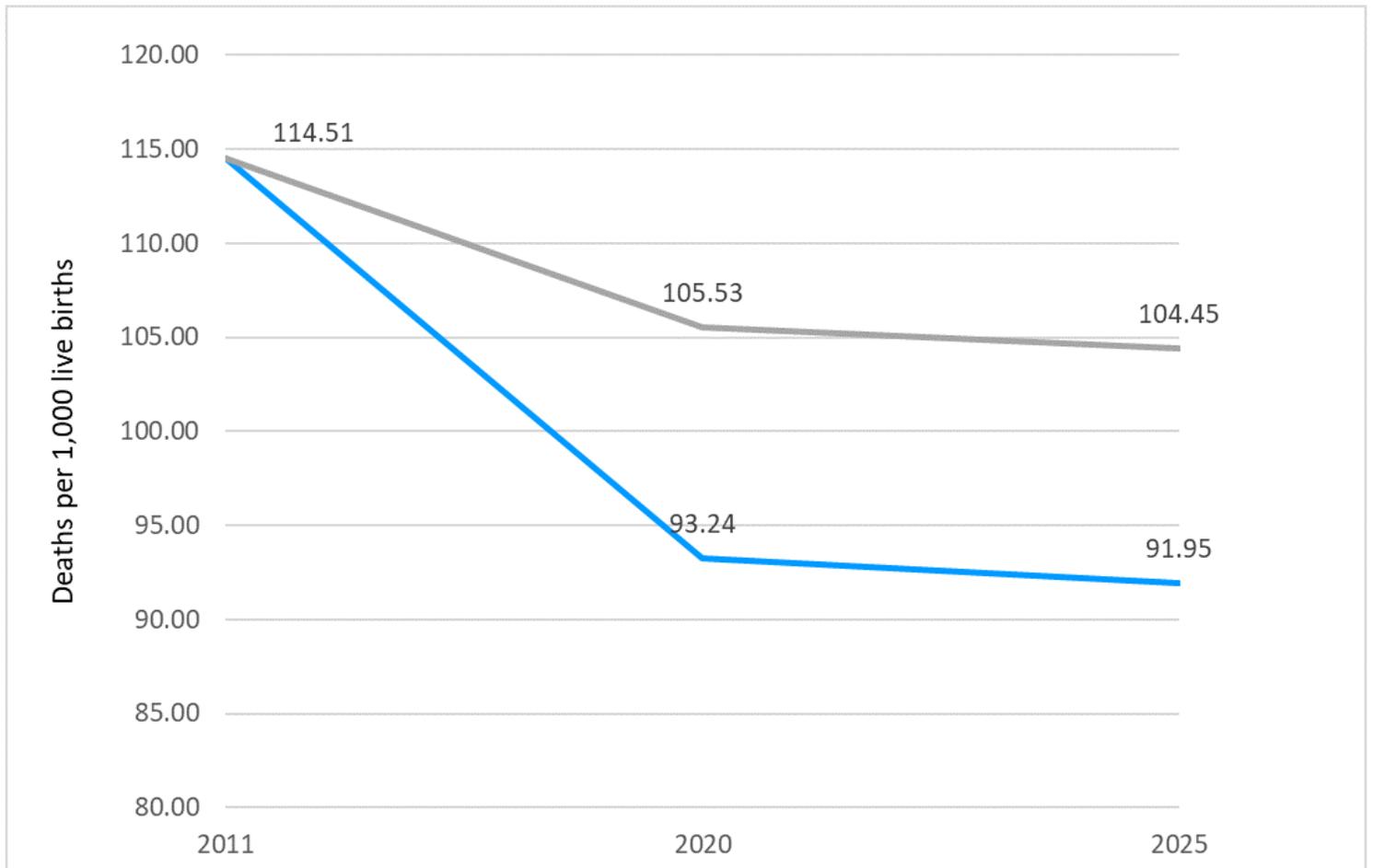


Figure 4

Estimated under-5 mortality rates (per 1,000) with and without LLIN distribution, and universal coverage after 2020 Key to Figure 4. Estimated reductions in all-cause under-5 mortality assuming no LLIN distribution and assuming actual distribution of LLINs from 2011 to 2020 and sustaining universal coverage of LLINs from 2021 to 2025. In 2011, the under-5 mortality rate was estimated at 114.51 per 1,000 live births in both models. However, by 2020, the estimated under-5 mortality rate had dropped to 105.53 per 1,000 in the baseline model (no LLINs), and to 93.24 per 1,000 in the LLIN distribution model. If universal coverage is sustained until 2025, the mortality rate drops marginally to 91.95 per 1,000 by 2025. If no LLINs are distributed, the mortality rate decreases from 105.53 per 1,000 in 2020 to a projected 104.45 per 1,000 in 2025.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [AdditionalFile1.xlsx](#)
- [AdditionalFile1.xlsx](#)
- [AdditionalFile2.xlsx](#)

- [AdditionalFile2.xlsx](#)