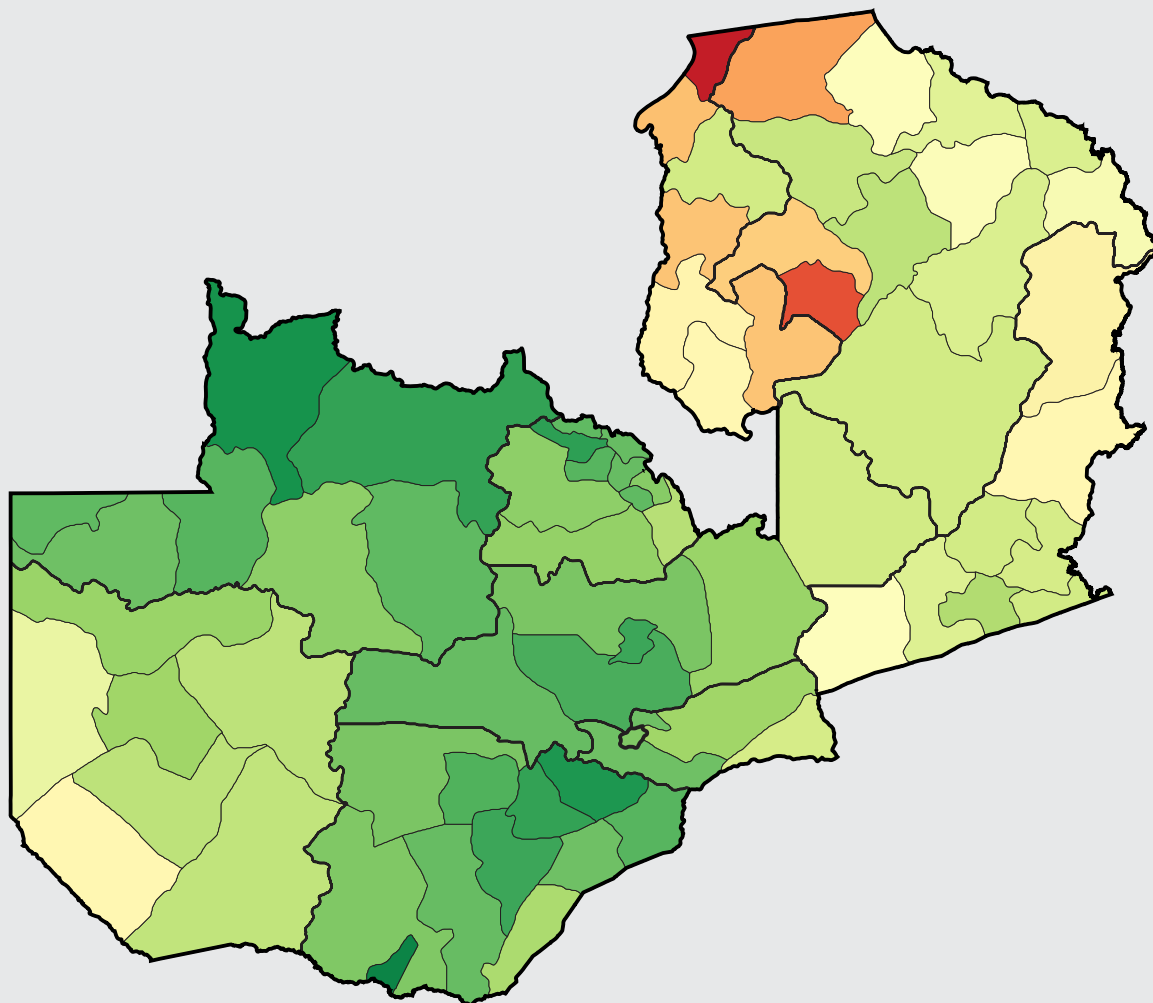Assessing Impact, Improving Health

# Progress in Child Health Across Districts in Zambia

**A REPORT OF THE MCPA PROJECT**



IHME **INSTITUTE FOR HEALTH METRICS AND EVALUATION**
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**UNIVERSITY OF ZAMBIA**

Assessing Impact, Improving Health

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## ABOUT IHME

The Institute for Health Metrics and Evaluation (IHME) is an independent global health research center at the University of Washington that provides rigorous and comparable measurement of the world's most important health problems and evaluates the strategies used to address them. IHME makes this information freely available so that policymakers have the evidence they need to make informed decisions about how to allocate resources to best improve population health.

## ABOUT THIS REPORT

*Assessing Impact, Improving Health: Progress in Child Health Across Districts in Zambia* provides the most up-to-date results from the MCPA project in Zambia, including district-level trends for a range of indicators and the impact of malaria control and other child health interventions on under-5 mortality. This report expands upon the 2011 report produced by IHME and the University of Zambia (UNZA), *Maternal and Child Health Intervention Coverage in Zambia: the Heterogeneous Picture*.

The MCPA project was led by Emmanuela Gakidou at IHME and Felix Masiye at UNZA. Data collation was primarily con-ducted by Peter Hangoma and Peter Mulenga, researchers at the Department of Economics at UNZA, and Frank Kukunga at the Central Statistical Office (CSO). Trends in under-5 mortality were produced by Laura Dwyer-Lindgren at IHME, with contributions from Casey Olives of the University of Washington. At IHME, intervention coverage analyses were conducted by K. Ellicott Colson, with contributions from Laura Dwyer-Lindgren, Tom Achoki, Nancy Fullman, and Matthew Schneider (now at USAID). The causal attribution analysis was performed by Marie Ng and K. Ellicott Colson. This report was written by Nancy Fullman, with contributions from William Heisel.

## ACKNOWLEDGMENTS

# Acronyms

| | |
|---|---|
| **AIDS** | Acquired immunodeficiency syndrome |
| **ANC4** | Antenatal care, a minimum of four visits |
| **BCG** | Bacillus Calmette-Guérin vaccine |
| **CSO** | Central Statistical Office |
| **DPT3** | Diphtheria-pertussis-tetanus vaccine (three doses) |
| **GPR** | Gaussian Process Regression |
| **HIV** | Human immunodeficiency virus |
| **IHME** | Institute for Health Metrics and Evaluation |
| **IPTp2** | Intermittent preventive therapy in pregnancy, a minimum of two doses |
| **IRS** | Indoor residual spraying |
| **ITN** | Insecticide-treated net |
| **JICA** | Japan International Cooperation Agency |
| **MCPA** | Malaria Control Policy Assessment |
| **MOH** | Ministry of Health |
| **MSL** | Medical Stores Limited |
| **NMCC** | National Malaria Control Centre |
| **PCA** | Principal component analysis |
| **PMTCT** | Prevention of mother-to-child transmission of HIV |
| **SBA** | Skilled birth attendance |
| **UNZA** | University of Zambia |

# Terms and definitions

**All-cause under-5 mortality:**
the probability (expressed as the rate per 1,000 live births) that children born alive will die before reaching the age of 5 years

**Antenatal care (ANC4) coverage:**
the proportion of women 15 to 49 years old who had four or more antenatal visits at a health facility during pregnancy

**BCG immunization coverage:**
the proportion of children under 5 years old who have been vaccinated against tuberculosis

**Childhood underweight:**
the proportion of children under 5 years old who are two or more standard deviations below the international anthropometric reference population median of weight for age

**DPT3 coverage:**
the proportion of children 12 to 59 months old who have received three doses of the diphtheria-pertussis-tetanus (DPT) vaccine

**Exclusive breastfeeding coverage:**
the proportion of children who were exclusively breastfed during their first six months after birth

**Indoor residual spraying coverage:**
the proportion of households that were sprayed with an insecticide-based solution in the last 12 months

**Insecticide-treated net (ITN):**
a net treated with an insecticide-based solution that is used for protection against mosquitos that can carry malaria

**Intermittent preventive therapy in pregnancy, two doses (IPTp2):**
the proportion of pregnant women who received at least two treatment doses of Fansidar (sulfadoxine/pyrimethamine) at antenatal care visits during pregnancy

**Intervention coverage:**
the proportion of individuals or households who received an intervention that they needed

**ITN ownership:**
the proportion of households that own at least one ITN

**ITN use by children under 5:**
the proportion of children under 5 years old who slept under an ITN the previous night, as reported by household heads

**Measles immunization coverage:**
the proportion of children 12 to 59 months old who have received measles vaccination

**Pentavalent immunization coverage:**
the proportion of children 12 to 59 months old who have received the pentavalent vaccine, which includes protection against diphtheria-pertussis-tetanus (DPT), hepatitis B, and *Haemophilus influenzae* type b

**Polio immunization coverage:**
the proportion of children 12 to 59 months old who have received three doses of the oral polio vaccine

**Prevention of mother-to-child transmission of HIV (PMTCT):**
the receipt of antiretroviral drugs as prophylaxis to reduce the risk of mother-to-child transmission of HIV among HIV-positive pregnant women

**Skilled birth attendance coverage:**
the proportion of pregnant women 15 to 49 years old who delivered with a skilled birth attendant (a doctor, nurse, midwife, or clinical officer)

# Executive summary

Zambia has seen remarkable improvement in childhood survival over the past two decades. While the scale-up of malaria control interventions has been proposed as one of the biggest drivers behind that improvement, little research has been done on how much of the reduction in childhood mortality may be attributed to malaria control and how much is the result of improvements in other child health interventions. To address this knowledge gap, the University of Zambia (UNZA) and the Institute for Health Metrics and Evaluation (IHME) worked together on the Malaria Control Policy Assessment (MCPA) project. The goal of MCPA was to harness existing data in Zambia and use rigorous statistical methods to quantify the impact of malaria control and other child health interventions on under-5 mortality trends across districts.

We found that between 1990 and 2010, a combination of rapidly scaled up child health interventions contributed to an additional 11% of declines in under-5 mortality across Zambia. We looked at the combined effect of these interventions because the scale-up in ownership of insecticide-treated nets (ITNs) and use of indoor residual spraying (IRS) coincided with the scale-up in three other key child health interventions: the pentavalent vaccine, exclusive breastfeeding, and services to help prevent mother-to-child transmission of HIV (PMTCT) at health facilities. Isolating the specific impact of each intervention is not possible. Nevertheless, jointly, these interventions contributed significantly to the reduction of under-5 mortality throughout the country.

The MCPA project in Zambia produced district-level trends for key child health outcomes and interventions from 1990 to 2010. This is the first time that annual estimates for under-5 mortality and intervention coverage have been generated at the district level. In this report, district profiles detail trends in child health over time and benchmark the districts' performance across indicators. With this information, local and national policymakers and health officials can identify areas of successful health service delivery and detect early signs of declining intervention coverage or stalled progress.

This report shows that Zambia is succeeding on several fronts in child health. First, countrywide reductions in under-5 mortality were also accompanied by improvements in equity across districts, as some of the districts with the highest mortality rates in 1990 recorded some of the greatest declines by 2010. Second, coverage of key malaria control interventions, such as ITN ownership, increased dramatically in many districts. Third, the majority of districts were successful in quickly increasing coverage of the pentavalent vaccine after its introduction in 2005. Finally, rates of exclusive breastfeeding markedly rose in most districts, reflecting the country's investments in improving child nutrition and breastfeeding practices (WBTi 2008).

These successes were accompanied by concerning trends for three key child health interventions in Zambia. First, most districts saw a decline in the 2000s in antenatal care (ANC4), which is the proportion of pregnant women 15 to 49 years old who had four or more visits to a health facility during pregnancy. This finding is particularly worrisome given that districts generally increased levels of ANC4 during the 1990s. Second, coverage of polio immunization dropped in some of the districts that are considered at high risk for polio importation from neighboring countries. Third, in some areas of Zambia, skilled birth attendance declined to very low levels. Targeting these areas for improvement should be a priority to ensure that the country's achievements in child health continue into the present decade.

With a focus on districts, findings from the MCPA project in Zambia provide side-by-side comparisons of health performance over time, geography, and intervention type. The child health landscape is remarkably heterogeneous across districts, highlighting the need for continuous and timely assessment of district-level trends. With regularly collected and analyzed district health information, policymakers can have the evidence base to make targeted, data-driven decisions for achieving greater and more equitable health gains in Zambia.

# Introduction

Over the past decade, Zambia's child health and development landscape has been substantially reshaped by new programs, interventions, and priorities, including extensive malaria control programs. In order to fully understand what has contributed to Zambia's progress in under-5 mortality, it is important to comprehensively account for all efforts to improve child health.

The MCPA project in Zambia had two main objectives:

1) Determine what proportion of the decline in all-cause under-5 mortality in Zambia was attributable to the scale-up of malaria control interventions, while accounting for a range of other key child health interventions and non-health factors.

2) Assess this impact at the district level between 1990 and 2010.

In order to achieve these objectives, annual estimates of district-level trends from 1990 to 2010 were systematically generated for each of the 72 districts in Zambia and across a range of key child health outcomes and interventions. Detailed descriptions of the findings for each district are presented in this report. District-level data can be downloaded from IHME's Global Health Data Exchange: http://ghdx. healthmetricsandevaluation.org/.

The MCPA project sought to use all available data sources, which are presented in Table 1. These analyses aimed to make full use of the best available data in Zambia. Provincial estimates of under-5 mortality and intervention coverage were previously available, but for the first time district-level trends were derived from these data sources using robust statistical methods. Annex 1 provides an overview of the analytical approach used to generate the estimates in this report.

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**BOX 1**

## MAIN FINDINGS FROM THE MCPA PROJECT IN ZAMBIA

▶ Under-5 mortality substantially declined throughout Zambia from 1990 to 2010. Some of the greatest progress was recorded in districts with the highest levels of under-5 mortality in 1990.

▶ Coverage of malaria control interventions rapidly increased, especially between 2005 and 2010. These gains in coverage were observed throughout Zambia.

▶ At the same time malaria interventions were scaled up, Zambia also successfully increased levels of coverage for three non-malaria child health interventions: the pentavalent vaccine, exclusive breastfeeding, and the availability of PMTCT services at health facilities.

▶ Together, these rapidly scaled up interventions were responsible for an 11% reduction in the under-5 mortality rate from 2000 to 2010. Sustaining high coverage of these interventions is critical for child health in Zambia.

▶ Amidst the country's health successes, some worrisome trends emerged that warrant attention. Most districts saw sharp declines in antenatal care visits during the 2000s, and skilled birth attendance fell to very low levels in several places. Others experienced a minimal scale-up of the pentavalent vaccine, and some of the high-risk districts for polio importation recorded drops in polio immunization coverage. Addressing these gaps in health service provision is crucial to maintaining the country's gains in child health.

**Table 1. Data sources used in the MCPA project**

| DATA SOURCE | YEARS REPRESENTED |
| --- | --- |
| **SURVEYS** | |
| Demographic and Health Survey (DHS) | 1992, 1996-1997, 2001-2002, 2007 |
| Malaria Indicator Survey (MIS) | 2006, 2008, 2010, 2012 |
| Multiple Indicator Cluster Survey (MICS) | 1999 |
| Living Conditions Monitoring Survey (LCMS) | 1996, 1998, 2002-2003, 2004-2005, 2006, 2010 |
| Health Facility Census | Japan International Cooperation Agency (JICA) (2005-2006) |
| Sexual Behavior Survey (SBS) | 2005, 2009 |
| Household Health Coverage Survey | 2008 |
| Netmark Survey reports | 2000, 2004 |
| **POPULATION CENSUSES** | |
| National census | 1990, 2000, 2010 |
| **ADMINISTRATIVE SOURCES** | |
| Health Management Information System (HMIS) | 2000-2008; 2009 |
| Malaria intervention databases | National Malaria Control Centre (NMCC) (2005-2010) |
| Facility-level PMTCT services | National AIDS Council quarterly status report (2005-2009) |
| HIV/AIDS projections | Central Statistical Office (CSO) (2005) |
| Drug supply and delivery records | Medical Stores Limited (MSL) (2007-2010) |
| Precipitation data | Global Precipitation Climatology Centre (1986-2012) |
| Malaria endemicity ($PfPR_{2-10}$) | Malaria Atlas Project (2007, 2010) |

An earlier version of this report was published in 2011, *Maternal and Child Health Intervention Coverage in Zambia: the Heterogeneous Picture*, and focused on intervention coverage trends between 1990 and 2010. The present report provides a broader range of updated results, including under-5 mortality and coverage of the pentavalent vaccine, and drills deeper into Zambia's trends in child health at the district level. Further, the present report quantifies the contribution of malaria control and other key child health interventions to Zambia's reductions in under-5 mortality.

# Main findings

## Under-5 mortality declines observed across districts, accompanied by reductions in inequities

Zambia made substantial progress in improving child survival between 1990 and 2010. At the national level, all-cause under-5 mortality decreased by 37%, from 174 deaths per 1,000 live births in 1990 (95% CI: 168, 181) to 109 in 2010 (95% CI: 104, 116). All districts saw reductions in their levels of under-5 mortality during this time. Moreover, many of the districts with the highest levels of under-5 mortality in 1990 showed the greatest declines by 2010. Figure 1 depicts how the range in under-5 mortality across districts has become narrower.

In 1990, levels of under-5 mortality spanned from 125 deaths per 1,000 live births (95% CI: 97, 161) to 276 (95% CI: 220,338) in different districts. Twenty years later, this gap substantially tightened, with a range of 83 deaths per 1,000 live births (95% CI: 60, 113) to 150 (95% CI: 109, 203). The difference between the district with the highest level of under-5 mortality and the lowest was more than halved from 1990 to 2010 (dropping from a difference of 151 to 67), illustrating how Zambia's progress in reducing under-5 mortality was also associated with decreased health inequities across districts.

Despite these improvements, it is worth noting that some districts and regions documented less progress. Districts in Northern province had very high levels of under-5 mortality in 1990, and though many recorded large declines, their rates still remained among the highest in the country in 2010 (greater than 120 deaths per 1,000 live births). Additional efforts to reduce under-5 mortality need to be prioritized in these districts.

## Malaria interventions are rapidly scaled up in Zambia, but most districts fall short of national targets

Coverage of malaria interventions greatly increased through-

out Zambia after 2000, with most of the gains occurring since 2005. Nationally, the proportion of households that either owned at least one ITN or received IRS increased from 8% in 2000 to 37% in 2005 and then rapidly climbed to 71% in 2010. Coverage of intermittent preventive therapy in pregnancy (IPTp2) quickly rose from 16% in 2002 to around 70% in 2008.

In the early 2000s, coverage of malaria control interventions was very low throughout Zambia, with only a few districts benefiting from ITN pilot programs and early implementation of IRS. By 2010, however, all districts had coverage levels exceeding 55% for having either ITNs or IRS. Figure 2 shows the rise in coverage of malaria control from 2000 to 2010.

Districts saw a wide variety of trends in IPTp2 coverage during the 2000s. IPTp2 levels rose rapidly in many districts throughout the 2000s. Others saw an increase in coverage and then a leveling off by 2010. A third group of districts experienced substantial declines in coverage during the late 2000s. Last, a subset of districts recorded very small changes in IPTp2 coverage during this period.

Zambia's *National Malaria Strategic Plan, 2006-2010* set several malaria intervention coverage targets to achieve by 2010, including (1) ≥ 80% of households with at least three ITNs; (2) ≥ 85% of eligible households in 15 target districts having received IRS; (3) ≥ 80% of pregnant women receiving ≥ 2 doses of Fansidar/SP (IPTp2); and (4) ≥ 80% of children under 5 years old sleeping under an ITN or residing in a house with IRS (MOH 2006). These targets were very ambitious, and despite marked progress since 2000, no district achieved all four targets in 2010. Only five districts reached two of the four targets. Table 2 displays the 28 districts that met one or more of these targets in 2010. The target that was most frequently met was the third target, with 16 districts achieving at least 80% IPTp2 coverage in 2010.

**Figure 1. District-level estimates of all-cause under-5 mortality for 1990, 2000, and 2010**
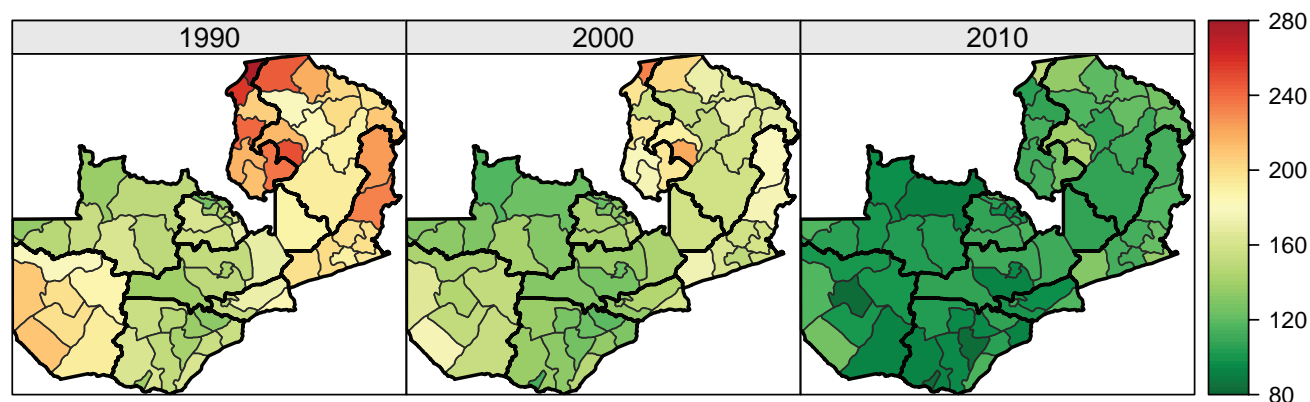
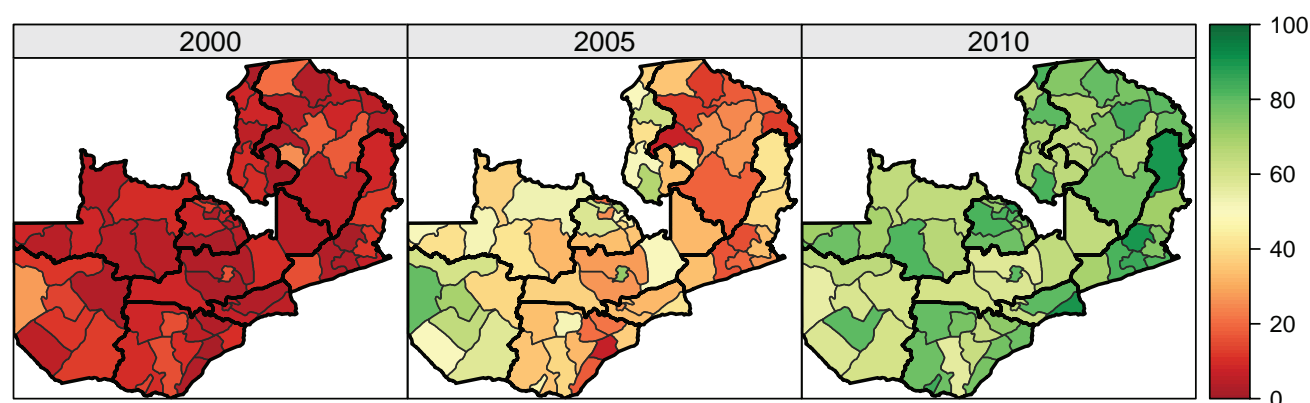**Figure 2. Percentage of households covered by an ITN, IRS, or both interventions, in 2000, 2005, and 2010**



**Table 2. District attainment of 2010 malaria intervention targets**

| GEOGRAPHY | | MALARIA INTERVENTION TARGETS | | | |
| --- | --- | --- | --- | --- | --- |
| **PROVINCE** | **DISTRICT** | **OWNERSHIP OF ≥ 1 ITN*** | **IRS COVERAGE**** | **IPTP, ≥ 2 DOSES** | **UNDER-5 ITN USE OR IRS** |
| Central | Kabwe | | | 81% | |
| | Mkushi | | | 92% | |
| Copperbelt | Chingola | | | 93% | |
| | Kalulushi | | | | 83% |
| | Kitwe | | | 87% | 81% |
| | Lufwanyama | | | 91% | |
| | Masaiti | | | 89% | |
| | Mpongwe | | | 89% | |
| | Mufulira | | | 80% | 85% |
| | Ndola | | | 94% | |
| Eastern | Chadiza | 81% | | 81% | |
| | Chama | 90% | | | |
| | Katete | 85% | | | 81% |
| | Mambwe | 90% | | | 89% |
| | Petauke | | | | 80% |
| Luapula | Chiengi | 80% | | | |
| | Milenge | 80% | | | |
| Lusaka | Chongwe | | | 87% | |
| | Kafue | | | 90% | |
| | Luangwa | 89% | | | |
| North-western | Mufumbwe | 82% | | | |
| Northern | Mpulungu | | | 87% | |
| | Mungwi | 84% | | | |
| | Nakonde | 81% | | | |
| Southern | Livingstone | | | | 90% |
| Western | Lukulu | | | 96% | |
| | Mongu | | | 89% | |
| | Senanga | | | 88% | |

*Notes:*

\* The NMCC goal was ownership of at least three ITNs by 2010.

\*\* The NMCC goal was 85% coverage of eligible households by 2010. Based on MCPA analyses, no district reached 85% IRS coverage; however, household eligibility could not be ascertained.

## Scale-up of the pentavalent vaccine varies, polio immunization falls in some areas

Just looking at the national level, trends in immunization coverage generally point to progress. But at the district level, we see a wide range of trends, with progress, stagnation, and troubling declines in coverage.

The pentavalent vaccine was formally introduced in Zambia in 2005, and the country achieved 67% coverage in 2010. At the district level, coverage of the pentavalent vaccine ranged from as low as 22% (95% CI: 8%, 44%) to as high as 90% (95% CI: 81%, 96%) in 2010, with some districts showing strong progress since 2005 and others showing minimal gains in coverage. Figure 3 depicts this range for pentavalent coverage in 2010. Many of the largest gains were observed in Eastern province, while several districts in North-western province continued to have some of the lowest levels of pentavalent coverage in 2010. Identifying how to improve the delivery or uptake of the pentavalent vaccine for these districts ought to be a priority.

In 2010, polio immunization coverage reached 81% at the national level. However, coverage varied greatly across districts, ranging from 24% (95% CI: 10%, 42%) to 99% (95% CI: 98%, 100%). Zambia's polio-free certification was accepted in 2005, but several districts that border the Democratic Republic of Congo (DRC) and Angola are considered at high risk for polio importation from these countries (WHO 2011). Some of these high-risk districts recorded declining coverage of polio immunization during the 2000s and had some of the lowest levels of coverage in Zambia in 2010. If Zambia is to optimally protect itself from imported polio, deliberate efforts are needed to ensure that levels of polio immunization are sustained at high levels in high-risk areas.

**Figure 3. The proportion of children who received the pentavalent vaccine in 2010**
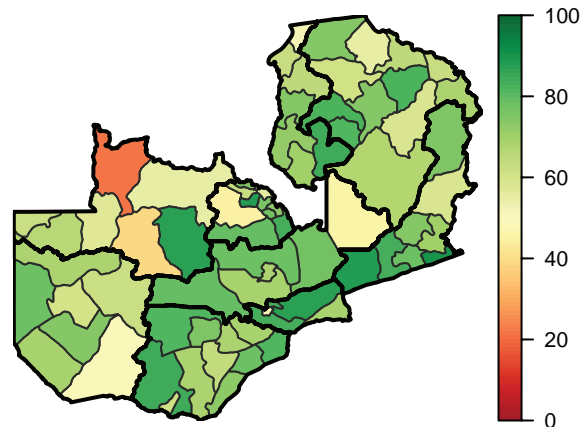


## Coverage of antenatal care substantial declined while skilled birth attendance gradually increased

After maintaining moderately high levels of ANC4 through the 1990s, coverage in Zambia declined during the 2000s, dropping to 37% in 2010. At the same time, skilled birth attendance (SBA) coverage gradually increased, rising to 55% in 2010.

For most districts, ANC4 coverage reached its highest levels between 1990 and 2000, after which coverage markedly fell. Figure 4 shows ANC4 coverage in most districts dropping from higher levels (green) to much lower ones (shades of orange to red). Understanding why so many districts experienced such sharp declines in antenatal care should be a high priority in Zambia. It is important to note that a few districts did increase ANC4 coverage during this time. It is likely that much could be learned from these districts about approaches to ANC4 provision and support of health-seeking behaviors.

Trends in SBA coverage widely varied across districts, as did the range in levels of coverage throughout the country. In 2010, SBA coverage ranged from less than 1% to 98% (95% CI: 91%, 100%). About five districts had very low levels of SBA

**Figure 4. Coverage of four or more antenatal care visits (ANC4) in 2000, 2005, and 2010**
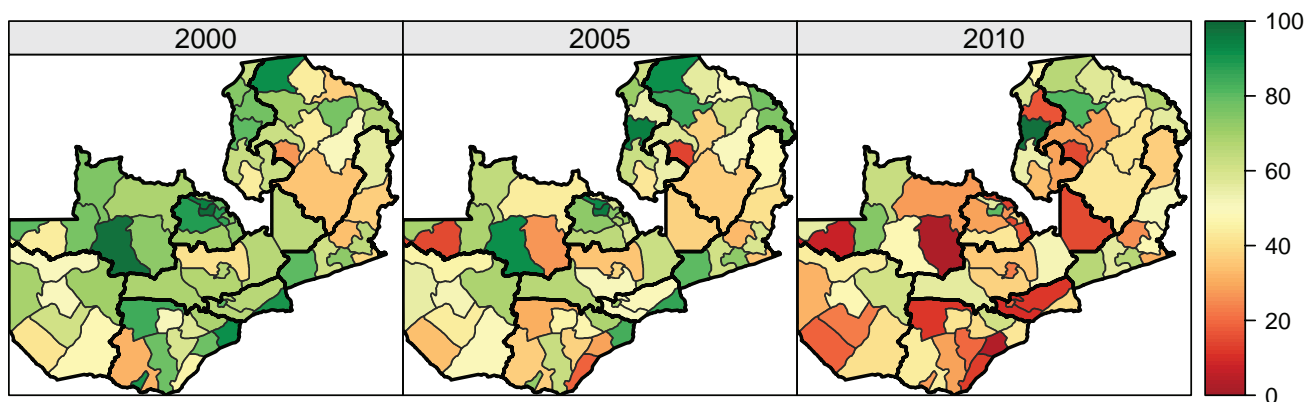
during the 1990s but then brought coverage to above the national average in 2010. Approximately 10 recorded steady gains in SBA during the 1990s before sharply falling to levels below 20%. A number of districts had consistently low levels over the two decades, while a few maintained high coverage. Zambia would likely benefit from further investigation into the district's differences in skilled birth attendance trends, especially to determine ways to improve coverage in places where SBA appears to be minimal.

### Breastfeeding increased to high levels

Rates of exclusive breastfeeding rose steadily throughout the 1990s and 2000s before reaching 80% nationally in 2010. Most districts followed this trend, but there were some notable exceptions. Some districts experienced an earlier scale-up of exclusive breastfeeding, recording their highest levels in the early 2000s, but saw coverage quickly decline by 2010. A few districts, mostly in Eastern province, consistently trailed the national scale-up of exclusive breastfeeding, barely reaching 60% in 2010.

### Rapid scale-up of key child health interventions contributes to declines in under-5 mortality

To assess the impact of malaria control on under-5 mortality in Zambia, the MCPA research team conducted a causal attribution analysis that included a full range of child health interventions and non-health factors. More details on the methods and statistical models used can be found in Annex 1.

The team found that Zambia had scaled up several interventions at the same time. Figure 5 shows how gains in ITN and IRS coverage coincided with rising levels of the pentavalent vaccine, exclusive breastfeeding, and the availability of PMTCT in health facilities. It was statistically impossible to tease out the individual effects of these interventions on under-5 mortality. Instead, researchers created a composite indicator of "rapidly scaled up interventions."

### Figure 5. The scale-up of malaria control interventions and a subset of key child health interventions



* Children under 1 year old
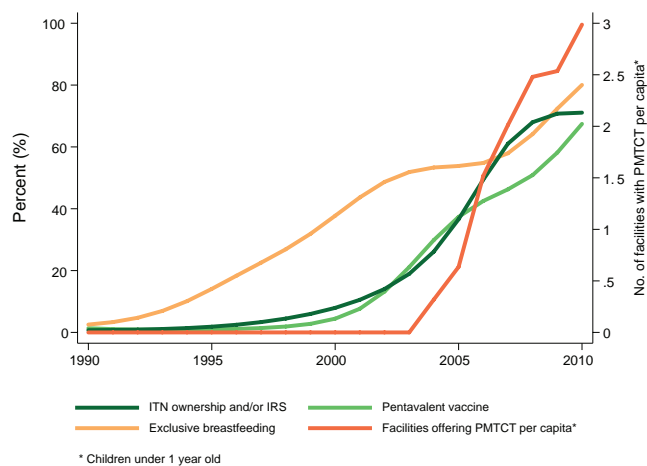
After accounting for other factors (including socioeconomic indicators), rapidly scaled up interventions were significantly associated with Zambia's reductions in all-cause under-5 mortality. If the coverage of these interventions had remained at levels observed in 2000, under-5 mortality would have been 11% higher in 2010 (124 deaths per 1,000 live births (95% CI: 118, 129)) than what was actually observed for that year (109 deaths per 1,000 live births (95% CI: 104, 116)) (Figure 6).

### Figure 6. Trends in under-5 mortality as observed and predicted in the absence of rapidly scaled up interventions, 1990-2010
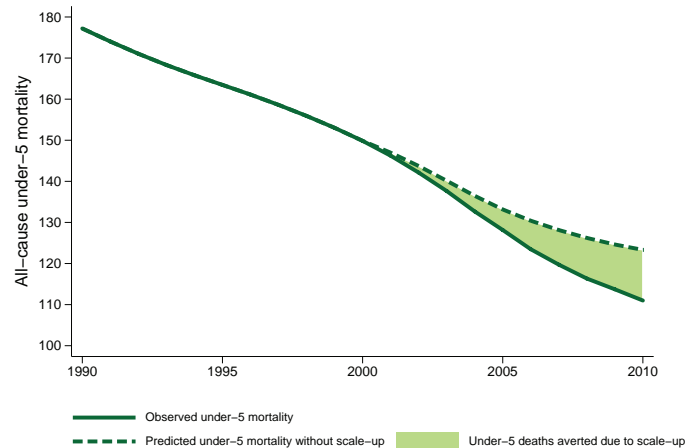


This finding suggests that the rapid scale-up of these five maternal and child health interventions hastened the decline of under-5 mortality by 1% per year. It is important to note that under-5 mortality rates would have continued to decline in Zambia between 2000 and 2010, even without the scale-up of these interventions. In fact, under-5 mortality decreased 14% between 1990 and 2000, dropping from 174 deaths per 1,000 live births (95% CI: 168, 181) to 149 in 2000 (95% CI: 144, 156). Given the declines that Zambia experienced in under-5 mortality from 1990 to 2000, we would have predicted an 18% decrease in under-5 mortality between 2000 and 2010. Instead, with the scale-up of these five interventions, the country recorded a 26% decline during this time. In other words, the simultaneous scale-up of ITNs, IRS, the pentavalent vaccine, exclusive breastfeeding, and PMTCT services accelerated the declines in under-5 mortality by an additional 1% per year.

# Conclusions and policy implications

Between 1990 and 2010, the health landscape in Zambia markedly changed, and for the most part, these changes reflect progress and service delivery success throughout the country. Under-5 mortality substantially decreased at the national level, and the gap between districts with the highest and lowest under-5 mortality substantially decreased. These declines in under-5 mortality can be tied to Zambia's successful efforts in expanding coverage for a subset of child health interventions: ITN ownership, IRS, the pentavalent vaccine, exclusive breastfeeding, and the availability of PMTCT services. These five interventions were rapidly scaled up during the 2000s and jointly contributed to an additional 11% reduction in all-cause under-5 mortality in Zambia beyond what would have been expected based on the country's trends in under-5 mortality during the 1990s. The scale-up of malaria control has been a key part of Zambia's improved health service environment, and sustaining high levels of malaria control interventions, alongside other life-saving interventions, is of critical importance.

Amidst these successes, IHME and UNZA identified some troubling trends that warrant further policy attention. Overall, the proportion of pregnant women who sought at least four antenatal care visits drastically decreased between 2000 and 2010. Several districts recorded levels of ANC4 below 20% in 2010, which suggests that a vast majority of women in these places do not receive optimal antenatal care during pregnancy. Knowing that antenatal care services are closely linked to better maternal and child health outcomes (WHO 2003), Zambia should address these declining trends in ANC4.

Immunization rates remained at least moderately high at the national level, but some districts showed concerning declines for certain vaccines, namely polio, and fell behind in the scale-up of the pentavalent vaccine. A number of districts that are considered at risk for polio importation from the DRC and Angola recorded recent declines in immunization coverage. Several districts showed minimal gains in coverage of the pentavalent vaccine, falling well below the national average in 2010. Prioritizing the acceleration of pentavalent coverage in districts lagging behind the national trend should be considered.

Zambia's new malaria strategic plan maps out an ambitious goal toward a "malaria-free Zambia" (MOH 2011), for which universal coverage of ITNs or IRS and increasing IPTp from two to three doses (IPTp2 to IPTp3) are new intervention targets for 2015. Given that fewer than half of Zambia's districts achieved at least one of the malaria intervention coverage targets for 2010, the country may need to consider strategies to further expand and sustain higher levels of malaria intervention coverage in order to meet its 2015 goals.

As demonstrated through the MCPA project in Zambia, national trends can mask significant differences at the district level. The district profiles included in this report provide a data-driven foundation for benchmarking district performance and targeting areas for improvement. It is important for governments to prioritize monitoring and data gathering at the district level to make future analyses more robust and to provide critical inputs for decision-making and priority-setting by district health offices.

To maintain and further accelerate the health gains Zambia has made in child survival, continued efforts dedicated to delivering a range of health interventions, including malaria control, are needed. The regular and timely collection of district health data will be crucial for guiding policy decisions and resource allocation. The country's investments in nationwide surveys served as the cornerstone for the analyses in this report, and they are likely to remain a vital source of health data alongside Zambia's health information systems. By using its district-level data and focusing on health gaps experienced by its districts, Zambia is in the position to further accelerate progress in childhood survival and to promote greater equality in health attainment throughout the country.

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# Annex 1. Overview of the MCPA analytical approach and methods

In order to comprehensively assess the impact of malaria control on under-5 mortality in a data-driven, systematic way, the MCPA research team's methodological framework took place in three main steps:

**(1) Collating data and generating source-specific estimates.** The MCPA research team brought together a broad range of data sources, including surveys, population censuses, and administrative sources, to generate source-specific estimates for all indicators of interest. In total, 20 household surveys, one health facility census, three population censuses, and two administrative sources (National Malaria Control Centre indoor residual spraying database and facility PMTCT services from the National AIDS Council) were included in the final analysis.

**(2) Estimating trends for 72 districts from 1990 to 2010.** Given the range of data types assembled for the MCPA project, statistical modeling approaches had to be used in order to synthesize the estimates from these different data sources into a unified trend. Demographic methods for analyzing birth history data were combined with small area estimation modeling to generate district-level trends for all-cause under-5 mortality. A two-step method involving spatio-temporal smoothing and Gaussian Process Regression (GPR) was used to produce district-level trends for intervention coverage and non-health indicators.

**(3) Conducting causal attribution analyses.** Many models and combinations of covariates were rigorously tested in order to identify the most robust and valid model for assessing the relationship between declines in mortality and individual health interventions and non-health indicators. The types of models that were explored included single- and multistage linear models, lasso, functional data analysis, first differences, differences-in-differences, structural equations modeling, and factor analysis. The model that was ultimately selected is a linear model with bootstrapping, as it better accounts for autocorrelation over years and districts. The list of covariates that were explored included rainfall levels, fertility, birth spacing, maternal education, school attendance among teenagers, female headship of households, mean household size, household sanitation, prevalence of improved sources of cooking fuel, prevalence of improved wall type in homes, electricity, immunization coverage, and coverage of malaria and maternal and child health interventions described in the main text of this report. Covariates that were not included because of lack of data availability include coverage of malaria treatment for children with fever, coverage of antibiotic treatment for children with pneumonia, coverage of oral rehydration treatment for children with diarrhea, coverage of pediatric HIV treatment, quality of district health office management, district health expenditures and health personnel, access to health facilities, malaria transmission intensity over time and by district, and nutritional interventions.

The MCPA research team found that it was statistically impossible to tease out the impact of malaria control interventions from other interventions that also experienced large gains in coverage during the 2000s. Instead, principal component analysis (PCA) was used to bundle these rapidly scaled-up interventions — malaria control, exclusive breastfeeding, facilities offering PMTCT per population under 1 year old, and coverage of the pentavalent vaccine — into a composite indicator. The final model estimates the joint effect of these interventions on under-5 mortality:

$$
\begin{aligned}
\ln(_5q_0)_{ij} = {} & \beta_0 + \beta_1 Scaled_{ij} + \beta_2 SES_{ij} + \beta_3 Und_{ij} \\
& + \beta_4 SES_{ij} * Scaled_{ij} + \beta_5 SES_{ij} * Und_{ij} + \beta_6 ANC1_{ij} \\
& + \beta_7 DPT3_{ij} + \beta_8 Meas_{ij} + \beta_9 Year_i + \mu_{k[j]} + \varepsilon_{ij}
\end{aligned}
$$

The final model was a linear model with bootstrapping, where for each district $j$, province $k$, and year $i$, $\ln(_5q_0)$ is the natural logarithm of the under-5 mortality rate, $\beta_0$ is the intercept, *Scaled* is the composite indicator for rapidly scaled up interventions, and *SES* is the composite measure for non-health factors. *Und* is the proportion of children who are underweight, *SES* ∗ *Scaled* is an interaction between the non-health factor composite measure and the composite indicator for rapidly scaled up interventions, *SES* ∗ *Und* is an interaction between the non-health factor composite measure and the proportion of children who are underweight, *ANC1* is coverage of one antenatal care visit, *DPT3* is coverage of three doses of DPT, *Meas* is coverage of one dose of the measles vaccine, *Year* is the corresponding year, $\mu_{k[j]}$ is a random effect on province $k$ to which $j$ belongs, and $\varepsilon_{ij}$ is the error term.

# District profiles

Tracking trends in child health outcomes and intervention coverage at the district level provides timely, useful, and actionable information to national and local policymakers in Zambia.

The district profiles are ordered alphabetically within each province. Each profile provides a "child health barometer" for 2010, which compares a given district's performance on key child health outcomes and interventions to the national average and the range observed across districts. Further, each profile details trends observed for each group of interventions: malaria interventions, immunizations, and other maternal and child health interventions.

These district profiles aim to provide a foundation from which local health officials can assess their districts' child health status and then target high-priority areas for improvement. Individual profiles can be downloaded from IHME's Global Health Data Exchange: http://ghdx.healthmetricsandevaluation.org/.