Epidemiology and control profile of malaria in

Mozambique

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Abbreviations

ACT	Artemisinin-based Combination Therapy
AL	Artemether-Lumefantrine
ANC	Ante-Natal Clinic
APE	*Agentes Polivalentes Elementares* – Community Health Workers
AQ	Amodiaquine
AQ-SP	Amodiaquine – Sulphadoxine pyrimethamine
AS	Artesunate
AS-SP	Artesunate – Sulphadoxine pyrimethamine
BIC	Bayesian Inference Criterias
CBS	Chromosome Banding Sequence
CDC	Centers for Disease Control
CHAI	Clinton Health Access Initiative
CHW	Community Health Worker (APE)
CISM	*Centro de Investigação em Saúde de Manhiça*
CMAM	*Central de Medicamentos e Artigos Médicos* – Central Medical Stores
CQ	Chloroquine
DCW	Digital Chart of the World's Populated Places
DDT	Dichloro-diphenyl-trichloroethane
DFID	Department for International Development (UK)
DHIS	District Health Information Systems
DHS	Demographic and Health Surveys
DVS	Dominant Vector Species
ESIA	Environmental and Social Impact Assessment
ETM+	Enhanced Thematic Mapper
EVI	Enhanced Vegetation Index
FAO	Food and Agriculture Organization
FEM	Fine Element Method
FORSSAS	*Fortalecimento dos Sistemas de Saúde e Acção Social*
GAUL	Global Administrative Unit Layers
GDP	Gross Domestic Product
GF	Gaussian Field
GFATM	Global Fund to fight AIDS, Tuberculosis and Malaria
GIS	Geographic Information Systems
GLWD	Global Lakes and Wetlands Database
GMP	Global Malaria Programme, WHO Geneva
GMEP	Global Malaria Eradication Programme
GMRF	Gaussian Markov Random Field
GoM	Government of Mozambique
GPS	Global Positioning Systems
GRUMP	Global Rural Urban Mapping Project
HDI	Human Development Index
HFDB	Health facility database
HMIS	Health Management Information System
iCCM	Integrated Community Case Management

INFORM	Information for Malaria Project
INLA	Integrated Nested Laplace Approximations
inSCALE	Innovations at Scale for Community Access and Lasting Effects
IPT	Intermittent Presumptive Treatment
IRS	Indoor Residual Spraying
ITN	Insecticide Treated Nets
JSI	John Snow International
LLINs	Long Lasting Insecticidal Nets
LMIS	Logistics Management Information System
MALTEM	Mozambican Alliance Towards the Elimination of Malaria
MAPE	Mean Absolute Prediction Error
MARA/ARMA	Mapping Malaria Risk in Africa
mASL	Metres Above Sea Level
MBG	Model Based Geostatistics
MDG	Millennium Development Goals
MeSH	Medical Subject Headings
MICS	Malaria Indicator Cluster Survey
MISAU	Ministerio de Saude
MIS	Malaria Indicator Survey
MODIS	MODerate-resolution Imaging Spectroradiometer
MOSASWA	Mozambique, South Africa and Swaziland
MPAC	Malaria Policy Advisory Committee
MPE	Mean Prediction Error
MPR	Malaria Programme Review
MTEF	Medium-Term Expenditure Framework
NFM	New Funding Model
NMCP	National Malaria Control Programme
NMSP	National Malaria Strategic Plan
OA	Open Access
ODA	Overseas Development Assistance
OR	Operational Research
PA*Pf*PR_{2-10}	Population adjusted *Pf*PR_{2-10}
PARP	*Plano de Acção para Redução da Pobreza* – The Poverty Reduction Action Plan
PCR	Polymerase Chain Reaction
PDP	Product Development Partnership
PESS	*Plano Estratégico de Sector da Saúde* – Health Sector Strategic Plan
PfPR_{2-10}	Age-corrected *Plasmodium falciparum* parasite rate
PMI	President's Malaria Initiative
PSI	Population Services International
R&D	Research and Development
RBM	Roll Back Malaria
RDTs	Rapid Diagnostic Tests
SCMS	Supply Chain Management System
SD	Standard Deviations
SNS	*Serviço Nacional de Saúde* – National Health Service
SP	Sulphadoxine-Pyrimethamine

SPA	Service Provision Assessment
SPDE	Stochastic Partial Differential Equations
SRTM	Shuttle Radar Topography Mission
TFR	Total Fertility Rate
TSI	Temperature Suitability Index
U5MR	Under-5 Mortality Rate
UN	United Nations
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
US	*Unidad Sanitaria* – Health Unit
USD	United States Dollar
USG	United States Government
USAID	United States Agency for International Development
WHO	World Health Organization

1. Introduction

The use of malariometric data, maps and epidemiological intelligence was a routine feature of control planning across most African countries during the Global Malaria Eradication Programme (GMEP) era from the mid-1950s. Data included epidemiological descriptions of transmission, vectors, topography and climate. More than 50 years ago the infection prevalence among children aged 2-10 years ($Pf PR_{2-10}$) was recognised as one important source of planning data and was used to define categories of endemic risk. These were then used to guide and monitor progress towards malaria elimination targets.

The art and skills necessary to design malaria control based on an understanding of the spatial epidemiology was lost during the 1970s when the malaria agenda fell under a less specialised, integrated primary care mandate focused on managing fevers. In 1996, a plea was made for better malaria cartography to guide malaria control in Africa (Snow et al., 1996; Snow and Noor, 2015) and over the last decade there has been enormous growth in spatial data on malaria and populations. Sixty years ago, this was not available to malariologists or programme control managers. The growth in data has been accompanied by the development of statistical approaches to model and map risk and intervention access in space and in time, using model based geostatistics (MBG) (Diggle and Ribeiro, 2007).

At the launch of the Roll Back Malaria (RBM) partnership, calls for universal coverage of all available interventions were probably an appropriate response to the epidemic that affected most of sub-Saharan Africa during the mid-late 1990s (WHO, 2000; Snow et al., 2012). A decade on, the international donor community is constrained by the global financial crisis; accessing overseas development assistance (ODA) and using limited national domestic funding for malaria control now requires a much stronger, evidence-based business case. These future business cases must be grounded in the best possible epidemiological evidence to predict the likely impact of interventions, assess the impact of current investment and, equally important, demonstrate what might happen should funding and intervention coverage decline.

This epidemiological profile of malaria in Mozambique attempts to assemble a brief history of malaria control in Mozambique and the epidemiological evidence base for a more targeted approach. It draws together data on parasite transmission risk from household surveys, the distribution of dominant vector species and coverage of insecticide-treated mosquito nets (ITN) and indoor residual spraying (IRS). This information is described by health district, and could inform the planning of targeted sub-national control efforts to accelerate progress towards the targets specified in the national malaria strategic plan.

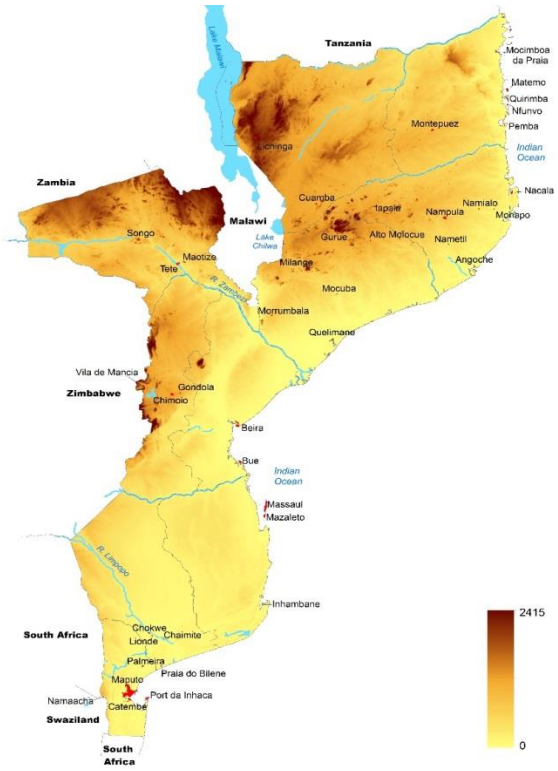
2. Country context

2.1 Geography and climate

Situated to the south east of the African continent, Mozambique covers an area of just over 800,000 km^2. It shares borders with six other countries – Tanzania, Malawi and Zambia to the north, Zimbabwe to the west, South Africa and Swaziland to the south – and has more than 2,500 km of coastline on the Indian Ocean.

Mozambique consists of a vast, low grassland plateau, covering nearly half the country's land area and extending from the coast towards the mountains in the north and west. The highest point in Mozambique, at 2,436 m, is Monte Binga within the Chimanimani Range in Manica Province, bordering Zimbabwe (www.peakary.com, 2014) (Figure 2.1). The Zambezi is the largest of the country's 25 rivers and divides Mozambique into distinct northern and southern halves. The other 24 rivers are more-or-less equally distributed across the country.

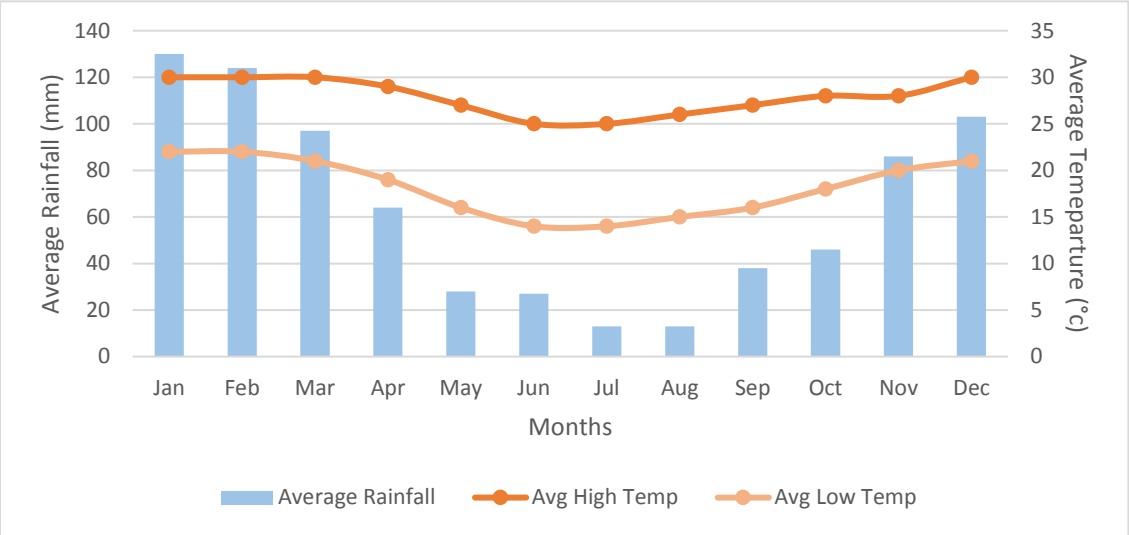
Figure 2.1 Extents of major rivers, cities and towns and their elevation in Mozambique



Metres above sea level

With a tropical to sub-tropical climate, Mozambique experiences high coastal temperatures for much of the year, while the interior is warm to mild even in the cooler, dry season from April to September. The rainy season in the south is from December to March, farther north this period lengthens by a few weeks. Figure 2.2 below illustrates average rainfall and temperature ranges for Mozambique as documented in 2012 (www.climateandweather.com).

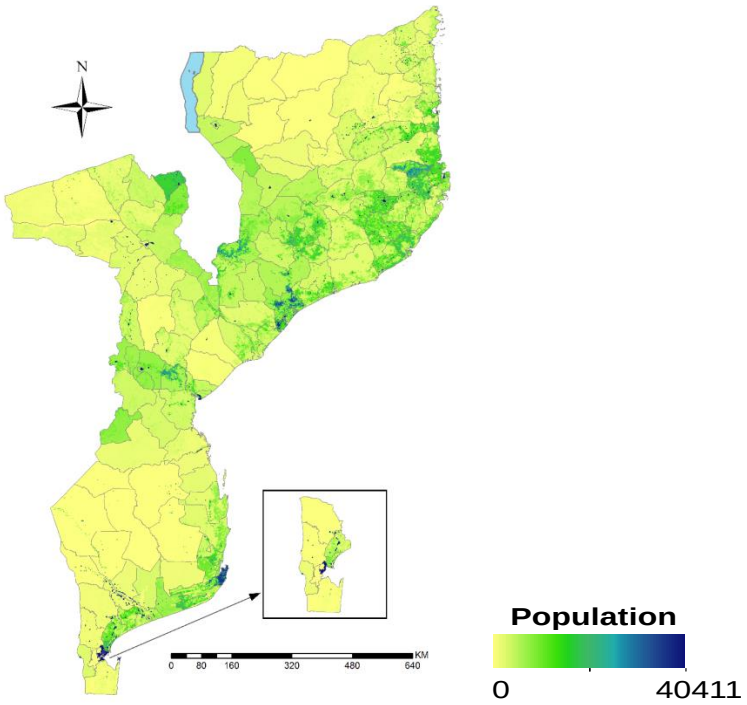
Figure 2.2 Average rainfall and temperature in Mozambique (2012)



The population of 7.6 million in 1960 grew to 26.47 million in 2014, an average population growth of approximately 2.5% per year in recent decades. The overall population density is 35 people per km^2, most of which are concentrated along the coast and the fertile river valleys (World Bank, 2014). Forty five percent of the population is under the age of 15 and Mozambique's population pyramids from 1970 to 2010 look nearly identical, reflecting a lack of change in the age structure over the last 40 years. The picture, however, is set to change. The total fertility rate (TFR), or the average number of children per woman over the course of her lifetime, declined from 6.2 children in 1990 to 5.7 children per woman in 2013 (Mozambique, Demographic Dividend, 2014) and the under-5 mortality rate (U5MR) fell from 226 per 1000 live births in 1990 to 97 per 1000 live births reported in the 2011 Demographic and Health Survey (DHS) (Fernandes et al., 2014; Ministério de Saúde, 2011).

Mozambique's human development index (HDI) for 2012 was 0.327 – in the low human development category – positioning the country at 185 out of 187 countries and territories. Between 1980 and 2012, Mozambique's HDI increased 51% from 0.217 to 0.327, an average annual increase of about 1.3% (UNDP, 2013).

Figure 2.3 Population density and distribution across Mozambique



Population distribution predictions for the year 2015 were derived from the population products shown in Figure 2.3. The population distribution provided at 100 m spatial resolution was resampled in ArcGIS (ver10.1 ESRI, USA) to obtain population density per km^2. A population density threshold of greater than 1,000 persons per km^2 was used to identify urban settlements, a threshold found to significantly influence malaria prevalence (Kabaria C, personal communication).

Polygons covering an area greater than 5 km^2 with population density across the polygon of >= 1,000 people per km^2 were selected. These were then matched to a place name gazetteer of Mozambique (www.geonames.nga.mil/gns/) to identify 46 major urban settlements shown in slide. These include Cabo Delgado (Mocimboa da Praia, Matemo, Quirimba, Nfunvo, Pemba, Montepuez); Niassa (Lichinga, Cuamba); Zambezia (Gurue, Milange, Mocuba, Morrumbala, Quelimane, Alto Molocue); Nampula (Iapala, Nampula, Namialo, Monapo, Nacala, Nametil); Tete (Songo, Tete, Maotize); Manica (Vila de Mancia, Manica, Gondola, Chimoio); Sofala (Beira, Bue); Inhambane (Massaul, Mazaleto, Inhambane); Gaza (Chokwe, Chaimite, Lionde, Praia do Bilene); Maputo (Palmeira); Maputo (Maputo; Porto da Inhaca; Catembe; Namaacha).

Digital elevation ranges from sea level (light brown) to a maximum of 2,415 m above sea level (dark brown).

References

30m ASTER DEM: www.asterweb.jpl.nasa.gov/gdem

Rivers from Global Lakes and Wetlands Database: GLWD; www.worldwildlife.org/ GLWD

2.2. Administration

The Republic of Mozambique is an independent, sovereign, unitary and democratic state. The president of the Republic is the head of state and government of a multi-party system. The prime minister is appointed by the president. His functions include convening and chairing the council of ministers (cabinet), advising the president, assisting the president in governing the country, and coordinating the functions of the other ministers. The Assembly of the Republic (*Assembleia da República*) comprises 250 members, elected for a five-year term by proportional representation (Constitution of the Republic of Mozambique, 2005).

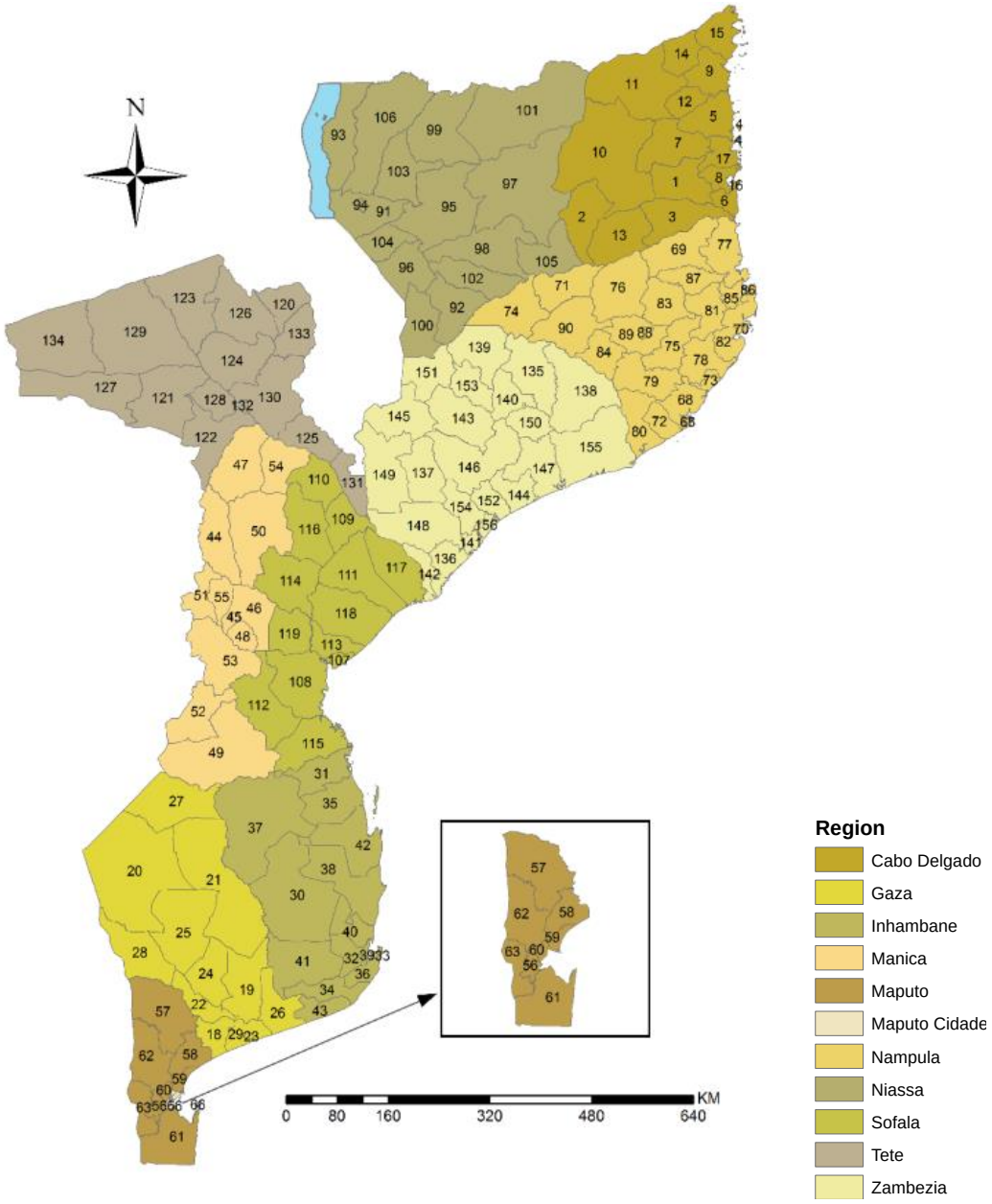
Following independence in 1975, Mozambique experienced an extensive period of civil war, economic mismanagement and famine. A peace deal in 1992 ended 16 years of civil war and led to considerable progress in economic development and political stability (CIA, 2017). In 2014, Mozambique's economy continued to perform strongly with real Gross Domestic Product (GDP) growth of 7.6% and the outlook remains positive. Sustained growth is expected at 7.5% in 2015 and 8.1% in 2016. The main sectors benefiting are construction, services to enterprises, transport and communications, the financial sector and extractive industries (African Economic Outlook, 2017).

The adoption of the Millennium Development Goals (MDGs) in 2000 catalysed a series of reforms by the government of Mozambique that led to radical shifts in policy vis-à-vis the social sectors. Policies for poverty reduction were adopted to include free education, affordable health schemes, child immunisation, malaria control, HIV/AIDS, infrastructure, etc. Both the government and its partners, including civil society and donors, endorsed and supported the MDGs and the Government of Mozambique (GoM) established clear linkages and synergies between the MDGs and the country's long-term vision, "Agenda 2025" (Agenda 2025, 2003).

2.2.1 Administrative decision making units

The country is divided into 11 administrative provinces (*províncias*) and one capital city (*cidade capital*) which has provincial status. The provinces are subdivided into 156 districts (*distritos*). The districts are further divided into 405 administrative posts (*postos administrativos*) and then into localities (*localidades*) (Mozambique Information, 2015). There are 33 municipalities covering Mozambique's 23 cities and 10 of the 116 towns in the districts (CLGF, 2009). According to the 1997 Law on Local Government Units (*Lei dos Órgãos Locais do Estado* – LOLE), the district is the "principal geographical unit for organisation and functioning of the local administration, and is the basis for planning the socioeconomic and cultural development of the Republic of Mozambique". At the end of the 1990s, autonomous local authorities known as *autarquias* were established in the principal cities and towns. The functions and degree of autonomy of districts and those authorities are still defined only vaguely. Note that administrative and health districts in Mozambique are one and the same of which there are a total of 156.

Figure 2.4 Mozambique administrative units



In Mozambique the health administration operates at the administrative district's level (*distritos*). There are also administrative posts (third level) and localities (fourth level).

To reconstruct health districts, we obtained a shapefile from the National Malaria Control Programme (NMCP) with 11 provinces and 145 districts; GAUL admin 2 shapefile (n=148) developed in 2008 by FAO, and a third level administrative shapefile from GADM. We compared the two lists, using the NMCP shapefile as the benchmark, and corrected inconsistently spelt districts (n=11), districts placed in wrong regions, mismatching names and missing districts.

Mozambique increased the number of health districts to 156 in 2014, but only had digitised maps available for 145 of these. These shapefiles were provided by the NMCP and have been checked against the UN approved GAUL national boundaries. The 11 additional districts

included Macate and Vanduzi districts in Manica province; Mozambique Island, Larde and Liupo districts in Nampula province; Doa and Marara districts in Tete province; Derre, Luabo, Mocubela, Mulevala, Mulombo, and Quelimane districts in Zambezia province.

A majority of the additional districts were created by upgrading the localities into districts, except for Larde district where Mucuali and Larde localities were merged; Liupo district where Liupo and Quinga localities were merged; and Mocubela district where Mocubela and Bajone localities were merged. The area of Quelimane district was changed to include Nicoadala locality.

Other changes included Pemba-Metuge district in Cabo Delgado, which was renamed to Metuge district; Nampula-Rapale district in Nampula, which was renamed Rapale district; and Lichinga district in Niassa, which was renamed Cimbonila district.

The allocation of resources to the local bodies – provincial governments, district departments (*secretarias distritais*), municipalities, provincial hospitals, provincial directorates, and others – is performed directly by the Ministry of Finance. However, despite the importance attached to decentralisation, in practice the funds are still held at the higher levels. In 2010, less than 1% of government expenditures were made by the municipalities, and only 4.8% were made at the district level (*Ministério de Saúde* – MISAU, 2013).

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2.3 The health system

2.3.1 Health system structure

The Ministry of Health (*MISAU*) is responsible for health policy and prioritisation. It develops national health guidance and policies and is responsible for their implementation and for monitoring their progress. It is also responsible for providing the necessary materials, equipment and training for health staff to fulfil their responsibilities.

In Mozambique the public health sector is a six-tiered pyramid system: *Hôpital Central, Hôpital Provincial, Hôpital Général, Hôpital Rural, Centro de Saude, Posto de Saúde*.

Health service provision is by health district and can be divided into four key groups:

1) **The public sector, grouped under the National Health Service (*Serviço Nacional de Saúde* -SNS)** is the most accessible, geographically.

The SNS is organised into four levels of service provision. Level I is the most peripheral and includes both rural and urban health centres and health posts. These health facilities provide a package of primary health care services, have very limited laboratory capacity, and usually have a maternity ward but do not provide other inpatient services. According to a 2004 World Bank Report, Level I facilities represent at least 40% (*MISAU*, 2013) of all health services and are typically the first point of contact with the health system for a large portion of the population, with the exception of areas that are serviced by community health workers. Level II is composed of the district, general, and rural hospitals, which may serve more than one district, and represent the primary referral level. Levels I and II are devoted to providing primary health care. Level III consists of provincial hospitals, which in addition to offering curative and diagnostic services also act as training centres for MoH staff. Finally, Level IV is made of the country's three referral hospitals in Maputo, Beira and Nampula, serving the southern, central and northern regions respectively.

Access to the SNS network is limited and it is estimated that only 60% (ibid) of the population had access to health services in 2010. Excluding the urban zone of Maputo, the reference population for each primary care health unit (*unidade sanitária* – US) exceeds 17,000 persons.

2) The growing private sector is limited to major cities and formed of two groups: for-profit – found almost exclusively in urban areas, such as Maputo, Beira and Nampula – and not-for-profit, the latter group having strong ties to the public sector and largely run by faith-based organisations. Public access to retail outlets and pharmacies for malaria treatment is largely dependent on easy physical access to community health workers or US (NMCP, 2015).

3) **Community Health Workers** (*agentes polivalentes elementares* – APEs) provide basic services in areas where access to the SNS infrastructure is limited, and are paid a basic stipend by MISAU. The APEs provide preventive and basic curative services, including malaria diagnosis (using rapid diagnostic tests, or RDTs) and treatment (with artemisinin-based combination therapy, or ACT). As such, it is an important component of Mozambique's malaria case management plan. *Agentes polivalentes elementares* serve as the first line of defence against malaria for people living in rural Mozambique, and for many people are the only opportunity to receive proper diagnosis and treatment for malaria. The President's Malaria Initiative's (PMI) support for the APE programme has focused on the

provision of RDTs and ACTs for the kits used by APEs for community case management, and limited central support to continue the expansion and training of APEs throughout the country. The GFATM also contributes support for these activities. Up until November 2015, 2,300 of the total targeted 3,600 had been trained. They are currently reporting through a parallel system to the HMIS but will be absorbed in to the new DHIS2 system.

4) **Lastly, practitioners of traditional medicine (PMT),** widely accepted by the communities, offer non-allopathic medicine (*MISAU*, 2013).

Malaria control in the public health system is implemented at three administrative levels: central, provincial and district. The NMCP is the central level, but challenged by understaffing with many of the existing staff being over-stretched as a result. Each province has a provincial malaria focal point, who is responsible for coordinating the implementation of malaria control activities at that level. In 2013, district malaria focal points were created and are responsible for all malaria control activities at district level and improving data management and reporting for malaria at district level (PMI-MOP, 2015; RBM, 2013).

2.3.2 Health context and priorities

Mozambique has had one of the highest rates of under-5 mortality in the world (79/1000) (World Bank-IDA, 2016), but has made substantial progress towards achieving MDG 4 (to reduce the U5MR rate by two-thirds between 1990 and 2015) since 2000; nationally, the rate fell from 226 per 1000 livebirths in 1990 to 97 per 1000 livebirths reported in the 2011 Demographic and Health Survey (DHS) (Fernandes et al., 2014; MISAU, 2011).

More than 75% of deaths in children under five years of age in Mozambique are caused by infectious diseases, with more than 60% attributable to malaria (42.3%), HIV (13.4%), and pneumonia (6.4%) (Mazive et al., 2009).

The health policy framework for Mozambique is articulated through the government's five-year plan (*Plano Quinquenal* – 2010-2014), the Action Plan for the Reduction of Poverty (*Plano* de *Acção para Redução da Pobreza* – PARP 2011-2014) and the annual National Economic and Social Plans.

The revised PESS (Health Sector Strategic Plan) 2014-2019 was approved following a comprehensive review of the previous 2007-2012 strategic plan. The Sector Strategic Plan comprises seven objectives and is based on principles of primary health care, equity and better quality of services:

- Increase access and utilisation of health services
- Improve quality of service provision
- Reduce geographic inequities and between different population groups in accessing and utilising health services
- Improve efficiency on service provision and resource utilization;
- Strengthening partnerships for health
- Increase transparency and accountability on management of public goods;
- Strengthen the health system.

2.3.3 Progress with malaria control in Mozambique

Accounting for 29% of all deaths and 42% of deaths in children under five, malaria is considered the most important public health problem in Mozambique. It is endemic throughout the country, and the entire population is at risk. Transmission is year-round with a seasonal peak during the rainy season, from December to April. Mozambique is susceptible to floods and cyclones which occurred in 2000, 2001, 2007, and 2008 in Inhambane, Tete, Zambézia, Sofala, Manica and Nampula. The floods led to serious malaria epidemics. *Plasmodium falciparum* is the predominant malaria species responsible for 90% of cases, with other reported species including *Plasmodium malariae* and *Plasmodium ovale* at 9% and and 1% respectively (*MISAU*, 2012).

The DHS showed a reduction in average malaria prevalence nationally, from 51.5% in 2007 to 38.3% in 2011. The 2011 DHS also showed a reduction in all causes of under-five mortality to 97/1000 from 138/1000 in the 2008 Multiple Indicator Cluster Survey (MICS). In the 2011 DHS, malaria prevalence among children under five years was 46% in rural areas and 17% in urban areas lower than the 2007 MIS in which malaria prevalence among children under five years was 57.8% and 26.5% in rural and urban areas respectively.

Malaria prevalence is reported to have decreased in all provinces between 2007 and 2011 despite a multitude of administrative and health resource challenges, which have slowed the progress of key malaria prevention and treatment interventions. No nationally representative data on malaria risk is available since the 2001 DHS survey. An MIS took place in 2015. The MoH has introduced DHIS-2 which should facilitate the monitoring of the burden of malaria in coming years.

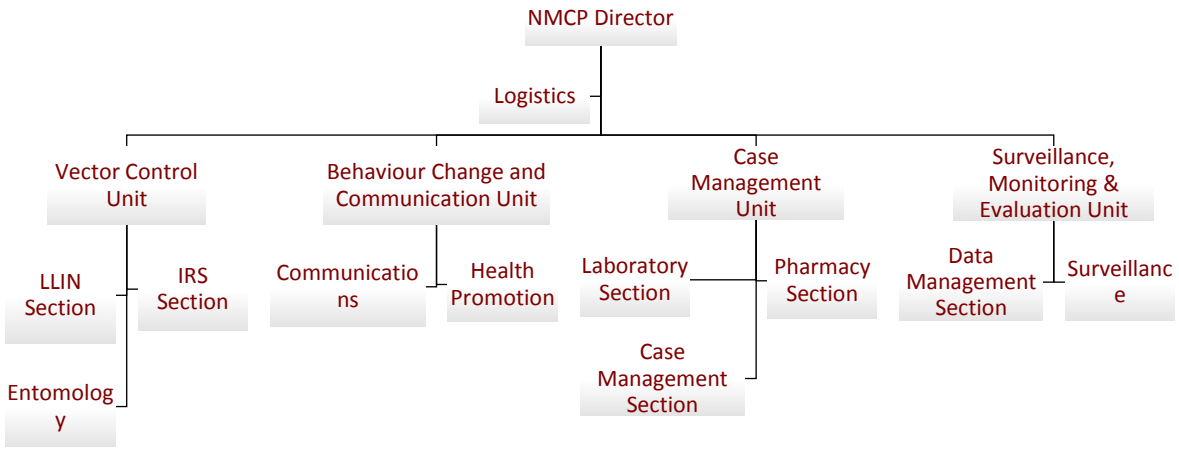
Progress with control is not expected to be homogeneous and it will become increasingly important to detect and understand variations in malaria epidemiology with greater spatial resolution. The DHS and other national household surveys are designed to be representative at the provincial level. However, the operational unit for malaria control is the district and ensuring the availability of key information on malaria risk at this level will become increasingly important.

As disease risk falls, the efficiency and utility of household surveys to monitor progress with transmission reduction will also fall. At some level of transmission it will become important to monitor case incidence, and then absolute case numbers. This will depend on the reliable capture and forwarding of data on parasitologically confirmed malaria cases presenting to health facilities.

3. Structure and function of the national malaria control programme

The National Malaria Control Programme (NMCP) falls under the Directorate of Public Health within the Ministry of Health in Mozambique. The programme is headed by the director of the NMCP to whom the four thematic unit leads report, as described in the organogram below (Figure 3.1). The individual thematic units are comprised of technical sections that are responsible for managing the relevant interventions. So, for example, ITN distribution is managed by the ITN section under the Vector Control Unit.

Figure 3.1 NMCP organogram, Mozambique



The NMCP is responsible for the coordination of all national malaria control efforts including the planning and mobilisation of funds for the implementation of the National Malaria Strategic Plan, developing and implementing malaria policies and strategies within the SNS and defining national and provincial targets for malaria indicators. The NMCP defines priorities and activities for each implementation area in a five-year strategic plan, which is then broken down into annual work plans. The NMCP is responsible for monitoring and evaluation of progress in malaria control in Mozambique as well as having oversight of all malaria research activities and surveys.

3.1 Financing malaria control

The Mozambican SNS is financed through two main sources:

- Domestic funds from the state budget, and
- External funds received from different mechanisms including budget support through the common fund (PROSAUDE), and various bilateral initiatives. Having peaked at 14% in 2004, the Government of Mozambique (GoM) allocation to the health sector in 2013 was about 9%. It is expected to remain at about the same level until 2016 according to medium term expenditure framework (MTEF) projections (International Health Partnership, 2013).

Since 2012, the Mozambique malaria programme has not been fully resourced. Based on the malaria strategy 2012-16 (an updated strategy was created for 2014-16 with minimal changes in activities – therefore original cost assumptions are presumed valid), resource requirements on an annual basis vary from US$ 85 million to US$ 124 million, with an average cost of US$108 million.

The GoM contribution to the malaria programme is difficult to estimate. However, using a conservative figure of 2.88% of total government health expenditure dedicated to malaria (as used in the Round 9 GFATM proposal), it is estimated the GoM contributed US$15 million, US$21 million and US$12 million in 2012, 2013 and 2014, respectively. During these years, government contributions were approximately 54% financed by a World Bank loan to the Ministry of Health (MISAU).

After 2014, the NMCP was not expected to receive any further funding of this type from the World Bank. To account for this, the GoM contributed an additional US $6.8 million to the NMCP, for a total GoM NMCP budget of US$ 12.6 million for 2015. Calculations in the current Concept Note (CN) (2015-2017) assume 2015 government funding levels will continue for 2016 and 2017.

Beyond GoM funding, the NMCP receives funding, primarily, from two donors – the PMI and GFATM. Over a continuous period of five years (2009-2013), the PMI contributed an average of US$ 26 million, GFATM contributed an average of US$ 11 million, and other donors contributed smaller amounts totalling an estimated US$ 6 million per year. Based on current trends, the PMI and GFATM will account for an average of 78% of total funding from 2012 to 2017. Smaller contributions have been made by UNICEF, DFID, Spain, the Netherlands, and WHO (*MISAU*, 2014)

The PMI commitment to Mozambique for FY 2015 was US$ 29 million. Under the GFATM Round 9 Phase 2, Mozambique was awarded US$ 92.4 million for malaria over five years and is eligible for a further US$ 6 million over 2.5 years under the GFATM new funding model (NFM), which was approved in June 2015. Between 2004 and 2014, the GFATM has disbursed a total of US$ 160,403,600 to Mozambique for malaria.

The Bill and Melinda Gates Foundation fund malaria projects through implementing partners, most notably the inSCALE (Innovations at Scale for Community Access and Lasting Efforts), a research project in Mozambique (and Uganda) implemented by the Malaria Consortium to evaluate community based health delivery, known as integrated community case management (iCCM). The project is a collaboration with the London School of Hygiene & Tropical Medicine and University College London's Institute for Global Health.

In 2014, the "la Caixa" against Malaria project was launched jointly by "la Caixa" Foundation and the Gates Foundation with the aim of eliminating malaria in southern Mozambique by 2020. The programme is being implemented by the Barcelona Institute for Global Health (ISGlobal) and the Centro de Investigação em Saúde de Manhiça (CISM - Manhiça Health Research Centre) with the participation of other partners and under the leadership of the Ministry of Health. After a long history working on diverse health problems in Mozambique, the partnership's new goal is to eliminate malaria from the country's southern provinces. The task involves working on many different fronts: the creation of epidemiological and entomological surveillance systems to provide reliable data to guide decision-making; the implementation of actions on the ground; a programme of scientific research to create and gather the knowledge needed to draw up a

strategic plan for eliminating malaria from the southern provinces – Maputo (including Maputo city), Gaza and Inhambane. All of these come together in the newly formed Mozambican Alliance towards the Elimination of Malaria (MALTEM), with a continued priority of strengthening Mozambique's PNCM, and coordination of the efforts of all the stakeholders currently working to combat the disease in the country (isglobal.org).

The Clinton Foundation began malaria projects directly implemented by the Clinton Health Access Initiative (CHAI) in 2015, through a five-year Gates grant, with a focus on pre-elimination areas around the country in partnership with CISM. In August 2015, ministers of health from Mozambique, South Africa and Swaziland signed an agreement to ensure that the malaria control fraternity from each of the countries support the development of infrastructure and expertise in southern Mozambique in order to lower the prevalence of the disease in the border regions of these countries. This initiative, MOSASWA (Mozambique, South Africa & Swaziland), will try to emulate the Lubombo Spatial Development Initiative, which ended in 2011. The CHAI will assist with the coordination of this initiative.

3.2. Supply chain overview

The Central Medical Store – *Central de Medicamentos e Artigos Médicos* (CMAM), which is at national directorate level (World Bank-IDA, 2014), manages Mozambique's public health supply chain. Its mandate is to manage the procurement, importation, central-level warehousing and distribution to provinces for medicines and commodities used by the public health system. The CMAM, the MISAU and their partners are guided by the Supply Chain Logistic Plan of Action 2012 (MISAU, 2012) and the new Pharmaceutical Logistics Strategic Plan 2013 (MISAU, 2013). Both of these plans have performance indicator framework and monitoring plans. The strategic and action plans aim to address several key issues:

- Improved quality and timeliness of information flow between districts, provinces, and CMAM and better use of this information for planning and procurement purposes
- Better planning for distribution from provincial warehouses to the districts
- Stronger supervision and internal audit of province/district stores by CMAM

The CMAM receives assistance from multiple donor and implementing partners. Most recently, this has included technical assistance and commodities from the U.S. government (USG); operational funding and commodities from the World Bank; and commodities from GFATM related to each of the GFATM programmes. The USG alone invests, on average, US$10 million – $15 million annually on technical assistance to CMAM through such projects as the Supply Chain Management System (SCMS), the USAID - DELIVER PROJECT, and *Fortalecimento dos Sistemas de Saúde e Acção Social* (FORSSAS).

Rapid diagnostic tests, ACTs and SP fall under the remit of CMAM. However, long lasting insecticidal nets (LLINs) are supplied through a temporary semi-parallel system that operates to directly deliver nets from port of entry to provisional and then district levels in target provinces. Long lasting insecticidal nets are also distributed in coordination with the Expanded Programme on Immunization to Ante-Natal Clinics (ANCs) for their routine distribution.

The quantification and procurement of antimalarial commodities (RDTs, ACTs, SP and LLINs for ANCs) is undertaken by CMAM and NMCP at the national level with the support of John Snow International (JSI). Quantification for RDTs and ACTs is done using demographics and Logistics

Management Information System (LMIS), i.e. consumption and distribution data. Distribution of ACTs, RDTs and SP is carried out through two systems. A "push" system delivers pre-packaged kits, per 1,000 consultations for US and 250 consultations for APEs, from CMAM to the provincial level on a quarterly basis. From there, kits are delivered to districts and to health centres once a month by the provincial and district health authorities, respectively. The APEs receive kits that include RDTs, ACTs and artesunate suppositories that they collect either at district level or from health facilities depending on their catchment area. The APE kits are supported with funds from the PMI. Malaria kits to US are delivered alongside essential medicine kits and only contain RDTs and ACTs. Due to the large quantities of commodities required, regional hospitals (Maputo, Sofala and Nampula) receive stocks directly from CMAM, while provincial hospitals receive them from the provincial warehouse.

The second system is the "pull" / *via classica* mechanism that allows health facilities to request extra quantities of RDTs and drugs based on consumption rates, including antimalarials. Requests from US are made to the district warehouse. Should the district warehouse not have enough stock, they then request stocks from the provincial warehouse. The district warehouse is then responsible for delivering requested stock to the US. This mechanism is reported to be functioning well for malaria, with facilities requesting antimalarials when out of stock, though there can sometimes be a delay in distribution to facility level due to logistical challenges. It is currently estimated that of the total number of ACTs consumed, two-thirds are from the kits and one-third is by requisition through the *classica* system. There is currently no mechanism for redistribution of anti-malarials at district level.

Currently, there is limited, even no data, on stock availability on a routine basis for Mozambique. Studies examining stock availability of essential medicines, including antimalarials and RDTs, have found that in one region (Sofala) between 4% and 18% of malaria consultations did not have an RDT or ACT available (Wagennaar, 2014). Hasselback et al (2014), examining stock availability of RDTs in the Cabo Delgado region, found that average monthly proportions of 59%, 17% and 17% of health centres reported a stock-out on stock cards, laboratory and pharmacy forms, respectively. Estimates of lost RDT consumption percentages were significantly high; ranging from 0% to 149%; with a weighted average of 78%. Each 10-unit increase in monthly-observed consumption was associated with a nine-unit increase in lost consumption percentage, indicating that higher rates of stock-outs occurred at higher levels of observed consumption.

While there is limited routine data stock-outs or otherwise, there has been significant investment to improve the availability of data on stocks. At the central level, a warehouse management system, known as MACS3, has been established and is being used by CMAM to provide tools to better control and manage stock and data. A monitoring and evaluation (M&E) framework has been developed and a dedicated M&E unit created within CMAM to routinely track performance (Spisak and Morgan, 2014).

In addition to central level investments, national and district levels have operationalised a computerised LMIS in all provincial capitals and in 68 out of 151 districts. This real-time LMIS, called SIMAM, is an access-based programme that warehouse staff in all provinces, and centrally, have been trained to use. The plan, as of 2015, is to continue the roll-out of the SIMAM system to all districts with USG and GFATM support (PMI, 2015; World Bank, 2014). In addition to support from PMI through the JSI | Deliver programme, CMAM distribution also received some support from CHAI, which is piloting the introduction of outsourced distribution with tablets for data collection.

3.3 Drug and insecticide safety and efficacy monitoring

Although there is not a formal pharmacovigilance plan currently being implemented by the NMCP, Mozambique has been involved in drug safety and efficacy monitoring at both a national and international level since the early 2000s. This has included trials on the safety and immunogenicity of the RTS S/AS02A malaria vaccine in children aged one to four in 2003 (Macete et al., 2007) carried out in Manhiça. In 2011, following the roll-out of artemether-lumefantrine (AL) in 2009, the NMCP, in partnership with CISM, undertook its first drug efficacy study of AL in five sentinel sites. AL showed high cure rates and rapid resolution of parasitaemia, fever and gametocytemia in adults and children, and showed an excellent safety and tolerability profile (Makanga et al., 2011). At the time, this study was the largest data set assessing AL therapy for treatment of acute uncomplicated *P. falciparum* malaria.

In 2015, the NMCP carried out a drug efficacy study in four drug-efficacy sentinel sites for AL (Gaza, Sofala, Tete and Cabo Delgado). The NMCP began bioassay studies in one district each – Maputo (Boane) and Mecufi (Cabo Delgado) in 2014. Both sites sprayed with deltamethirin and the insecticide was found to be effective after four months of application on all walls surfaces (grass, plastered and painted). The quality of spraying was found to be good on all types of walls in Boane, with the exception of four houses out of 10 in Mecufi where spraying was not consistent. These studies are continuing in 2015 with the addition of a new insecticide, DDT, in Boane and Metuge districts in Cabo Delgado with both deltamathrin and DDT.

Routine (annual) insecticide resistance monitoring also began in 2014 at 21 sentinel sites studying four insecticides (DDT, lambacyhalothrin, deltamethrin and bendiocarb). In 2015 one other insecticide was added (perimiphos-methyl) and tested in six sentinel sites (Nampula city, Chimoio city, Xai-Xai city, Boane, Magude and Maputo). Sentinel sites for resistance monitoring are selected by the NMCP according to the National Strategic Plan (2012-2016) criteria:

- Area has been IRS-sprayed or has plan to be sprayed
- Malaria incidence

From 2015, the entomology department will select sites based on a number of criteria, such as funding, location of insectaries and where IRS should be carried out (in line with the revised vector control strategy).

3.4. Monitoring malaria control

Data used to inform malaria control in Mozambique comes from three main sources: (i) routine health information, which gathers data from the public health system and may be complemented by other types of official data such as socio-demographic information; (ii) large-scale household (DHS, MICS, MIS); and (iii) operational research and intervention studies. The analyses presented here are based largely on data from cross-sectional household surveys and are described in detail in Section 6 - Overview of technical methods. Here we briefly describe the routine health information system and sentinel sites, and give examples of data generated through operational research.

3.4.1 Routine health information system

Mozambique's health management information systems (HMIS) include a variety of population-based and health facility-based data sources. The health facility-related data sources are public health surveillance, health services data and health system monitoring data. The HMIS is

comprised of multiple systems. The majority of these are paper-based individual level data collection (in a health register or patient file) at the service level; aggregate facility data are reported monthly through the national data flow, meaning individual patient data are sent from health facility to district level where data are aggregated and sent to the provincial level, before being again aggregated and sent to the national level. A key tool of the HMIS is the aggregate data reporting system, which is the conduit for data flow for the majority of programme data from facility to district to province to central level. Several years ago, an effort to implement the District Health Information System (DHIS) reportedly yielded poor results.

Following that, Mozambique developed its own approach and a software package called the *módulo básico*, a routine HMIS that includes surveillance and disease notification, and has since experienced success with implementation throughout Mozambique. Paper-based reports with aggregated data from peripheral health units are entered into a computer database at district level, and then electronically aggregated reports are transmitted mostly by flash drive or CD to the provincial level, aggregated there and then transmitted onward to the central level.

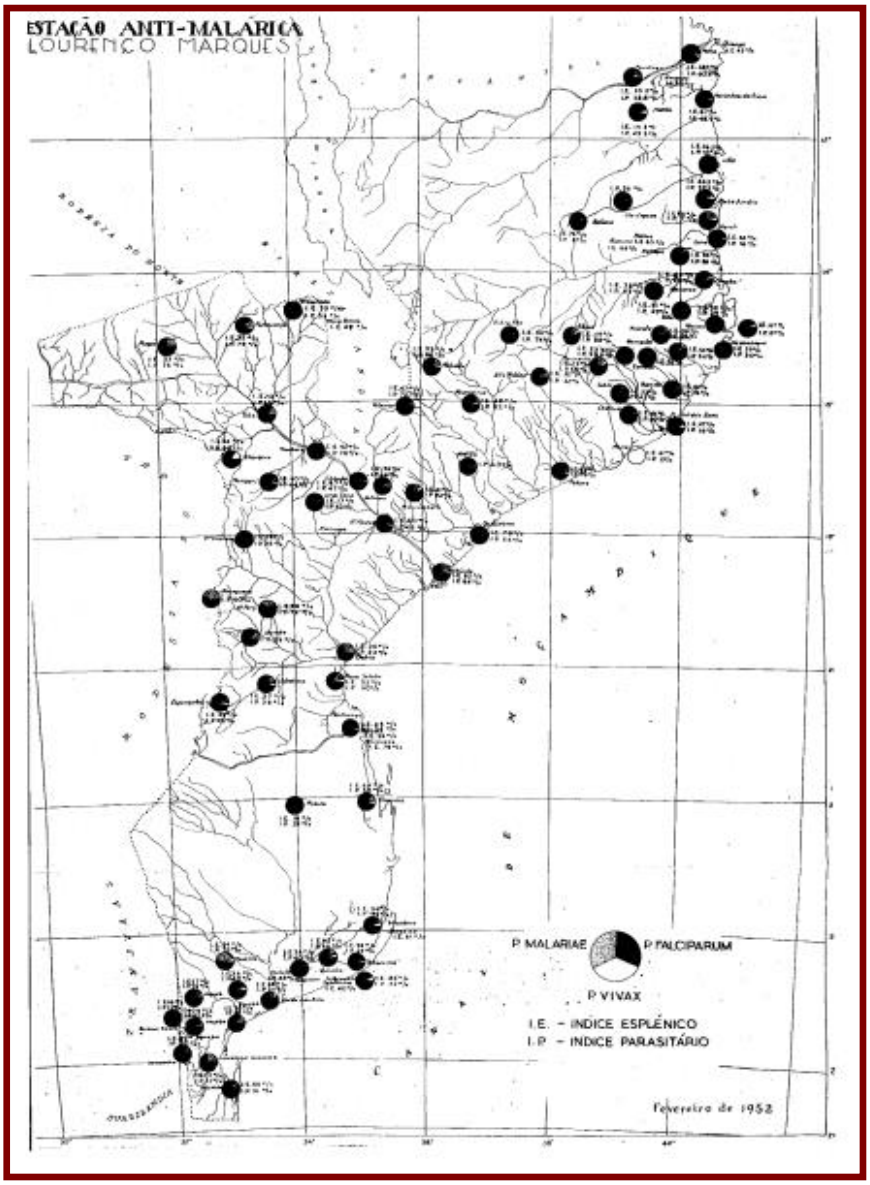
An assessment of HMIS data quality in Sofala by Gimmbel et al (2011) found that HMIS data are both reliable and consistent, supporting their use in primary health care programme monitoring and evaluation. However, an earlier study, when analysing the quality of routine data for malaria control, revealed primary data to be of poor quality and not meeting the needs of malaria control management (Chilundo et al., 2004). With a lack of malaria sentinel sites and data limitations through the HMIS, the NMCP is still heavily dependent on national representation household survey data for planning and management of malaria.

Efforts to improve capacity include staff training, rationalisation of the forms used at health facility and district level, as well as the (ongoing) development of the new HMIS (*SIS-MA* in Portuguese). This is a full information M&E system based on the DHIS2 platform and other software, which will enhance the quality of data and reporting. The intention is to enhance the efficiency of programme implementation. No major issues have been revealed during field-testing, which took place with the direct participation of the MISAU and pilot districts.

4. Mapping malaria risk

The first known malaria risk map of Mozambique dates from 1956 and was based on the community prevalence of *P. falciparum*, *P. vivax* and *P. ovale* (Figure 4.1)

Figure 4.1 Historical malaria risk mapping in Mozambique (Soiero, AN, 1956)



More recently, Mozambique's NMCP has used climate suitability maps (Figure 4.2), provincial parasite prevalence maps (Figure 4.3) and malaria incidence maps (Figure 4.4) to support planning for malaria control and to design suites of interventions on the control-elimination pathway. Figure 4.5 shows a map dating from 1940 that summarises the findings of an extensive entomological survey. The purpose of the study was to distinguish among species in the *Anopheles funestus* Giles series, which closely resemble each other. De Meillion and Perreira (1940) describe in detail the distribution and the morphological differences among four anophelines, namely *A. funestus*, *A. lessoni*, *A. riculorum*, *A. ricolorum* var. *garnhamelins.* They go on to do the same for *A. brunnipesi*, *A. seydeli* and *A. marshalli*.

Figure 4.2 Climate suitability map (Craig et al., 1999)

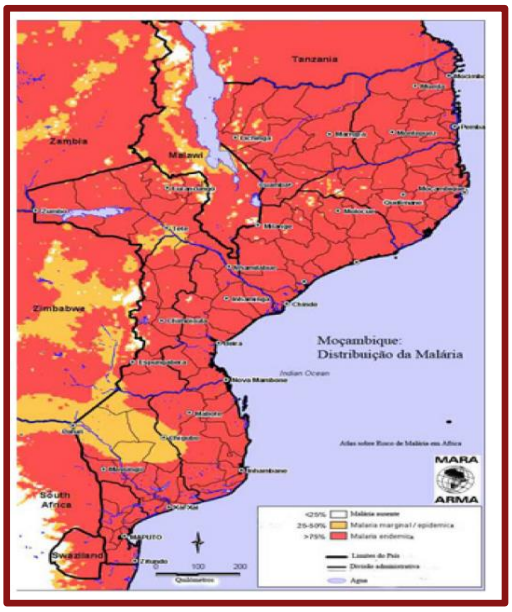


Figure 4.3 Provincial parasite prevalence (MIS, 2007)

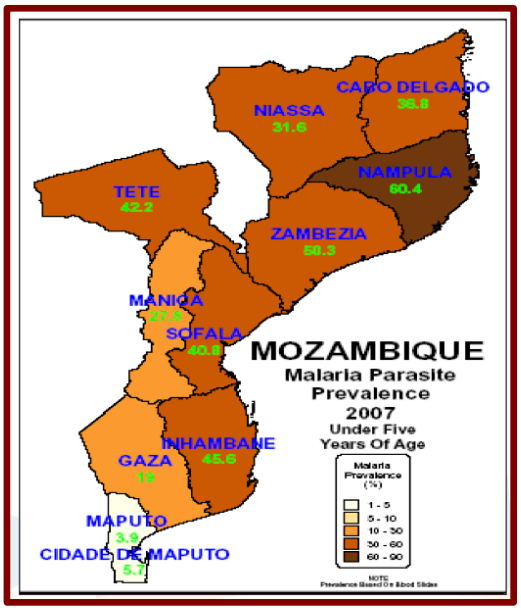


Figure 4.4 Malaria incidence, based on HMIS case reporting (Plano Estratégico da Malária 2012-2016)

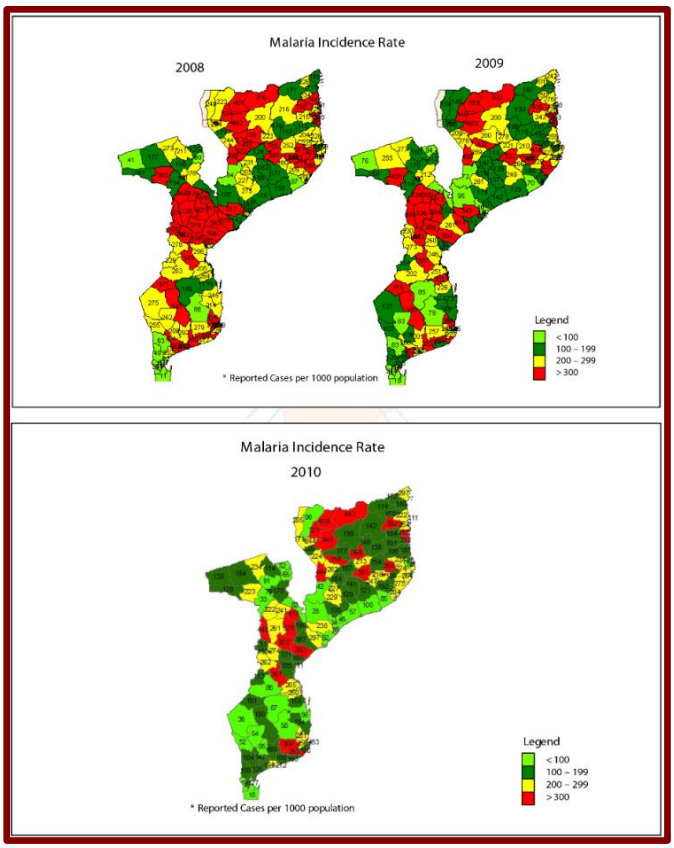
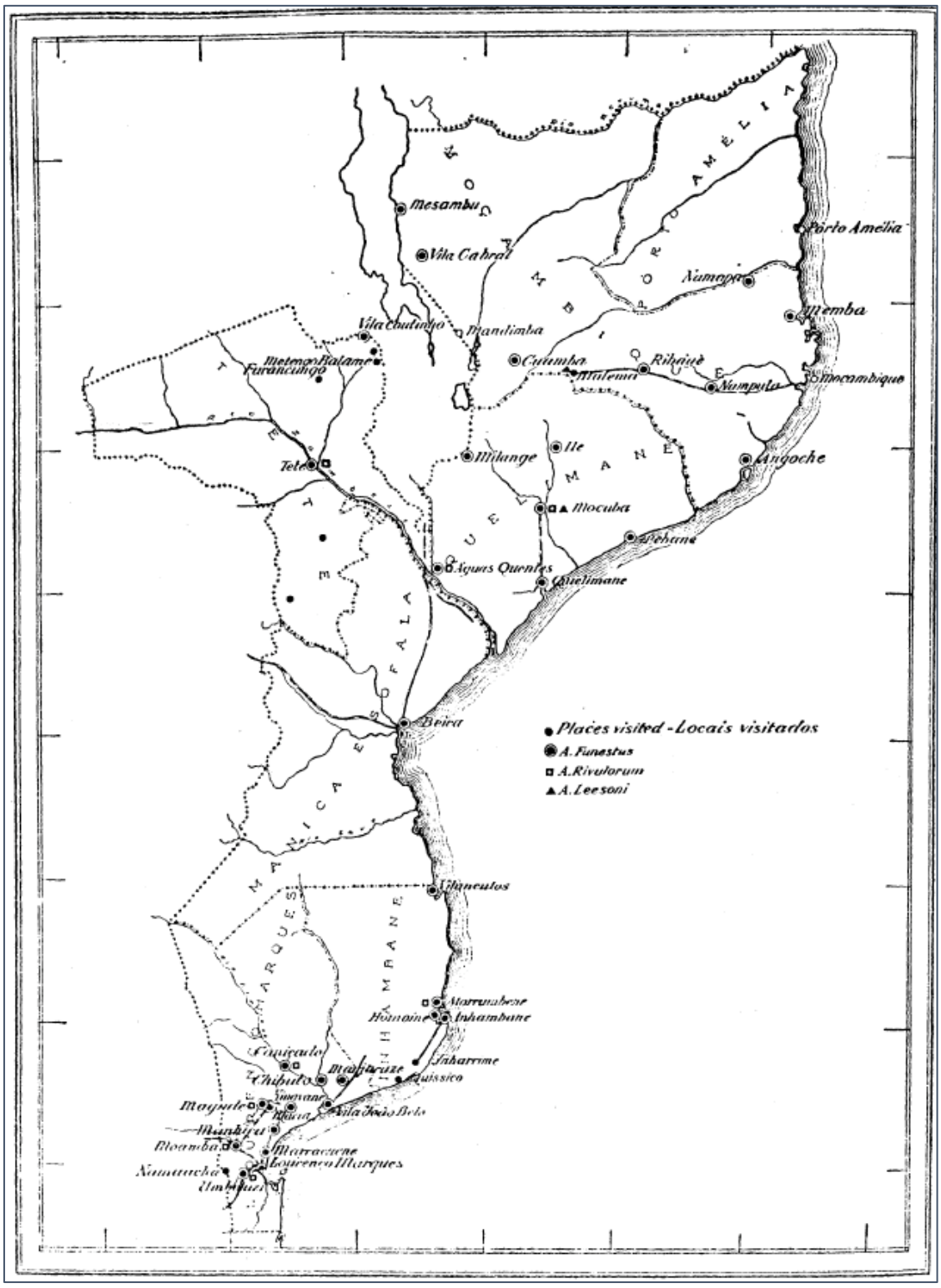


Figure 4.5 Distribution of anophelines in Mozambique in 1940 (De Meillon and Pereira, 1940)



5. Malaria control in Mozambique – Milestones

Key decisions and action have been taken by the Government of Mozambique to control malaria during the last 35 years. Efforts have intensified over the last 15 years as the government, along with internal and external partners worked to achieve the Millennium Development Goals. This section attempts to capture key initiatives across the main intervention areas.

Fever-related hospital admissions were a huge burden on the population in the early 1900s, and were largely attributed to malaria. The highest proportion of malaria cases was in Lourenço Marques province. Between 1901 and 1920, a drop in the prevalence of malaria was documented across the country. In Lourenço Marques, the prevalence fell from 61% in 1901 to 30% in 1920. These changes were attributed to petrolage of the swamps and drainage and levelling of marshes, typical breeding sites for the mosquito vectors (Soromenho, 1923).

Structured malaria control in Mozambique began in the late 1930s when the *Estação anti-malárica de Lourenço Marques (*the anti-malaria station) was formed in what is now Maputo city. This initiative began the sub-division of the city into urban, sub-urban and rural locations for vector control efforts, which focused on larval control, delivered by "sanitary police". Malaria control continued to focus on vector control activities up to 1970, with the continued use of larviciding and the introduction of IRS usuing DDT, gammexane and dieldrin. Selection criteria of areas for vector control activities included provincial capitals and their suburbs largely due to population concentrations and economic activities. Between the mid-1940s and the late 1970s, there were also reports of the national use of chloroquine (CQ) or proguanil as prophylaxis in school children as documented by Schwalbach and De la Maza (1985).

With the advent of the civil war, malaria control in Mozambique came to a halt between the mid-1970s and early 1990s. In 1982, the *Programa nacional de controlo da malária*, the NMCP, was re-established and limited malaria control activities were carried out within Maputo city. Efforts to control malaria expanded in the 1990s, with trials of various insecticides for IRS (lambda-cyhalothrin, cyfluthrin), the first trials of ITNs in Mozambique and the documentation of CQ failures, which ran between 15% and 40%.

With the beginning of the Roll Back Malaria (RBM) partnership in 1999, African Heads of States commited to fight malaria and its effects on the workforce and economies, and to dedicate an appropriate share of their national budgets to health. In 2013, the Mozambique government allocated 9% of its expenditure to health. In 2000, with support from a range of partners, Mozambique developed its first malaria strategic plan, covering the period 2001-2005. The same year saw a number of other collaborative projects take off, including the *Vurhongha* project, which used community aids to distribute ITNs in three districts of Gaza Province (Guija, Mabalane and Chokwe).

The Lubombo Spatial Development Initiative (LSDI), a tri-lateral initiative between the governments of South Africa, Swaziland and Mozambique aimed to accelerate the agricultural and economic development of the Lubombo Mountains region, which straddles the three countries. Malaria was identified as one of the main threats to the success of the initiative, with large parts of the region classified as endemic or seasonally endemic and a high incidence of severe malaria caused by *Plasmodium falciparum*.

The loss of productivity associated with malaria morbidity and mortality, in conjunction with the high cost of treatment and control of the parasite and its vectors, contributed to economic and social decline and a lack of development in the region. The need for a regional, inter-country approach to fight malaria led to the establishment of the Lubombo Malaria Control Programme in October 1999 through the signing of the Malaria protocol of understanding at ministerial level between the three countries. The purpose of the control programme was to address cross-border issues of population, parasite and vector movements, as well as the development and spread of vector and parasite resistance. The project started in Mozambique in 2000 with a focus on four project zones within Maputo province.

The LSDI project was a show-case for successful public private partnerships (PPP) in malaria control, with funding from the private sector (notably BHP Billiton) and with government contributions from 2003. The majority of funds for the programme from 2003 onwards were provided by the GFATM, with additional inputs from an array of private and public partners (Laas, 2012).

With greater support from the wider malaria community, and more data available from the MDHS of 1997 and 2003, the period 2001-2010 saw renewed efforts from the NMCP. The focus of vector control activities continued to be around the colonial rationales of prioritising provincial capitals and suburbs, with some expansion based on annual malaria incidence. Emerging resistance to pyrethroids (lambda-cyhalothrin) and carbamates (bendiocarb) motivated timely replacement of insecticides for IRS, often reverting back to DDT. The LSDI project expanded to cover all of Maputo province and Gaza province in 2006. Changes in first line treatment were also made, moving from SP monotherapy to AQ-SP as the interim policy in 2002, followed by AS-SP as first line in 2006 and to AL in 2009.

Within this period (2001-2010), Mozambique successfully secured two GFATM grants that facilitated phased distribution of free LLINs across the country. The PMI support from 2007 allowed IRS to be scaled up alongside comprehensive malaria control support – consisting of LLIN distribution via ANC, APE, procurement and distribution of RDTs and ACTs, and procurement and distribution of SP. Manhiça became one of the global malaria vaccine trial sites through CISM. The second national malaria strategic plan covering 2006-2009 was developed.

Between 2011 and 2015, the third National Malaria Strategic Plan (2012-2016) helped to co-ordinate concerted efforts to control malaria. Distribution of LLINs expanded to areas that had previously not received nets and net replacement was prioritised. The period 2011-2014 saw large-scale coverage across the country with ITNs, with a total of 12 million nets delivered via mass campaigns and another five million distributed through ANCs. Emerging insecticide resistance was more carefully documented with *An. gambiae* s.s. found to remain pyrethroid sensitive, but *An. funestus s.s.* documented as resistant to all classes of pyrethroids in southern Mozambique. The years 2014 and 2015 saw the NMCP initiate more efforts in drug and insecticide efficacy monitoring across the country and pre-elimination MDA pilots also taking off, supported by CISM through the MALTEM project.

1920
Possible epidemic with rises in hospital case fatalities

1937
Foundation of the *Estação anti-malárica de Lourenço Marques* that launched sub-division of city into urban, sub-urban and rural locations monitored by "sanitary police" applying larvicides and breeding site reduction

1946
Larval control and fogging expanded to Beira city

Beginning of IRS in Mozambique, from 1946 through to 1970, using DDT. Starting with outskirts of Maputo, expanding to João Belo, Inhambane and Limpopo valley, southern Mozambique – on outskirts included larviciding; limited use of gammexane IRS and CQ or proguanil prophylaxis

1948
DDT expanded to Beira City

1960
Malaria eradication project started in Southern provinces, south of the Save (Zambezi) River, using DDT IRS, surveillance and treatment

1961
Dieldrin used briefly in River Save area

1970
IRS programmes come to an end across country

1975
Independence from Portugal

1975-1978
Reports of national use of CQ prophylaxis among school children

1977
Civil war: breakdown of malaria control until 1992

1980s
Malaria control focused only on Maputo city

1982
Programa Nacional de Controlo da Malária (PNCM) re-established

1983
CQ resistance detected

1985-1987
First trials of nets at community level in Boane

1989-1991
Field trials of permethrin impregnated wall curtains in Maputo suburbs

1990
UNICEF ITN trials in Gaza province

1992
Civil war ends

Epidemics in southern provinces with case numbers rising from between 200-300 in the first quarter of 1992 to more than 1,500 in the first quarter of 1993, as documented by Luis Franco in 1994

IRS resumed in Maputo city and Matola suburbs using lambda-cyhalothrin

1993
Trials of Cyfluthrin for IRS in Boane district

1994
IRS resumed in provincial capitals following last use in 1970s, and the sugar factories in Mafambisse and Marromeu in Sofala province, and Chinavane in Maputo province

Trials of ITN in Boane district until 1998

1999
CQ failures between 15% and 40%

Cross border Lubombo Spatial Development Initiative (LSDI) started in Namaacha, Matutuine & Matola districts in Maputo province, along with Swaziland and South Africa, using bendiocarb for IRS

2000
Wide-scale flooding in Gaza and Zambezia provinces led to ITN distribution to contain a potential epidemic

Vurhonga project using community health aides to distribute free ITN in Chokwe, Guija and Mabalane districts in Zambezia Province

Pyrethroid resistance detected at Beluluane

2001
First post-RBM National Malaria Strategy (2001-2006)

2002
Trial of intermittent presumptive treatment of infants using SP at routine EPI visits in Manhiça, completed 2004

First-line treatment changed from CQ to AQ+SP as interim policy

2003
RTS S/AS02A vaccine trial starts in Manhiça with final follow-up in 2006; Phase II trials in infants follow 2005-2007

2004
Mozambique awarded Global Fund Round 2 financing

ACT policy implemented as AS-SP

2005
Change in policy from subsidised ITNs for pregnant women to free nets for all

ITN free distribution in some districts in Sofola and Manica provinces

IRS re-started in Zambézia province using DDT in Quelimane, Nicoadala and Namacurra districts; lamdacyhalothrin in Mocuba and Morrumbala

LSDI project moves to using DDT in all four project zones of Maputo province, following documented resistance to bendiocarb

Introduction of RDTs in health facilities without laboratory / microscopy facilities

2006
Second National Malaria Strategic Plan (2006-2009) begins

IPTp with two SP doses implemented nationwide following 2005 policy decision

ACT (AS-SP) policy implemented to replace AQ+SP as first-line treatment, following 2002 decision

LSDI expands to include all of Maputo province and Gaza province

An funestus resistance to deltamethrin in Catembe and Bela Vista and lambacyhalothrin in Catembe, Catuane, Benfica

An gambiae resistance to deltamthrin in Manjacaze

2007
7% of children slept under an ITN (MIS, 2007)

PMI funds start and IRS expands into six districts in Zambazia province, from 2007-2015, starting with deltamethrin and swapping to DDT in 2008 due to resistance to deltamethrin

1.7 million nets distributed in Nampula and Inhambane provinces during 2007-2008 as part of mass Vitamin A and albendazole campaign

2008
Mozambique awarded Global Fund Round 6 financing

23% of children slept under an ITN (MICS 2008)

2009

IRS reverted to using pyrethroids and lambdacyhalothrin in selected districts

Free mass distribution for universal ITN coverage piloted in Sofala and Gaza provinces

Artemether-lumfantrine replaced AS-SP as first-line treatment

Phase III RTS S/AS02A vaccine trial start in Manhiça

5.2 million ITNs distributed nationwide using ANC clinics and small-scale distribution campaigns since 2007

An funestus resistance to deltamethin in Chokwe

An gambiae resistance to delthamethin in Inharrime

2010

62 districts nationwide targeted for IRS with a mix of insecticides through to 2015

11 of 151 districts targeted for free mass ITN distribution; 609,846 distributed via campaign and 916,150 via ANC

LSDI cross-border funding reduces subsequently reducing IRS coverage in Maputo and Gaza provinces

An funestus resistance to lambdacyhalothrin in Mugeba and Majaua

2011

Mozambique awarded Global Fund Round 9 financing

LSDI project comes to an end

Free mass ITN campaign expanded to a further 45 districts in six provinces, distributing 2.3 million nets; 961,380 via ANC

AL treatment policy rolled out nationwide following 2009 policy decision

Introduction of RDTs at community level to be used by APEs

Introduction of quality assurance of microscopy in selected laboratories nationwide increasing over years

36% of children slept under an ITN (DHS, 2011)

Integrated community case management of malaria by APES started in six districts in Zambézia

An gambiae resistance to lamdacyhalothrin in Macomia, Pemba-Metuge and Namuno

2012

National Malaria Strategic Plan (2012-2016) launched with general objective to halve morbidity and mortality from malaria compared to 2009, by 2016

Free mass ITN campaign expanded to additional 21 districts distributing 1.6 million nets; 998,046 via ANC

IRS scaled back due to funding constraints; 500,000 households reached compared to 2.5 million households in 2011

Introduction of quality assurance of RDTs at central level before distribution

An funestus resistance to lambacyhalothrin in Inhambane city and to bendiocarb in Matola

An gambiae resistance to lambacyhalothrin in Montepuez and Tete city

2013

Free ITN distributions campaign expanded to an additional 23 districts distributing 2.8 million nets; 1.2 million via ANC

Introduction of injectable artesunate nationwide

Introduction of artesunate suppositories for use by APES

2014

An. gambiae s.s. remain pyrethroid (deltamethrin) sensitive; however, *An funestsus s.s.* resistant to all classes of pyrethroids in southern Mozambique

Free ITN distribution of 5.2M in 36 districts, including replacement of 2011 nets; 1.3 million via ANC

IPTp with three or more doses

An gambiae resistance to lambdacyhalothrin in Dondo and to bendiocarb and deltamethrin in Maputo city

An funestus resistantane to lambdacyhalothrin in Lichinga

2015

Free ITN distribution of 1.8 million in 16 districts, including replacement of 2012 nets; 668,430 via ANC

MALTEM pre-elimination MDA trials in Magude

ITN durability studies in Inhambane, Tete and Nampula

An funustus to deltamethrin in Lichinga and Moatize, and lambdacyhalothron in Magude

An gambiae resistance to deltamethrin in Dondo, Tete city, Chimoio, Morumbala and Mocuba Morombala, Mocuba, Montepuez and Metuge

An gambiae resistance to bendiocarb in Magude and Boan

An gambiae resistance to DDT in Chimoio*An gambiae* resistance to lambdacyhalothrin iMaputo city, Magude, Beira, Tete City, Chimoio, Morumbala and Mocuba

An gambiae resistance to lambdacyhalothrin in Maputo city, Magude, Beira, Tete city, Morombala, Mocuba, Montepuez and Metuge

*An gambi*ae resistance to bendiocarb in Magude and Boane

An gambiae resistance to DDT in Chimoio

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6. Overview of technical methods

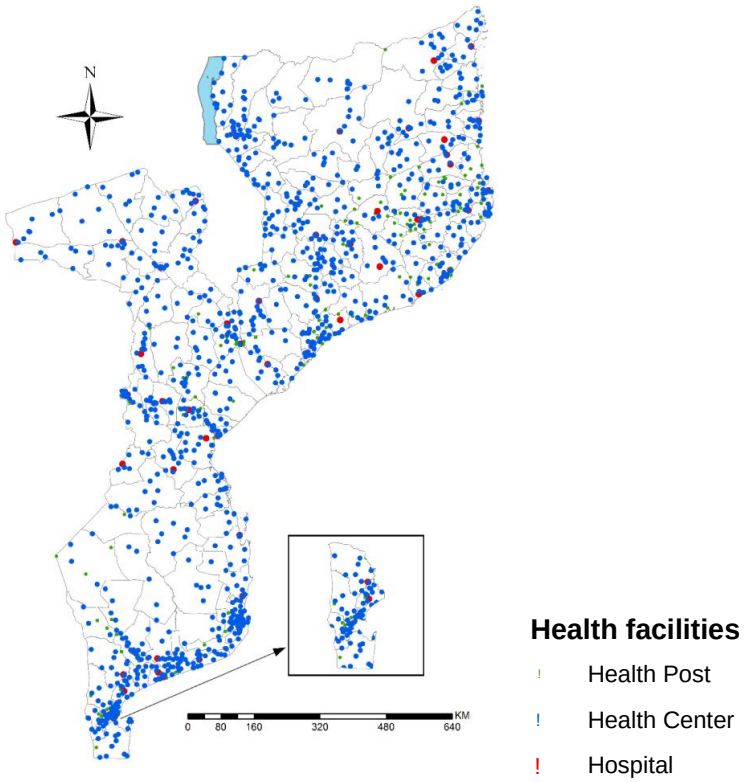
The analyses presented here draw on a series of datasets which were assembled to house information on administrative boundaries, health facility location, population, parasite prevalence and entomological data. The full digital PDF library, database and bibliography accompany this report.

6.1 Database of geolocated health facilities

Defining district level incidence has been an important part of understanding malaria risk and understanding access to care. Mozambique aims for elimination in the three Southern provinces of Maputo (including Maputo city), Gaza and Inhambane. Surveillance will be key to these ambitions. Health facility surveillance data, in addition to the parasite prevalence data, will form the basis of control-to-elimination milestones and suites of intervention packages. HMIS data provided by health facilities will be incomplete and modelling the incidence of disease presenting to facilities requires an understanding of the universe of service delivery points. To this end, a geocoded database of health service providers is key.

In Mozambique, the public health sector is a six-tiered pyramid system: *Hôpital Central, Hôpital Provincial, Hôpital Général, Hôpital Rural, Centro de Saude, Posto de Saúde*. (Figure 6.1)

Figure 6.1 Distribution of available public hospitals (red), health centres (blue) and health posts (green)



Data Source
The initial health facility lists provided by UNICEF Mozambique consisted of 10 separate excel files for each of the provinces. Information on facility type, name, location (province, district, and administrative posts) was abstracted into a single excel sheet containing 1,299 records.

A second list of health facilities was then provided by the NMCP. This list contained 1,441 health facilities with information on province, district and facility type. The facility types were abbreviated as follows: CSRUR – I, CSRUR – II, CSURB – A, CSURB – B, CSURB – C, HC, HD, HE, HG, HM, HP, HR, PS. Using existing information from the initial database, these abbreviations were defined as: CSRUR – I = *Centro de Saúde Rural Tipo 1*; CSRUR – II = *Centro de Saúde Rural Tipo 2*; CSURB – A = *Centro de Saúde Urbano Tipo A*; CSURB – B = *Centro de Saúde Urbano Tipo* B; CSURB – C = *Centro de Saúde Urbano Tipo C*.

For simplicity, the map (Figure 6.1) shows aggregated facilities in three overall classes: hospitals, health centres and health posts. Only public health facilities are included.

Summary of data cleaning
The database obtained from UNICEF had several anomalies, namely: incomplete facility name, misspelt facility names and types, duplicated facilities and missing facility names. These were corrected by looking up abbreviated names and replacing them with complete and correctly spelt names. Facilities duplicated in names only were retained as these had different coordinates and there was no lower level administrative unit to show whether these existed in the same locality or not.

One facility without a name was assigned a name through reverse geocoding, whereby its coordinates were plotted in Google Earth and the name of the village corresponding to the coordinates was used. Facilities duplicated in both name and coordinates, closed facilities, facilities offering specialised care, and other health structures including maternity centres, psychiatric hospitals and health offices were removed (n=83). Though the file had GPS coordinates, several coordinates were duplicated. Among the remaining 1,215 public facilities, 150 duplicated sets of coordinates were identified and deleted and the facilities were re-positioned. In total, 1,156 (95%) of facilities were geolocated.

The second list from the NMCP contained 1,440 health facilities, none of which was geocoded. Health facilities were geolocated using online gazetteers, such as ENCARTA, Google Earth, Geonames (http://www.geonames.org/) and Fallingrain. Coordinates were checked with the health administrative boundaries to locate those facilities that were in the wrong administrative boundary. Points along the coastline were checked using the GAUL 2008 coastline shape file. The Global Lakes and Wetlands Database (GLWD) developed by the World Wildlife Fund was used to ensure facilities were within defined land areas. We used the spatial join tool in ArcGIS (ArcMap 10.1, Esri systems, CA, Redlands) to identify facility coordinates that fell slightly off the coastline, located on a river/lake or slightly outside their correct administrative units: every anomaly was re-positioned using small shifts in combination with Google Earth. A second attempt at geocoding was undertaken using the Mozambique DHIS 2 website (http://sis-ma.in/?page_id=1327) and where there were discrepancies, GPS coordinates were prioritised.

The final database contains 1,440 verified public health facilities of which 47 (3.2%) were not geocoded. In addition, there are 181 unverified health facilities that were described as owned by the government.

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6.2 Mapping the population in Mozambique

A basic requirement for mapping malaria risk across a country is an understanding of the distribution of its population. We have built on standard approaches to distribute Mozambique's population across its geographic extent as shown in Figure 2.3 in Section 2.

Modelling techniques for the spatial reallocation of populations within census units have been developed in an attempt to (i) disaggregate population count data to a finer spatial detail and (ii) convert population count data from irregular administrative units to regular raster layers (Linard et al., 2011; 2012). Population census size estimates and the boundaries of the corresponding census enumeration unit were acquired at the highest spatial resolution from the most recently publically available census (2007). Typical regional per-land cover class population densities were estimated from African countries for which very fine resolution population data were available, following approaches previously outlined (Linard et al., 2012). These typical population densities were then applied as weightings to redistribute census counts according to the land cover and to map human population distributions at a finer spatial resolution using dasymetric modelling techniques (Mennis, 2009). The modelling method distinguishes urban and rural populations in the redistribution of populations. The population map is based on the 2007 census data resolved to the district level. The population maps could be improved if census data at smaller geographic units were available.

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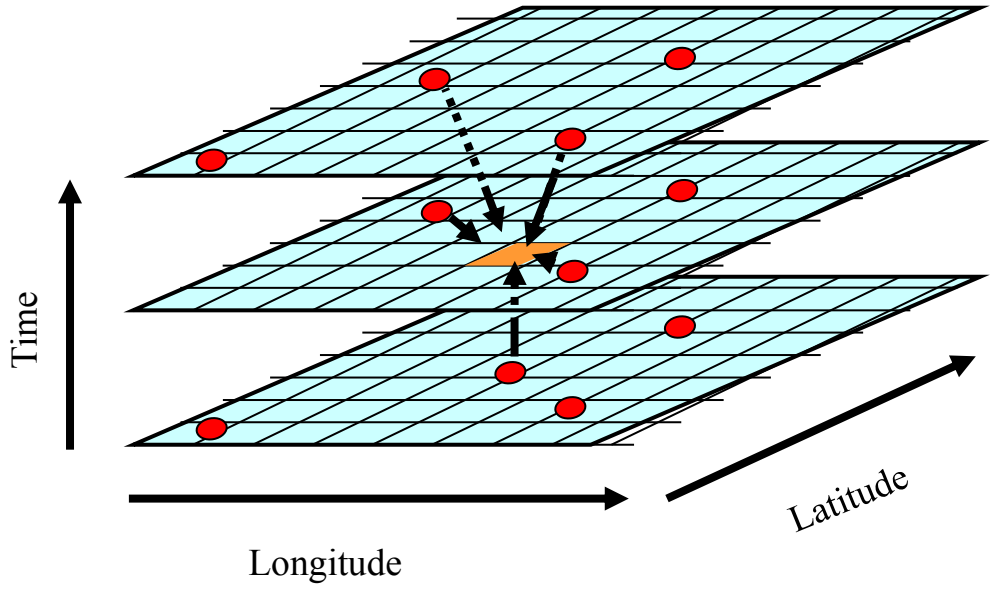
6.2.1 Space-time geostatistical modelling

Geostatistical methods were developed to interpolate from data at sampled locations in space and time to provide predictions of quantities at locations and times where data did not exist. All model-based geostatistical (MBG) methods operate under Tobler's First Law of Geography (Figure 6.2), which states that things that are closer in space and time are more similar than those more spatially and temporally distal (Tobler, 1970). When applied with a Bayesian inference framework, these methods are referred to as MBG methods. Bayesian inference allows for better use of sparse data and through the application of prior knowledge of an outcome in an iterative process. Model-based geostatistical methods allow for robust estimation of uncertainties around the estimates of the outcome.

Figure 6.2 Space-time geostatistical models of *P. falciparum* transmission intensity



Each blue grid represents a geographic space at one of three time points. The red dots represent positions and time for which *P. falciparum* parasite prevalence data are available. The small orange square represents a position and time of interest, but for which no data exists. The black arrows indicate that the data points surrounding (in time and space) the square of interest are used to predict the likely parasite prevalence in the orange square.

The procedures used to assemble, geocode, archive, model and validate the transformation of empirical *P. falciparum* parasite prevalence data to continuous predictions of age-corrected mean prevalence in children aged 2-10 years (*Pf*PR_{2-10}) are provided by Noor (2014), Snow et al (2015) and Snow and Noor (2015). In brief, we used information from available age-corrected survey data (sample size and numbers positive) at known locations (longitude and latitude) and times (year) with a minimal set of conservative, long-term covariates traditionally used in vector-borne disease mapping. These were brought together in a Bayesian hierarchical space-time model, implemented through an adapted Stochastic Partial Differential Equations (SPDE) approach using Integrated Nested Laplace Approximations (INLA) for inference (www.r-inla.org; Rue et al., 2009) to produce continuous maps of *Pf*PR_{2-10} at 1 km x 1 km spatial resolutions.

Estimating precision

A spatially and temporally de-clustered 10% of the P*f*PR_{2-10} data was held out for model validation. Model accuracy was estimated by computing three variables based on the observations and predictions of the holdout dataset: (i) the linear correlation, which quantifies the strength of the linear relationship between the observed and predicted values for the 10% validation data; (ii) the mean prediction error (MPE), a measure of the bias of predictions (the overall tendency to over or under predict); and (iii) the mean absolute prediction error (MAPE), a measure of overall precision (the average magnitude of error in individual predictions). Covariates were not used in mapping P*f*PR_{2-10} in Mozambique.

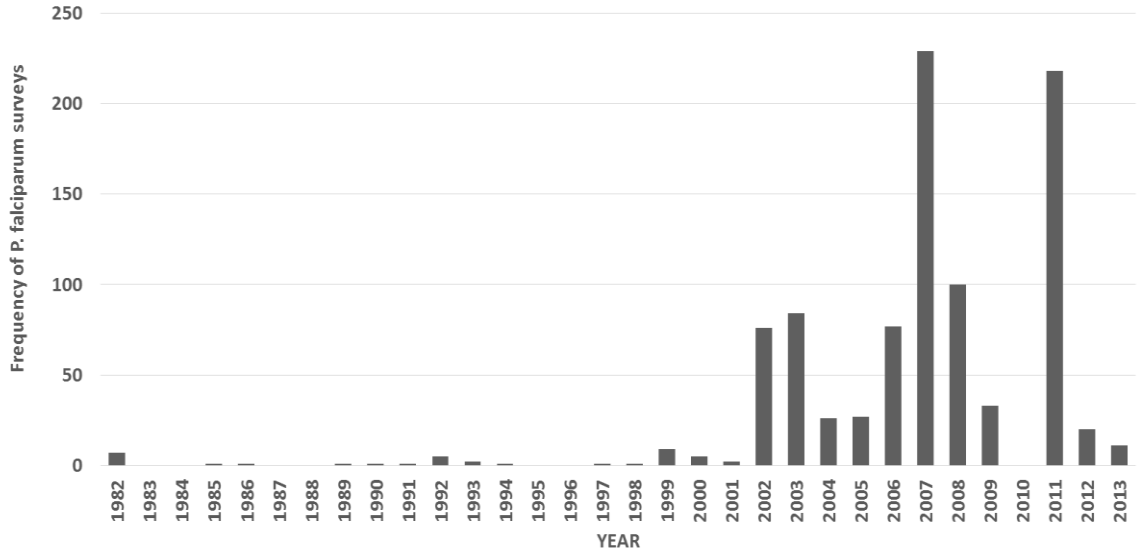
The coefficient of variation (CV) is defined as the ratio of the standard deviation to the mean (Kirkwood, 1979). It has no measurement units and is an indicator of the magnitude of

variability in relation to the mean or dispersion in data or estimates of a variable. One disadvantage of the CV is that where the mean is equal to zero, it approaches infinity and is therefore sensitive to small changes in the mean. In such a case, the standard deviation should be used to describe the uncertainty of the model predictions.

6.2.2 Malaria prevalence survey data in Mozambique

We assembled community-based surveys of malaria parasite prevalence from a variety of sources. These included peer-reviewed journals, international and national ministry of health and academic archives, personal correspondence and more recent national household survey samples. The detailed methods used to identify, extract and geocode survey reports are presented elsewhere (Noor et al., 2014; Snow et al., 2015).

Figure 6.3 Mozambique: malaria parasite prevalence surveys by year 1982-2013. MIS = malaria indicator survey



A total of 1,012 malaria prevalence surveys undertaken between 1982 and 2013 were identified in time and space through the data search process. Four surveys were excluded because data could not be disaggregated below the regional level. A total of 73 surveys were excluded because their sample sizes were less than 10 individuals. The remaining 939 surveys are shown by year in Figure 6.3.

The data volumes to make reliable spatial predictions are temporally sparse between 1982 and 2002. We have therefore elected to only use data from the most data-rich period, 2002-2013 (n = 902). These data include the national household surveys of 2007 and 2011. Other survey data were obtained from smaller-scale studies. Microscopy was used for parasite detection in 592 surveys and the rest used RDTs. A complete excel database of all geocoded surveys was provided for the NMCP alongside this report.

6.2.3 Malaria vector data in Mozambique

We have used historical archives and published sources, increased the documentation of potential secondary vectors and sourced more recent unpublished data from scientists and control agencies working in Mozambique. Full details of the data assembly, geocoding methods and classifications of species according to their role in malaria transmission are provided elsewhere (Snow et al., 2015). The database has been arranged as a site-specific, referenced

inventory to capture details of species identification recorded since the earliest surveys in 1900 through to the latest records in 2014. The full digital PDF library, database and bibliography accompanies this report.

From each identified report, data extraction included whether a species was identified at a given site, methods used to capture adults or larvae and the methods used to speciate each anopheline collection. "Y" was recorded if a species was identified and "N" was only recorded when the absence of the species was reported. The database is therefore one of species presence, not absence or proportional presence of the different vectors.

We have not assembled geocoded information related to vector resistance. These data have been carefully curated, validated and mapped by the IRBase initiative (Knox et al., 2014; www.irmapper.com).

6.2.4 ITN/LLIN coverage mapping

Typically, national household surveys are designed to be precise at national and regional levels and rarely at lower levels, such as districts. Simply aggregating survey data to provide district level estimates of an outcome of interest will lead to values of low precision. Small Area Estimation (SAE) methods handle the problem of making reliable estimates of a variable at these units under conditions where the information available for the variable, on its own is not sufficient to make valid estimates (Rao, 2003; BIAS, 2007).

We used hierarchical Bayesian spatial and temporal SAE techniques using a geoadditive regression approach (Banerjee et al., 2004; Best et al., 2003) to estimate the proportion of the population in each health district sleeping under an insecticide treated net (ITN) the night before the survey. This was done by health district for the years 2005, 2008-9 and 2010-11 and 2012-13. This method uses survey data from a health district and neighbourhood information from adjacent districts to smooth values at the health district level.

Covariates were not used in this approach. However, if information on the distributions of ITNs by month were to become available for each health district, this would improve the precision of the estimates.

7. Mapping malaria risk

Figure 7.1 shows the locations of the 901 *P falciparum* parasite prevalence (P*f*PR) survey data points reported between 2002 and 2013. The data were age-corrected to reflect the prevalence in 2-10 year olds ($Pf PR_{2-10}$). These data points are split into their respective time periods in Figure 7.2.

Figure 7.1 Location of 901 age-corrected parasite prevalence data (P*f*PR2-10) in 2002-2013 (Green=zero: light orange >0 - <5%: dark orange >= 5%)

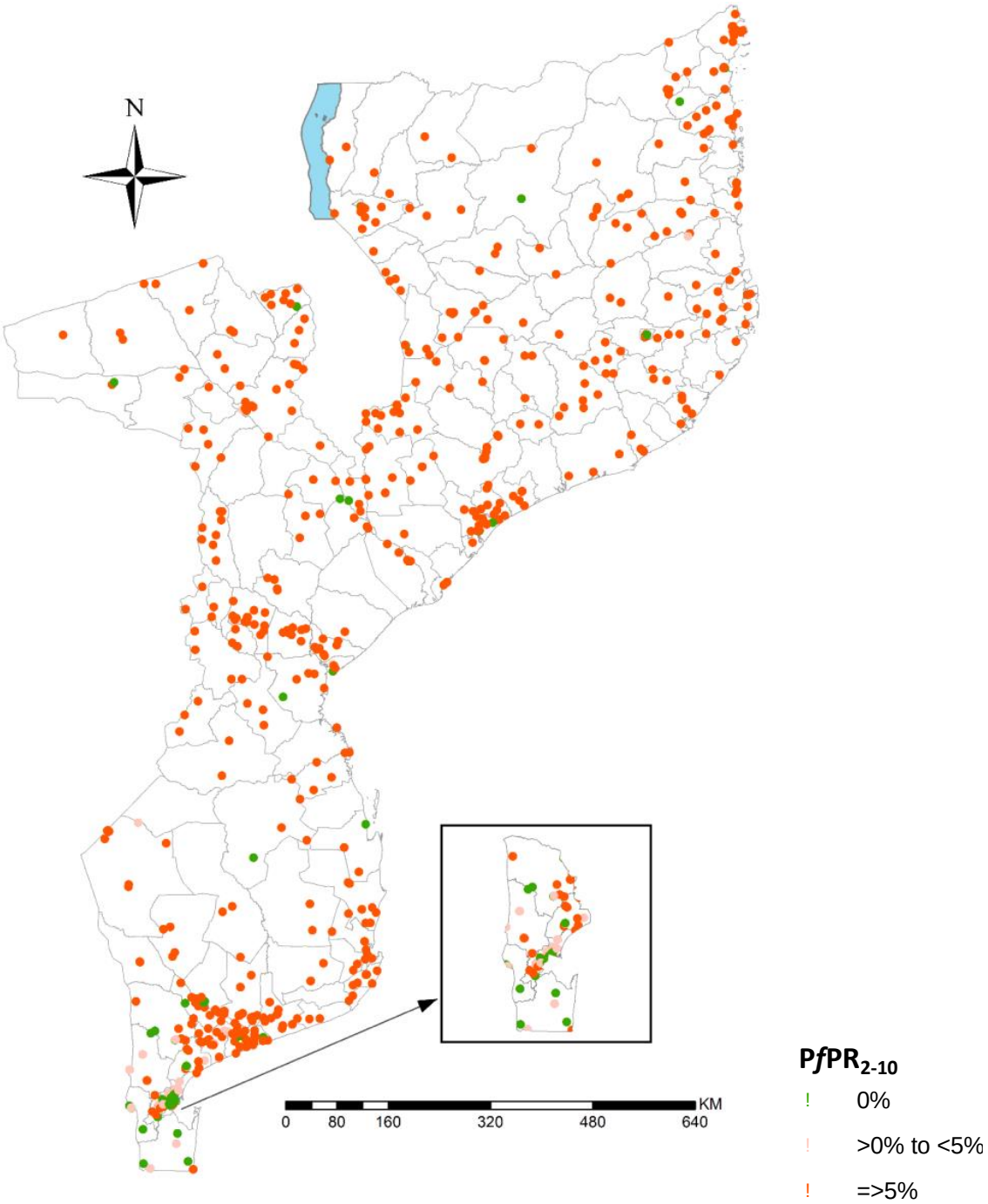
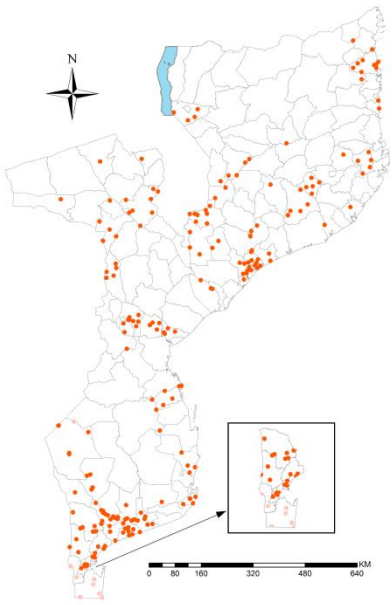
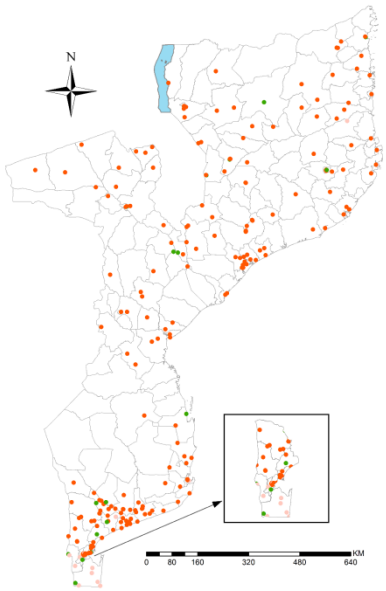


Figure 7.2 Location of age-corrected parasite prevalence data P*f*PR$_{2-10}$ (green=zero: light orange >0 - <5%: dark orange >= 5%)

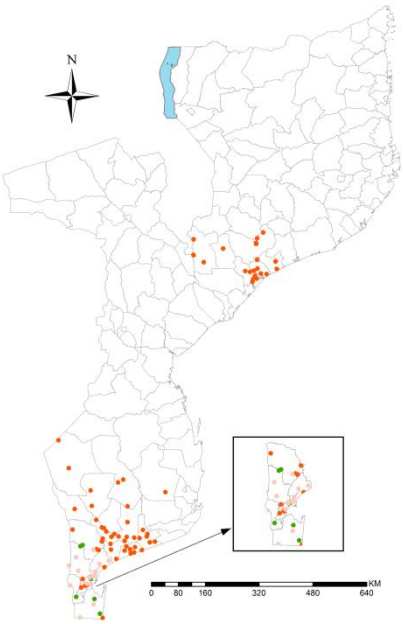
Location of 290 age-corrected parasite prevalence data (P*f*PR $_{2-10}$) in 2002-2006



Location of 229 age-corrected parasite prevalence data (P*f*PR $_{2-10}$) in 2007



Location of 133 age-corrected parasite prevalence data (P*f*PR $_{2-10}$) in 2008-2009



Location of 249 age-corrected parasite prevalence data (P*f*PR $_{2-10}$) in 2011-2013

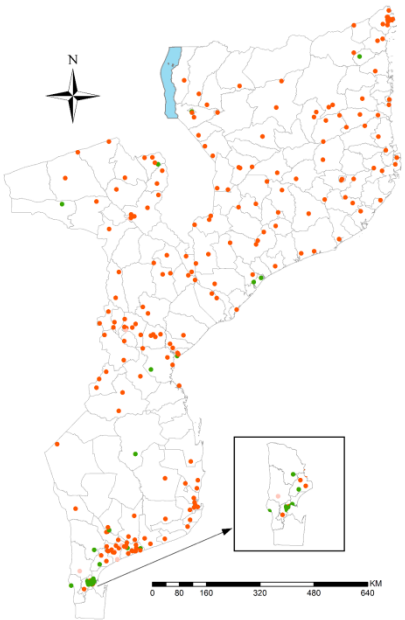


Figure 7.3 shows the evolution of malaria risk, reflected by the P*f*PR$_{2-10}$, between 2002 and 2011. The accompanying pie charts reflect the marked changes in the proportions of the population living at different levels of malaria risk. In 2002, no districts had a population adjusted P*f*PR$_{2-12}$ (PAP*f*PR$_{2-12}$) less than 5%. By 2007, 2.6% of the population were living in areas with a PAP*f*PR$_{2-12}$ of <5%, and this proportion increased to 7.1% in 2011.

At the other end of the malaria risk spectrum, the proportion living in areas with a PAP*f*PR$_{2-12}$ of >50% fell from 27.6% in 2002 to 9.0% in 2007, with a modest increase to 14.7% in 2011. Similar patterns of change were seen for populations living in areas with a PAP*f*PR$_{2-12}$ of 30%-50% and 10%-30%. It is noteworthy that the increase in risk between 2007 and 2011 was most pronounced north of the Zambezi, whereas the southern districts of Magude, Matutuine, Moamba and Namaacha in Maputo province experienced a progressive decline in malaria risk.

Figure 7.3 Population adjusted P*f*PR$_{2-10}$ prediction by health district

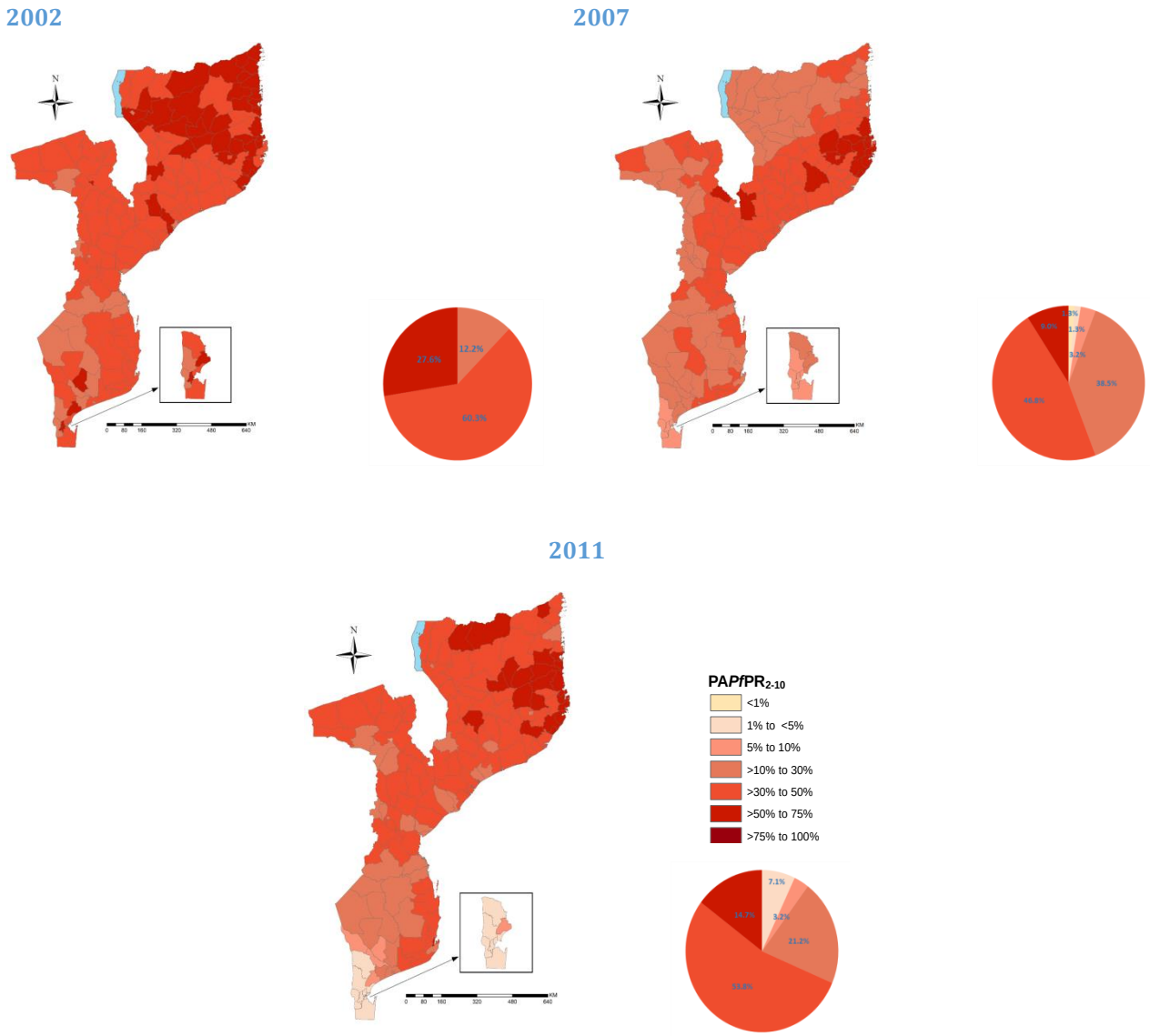
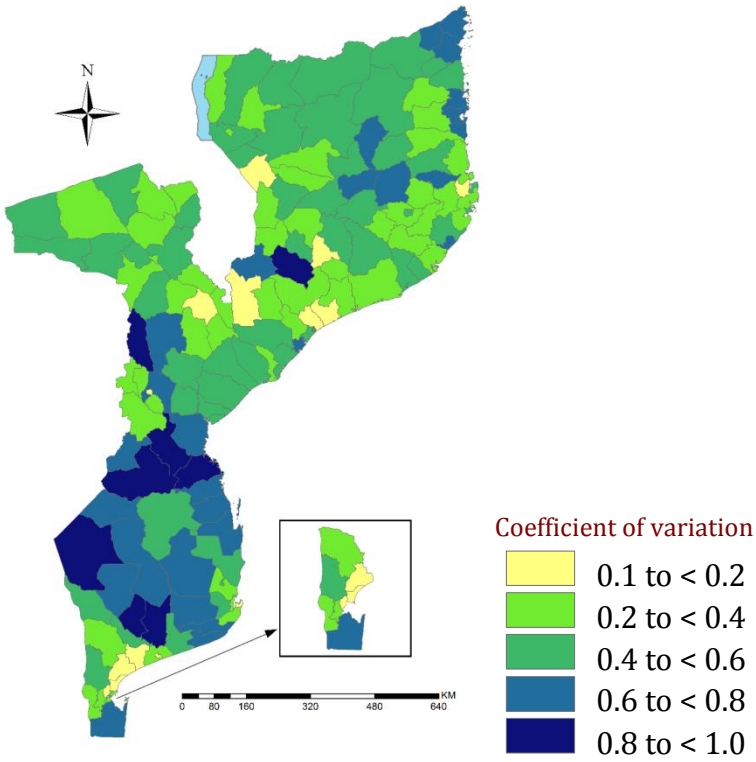


Figure 7.4 P*f*PR$_{2-10}$ model precision – the coefficient of variation (ratio of standard deviation to mean) as a measure of uncertainty



The population adjusted 2014 P*f*PR$_{2-10}$ model was validated as described earlier ("Estimating Precision" in Section 6.2.1 – Space-time geostatistical modelling).

Estimates were computed from a comparison of the predictions and observations for a 10% "hold out" dataset. The precision parameter estimates were a linear correlation of 0.82, a mean percentage error (MPE) of -0.45%; and a mean absolute percentage error (MAPE) of 5.3%. These statistics suggest good prediction accuracies.

Generally, low coefficient of variation (CV) values suggest that the standard deviations around the mean are relatively small, whereas high values may indicate increasing model uncertainty (Noor et al., 2012). In Mozambique, the upper limit of the CV values is less than 1 (Figure 7.4), indicating that in most districts predictions of PA*Pf*PR$_{2-10}$ are of good precision. The highest CV values appear to be in the lower transmission but sparsely populated districts of the south. To improve the precision of estimates for these districts, future surveys could consider over-sampling in these districts. Alternatively, household surveys could be supplemented with school parasitaemia surveys.

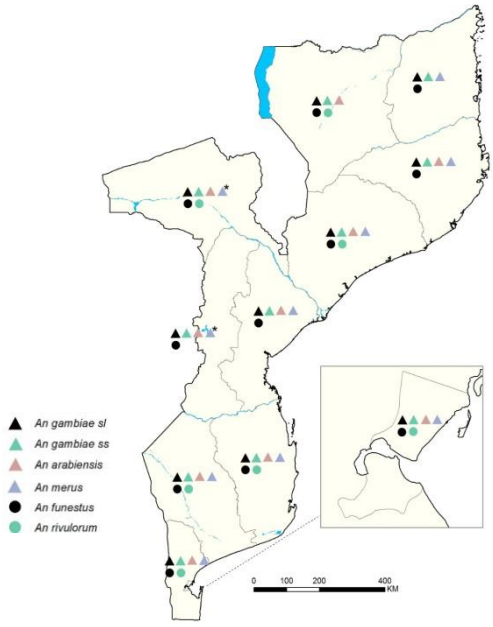
8. Entomological profile

We used historical archives and published sources, and sourced more recent unpublished data from scientists and control agencies working in Mozambique to increase the documentation of potential secondary vectors. Full details of the data assembly, geocoding methods and classifications of species according to their role in malaria transmission are provided elsewhere (Snow et al., 2015). The database has been arranged as a site-specific, referenced inventory to capture details of species identification recorded since the earliest surveys in 1900 through to the latest records in 2014. The full digital PDF library, database and bibliography accompanies this report.

The final entomological database included 269 site/time specific reports of disease vector species between 1900 and 2014. We were unable to geolocate two sites. Of the 267 geolocated sites, 41 (15.4%) dated from after 2005.

The presence of the *An. gambiae* complex and members of the *An. funestus* group are sympatric across the entire country (Figure 8.1). Among the *An. gambiae* complex, *An. gambiae ss, An. arabiensis* and *An. merus* have been recorded in all provinces except two northern (Niassa and Cabo Delgado) Provinces where *An. merus* and *An. arabiensis* (respectively) have not been reported. *An. gambiae s.s.* (M form (*An. coluzzi*) has not been reported in Mozambique at all, whereas the S form has been reported in all 11 provinces.

Figure 8.1 Reported vector species by province



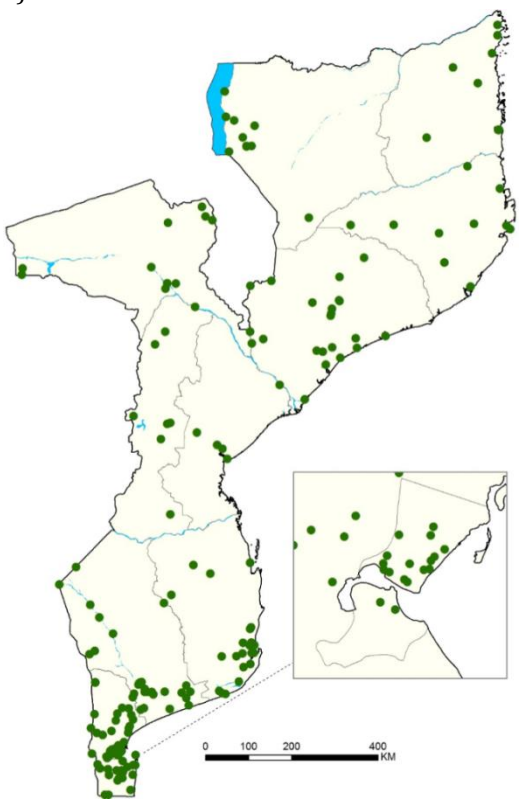
Despite being a salt water breeding vector, *An. merus,* has been described hundreds of kilometres inland in Mambone (Manica province) and Mazoe (Tete province) (shown with asterixs in Figure 8.1).
These were determined by CBS (chromosome banding sequence) and Enzyme electrophoresis and PCR (Mahon et al., 1976; Cuamba and Mendis, 2009).

An. moucheti group and *An. hancocki* have not been described in Mozambique. Members of the *An. nili* group have been described in Maputo province, and at single sites in in Nampula, Tete and Zambezia provinces.

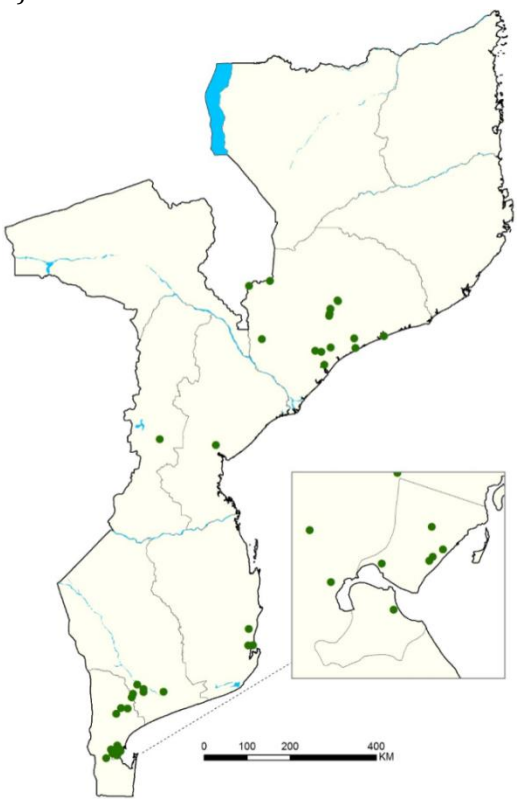
Reports since 1900 of other Anopheline species include *An. Marshalli*; the potential secondary vectors *An. Pharoensis*, *An. Coustani*, *An. rufipes s.l.* and *An. Squamosus*; and the following species not implicated in transmission: *An brunnipes, An confusus, An theileri*, *An demeilloni, An cydippis, An cinereus, An leesoni, An longipalpis, An seydeli, An maculipalpis, An rhodesiensis, An natalensis, An theileri, An maculipennis, An multicolour, An tenebrosus, An listeria, An wellcomei, An ziemanni*.

Figure 8.2 Site locations of entomological surveys describing anopheline species undertaken between 1900 and 2014

a) 1900-2004



b) 2005-2014



9. Intervention coverage

9.1 Insecticide treated mosquito nets (ITN) and long lasting ITN (LLIN)

From January 2012 to June 2015, data on distribution of LLINs by district were obtained from the NMCP. Over this period LLINs have been distributed through routine and mass distribution channels. The maps below depict nets delivered through mass distribution.

Figure 9.1 Total number of LLINs distributed from 2012-2015

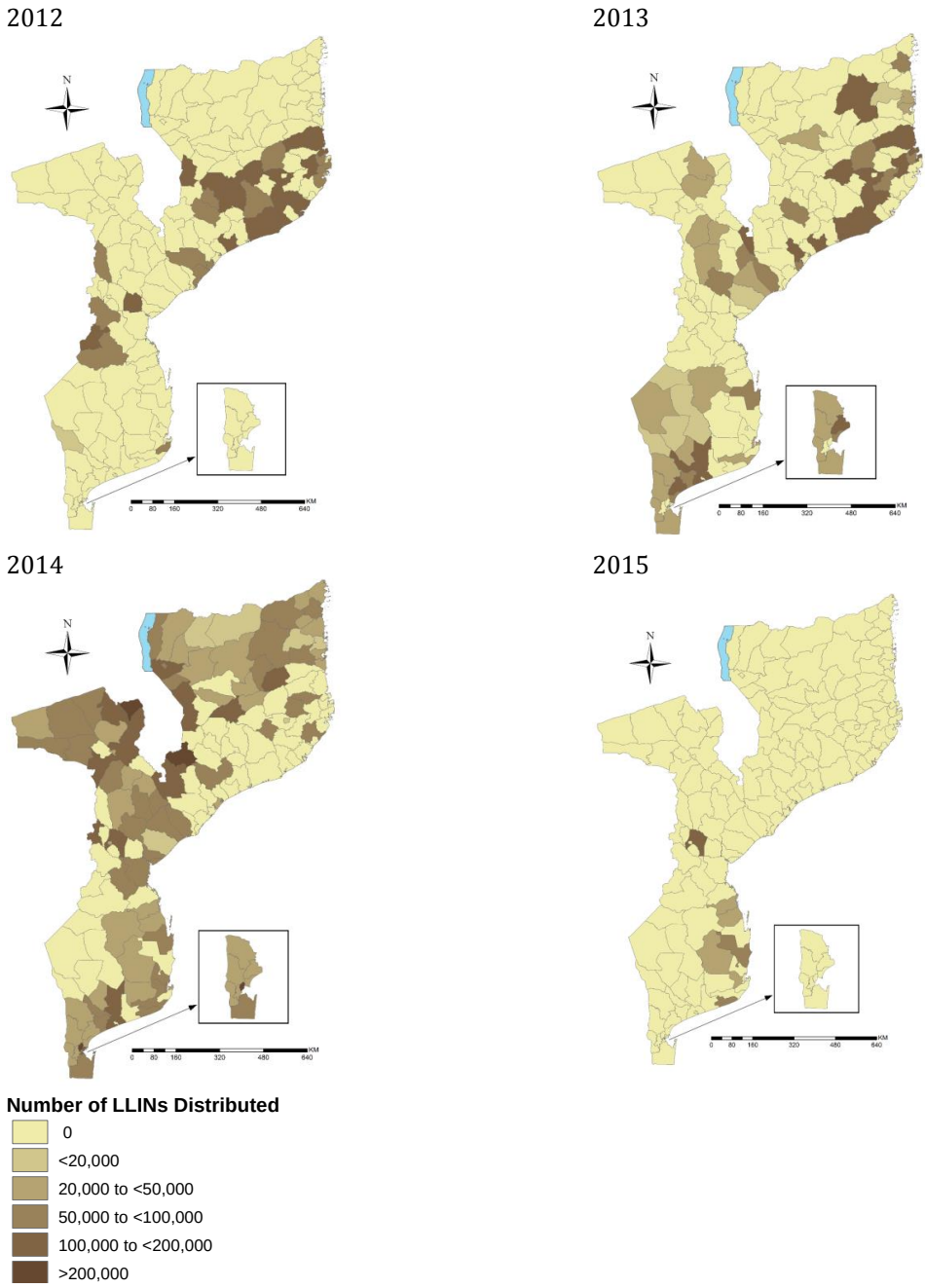
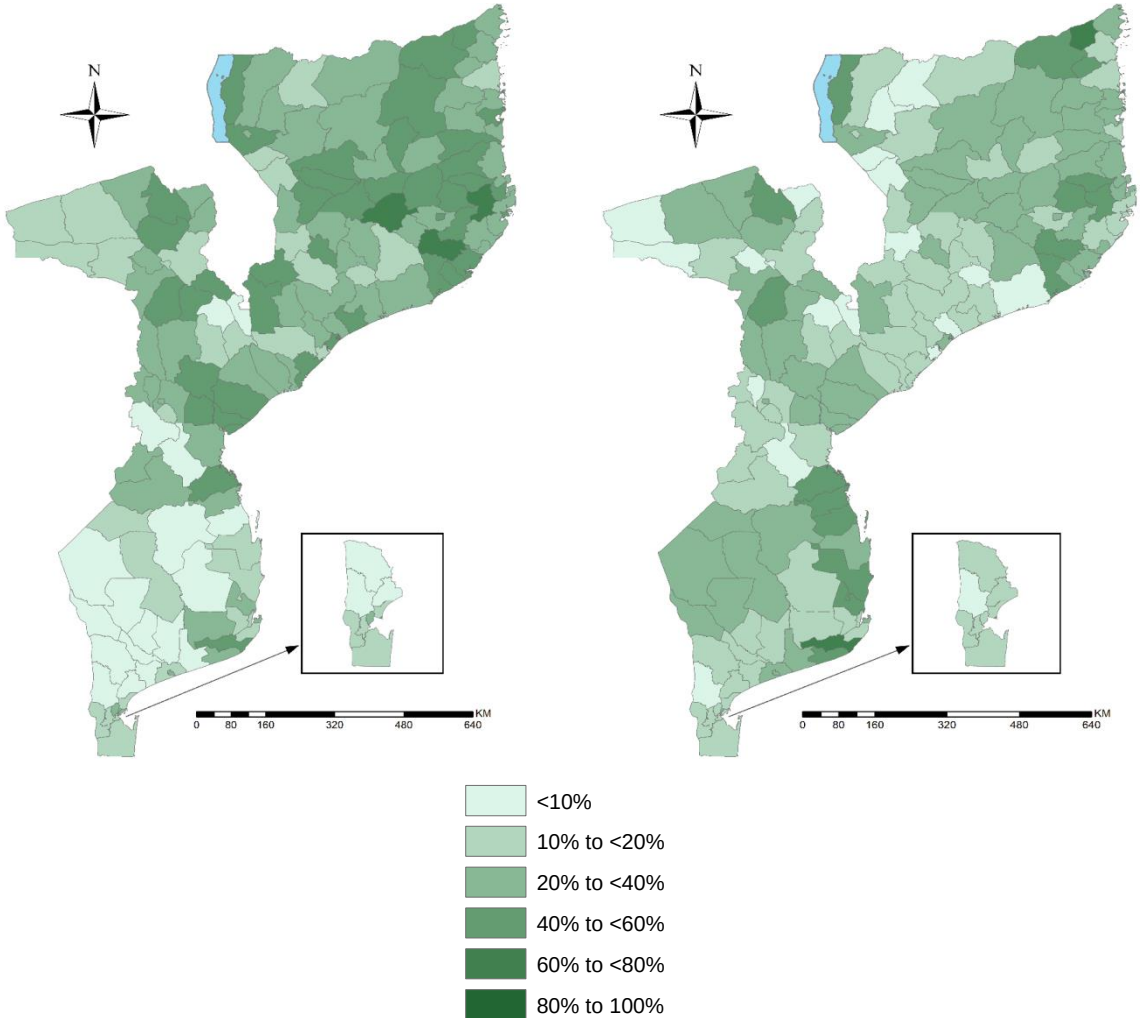


Figure 9.2 shows two indicators of ITN coverage – ITN use and an indicator of universal coverage – by health district, for 2011.

Figure 9.2 Proportion of population sleeping under ITN and households with at least one ITN per two people in 2011

a) Population sleeping under ITN

b) Proportion of households with one net for every 2 persons



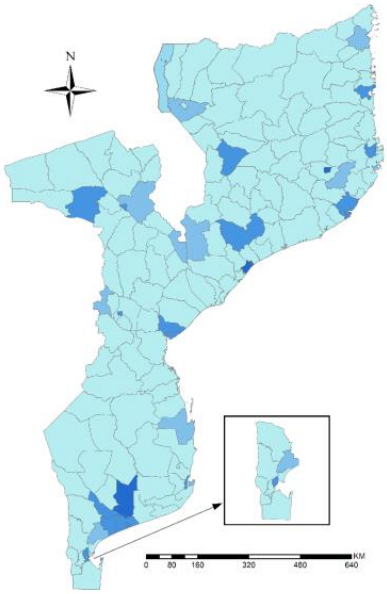
9.2 Indoor residual spraying

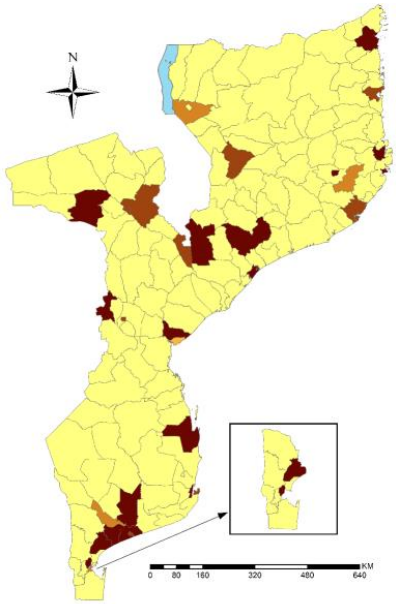
Figure 9.3 shows the districts targeted for indoor residual spraying (IRS) since 2004. IRS has a long history in Mozambique and has been scaled up over the last 10 years.

Data by year from 2004 on the number of households – and population – targeted, and the number of households (and population) covered with IRS were provided by the NMCP. The maps show the number and percentage coverage of households targeted for IRS by year. For some years, data were combined for every two cycles if they were done at the end of one year and beginning of the next.

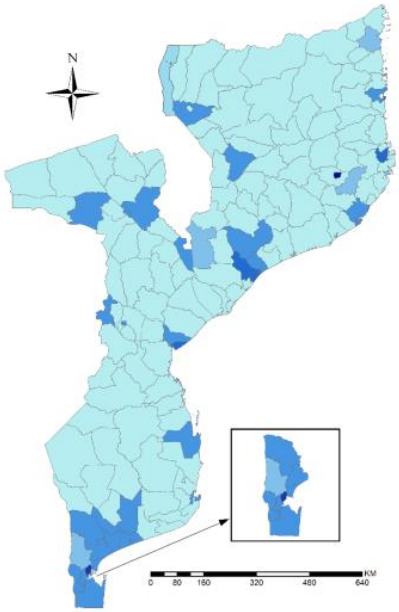
Figure 9.3 Indoor residual spraying (IRS) in Mozambique 2004-2014

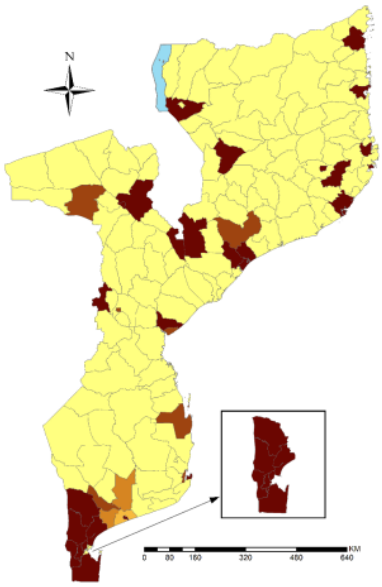
Indoor residual spraying (IRS) in 2004-2005



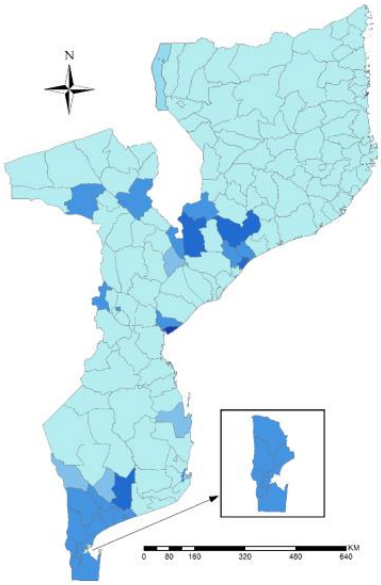


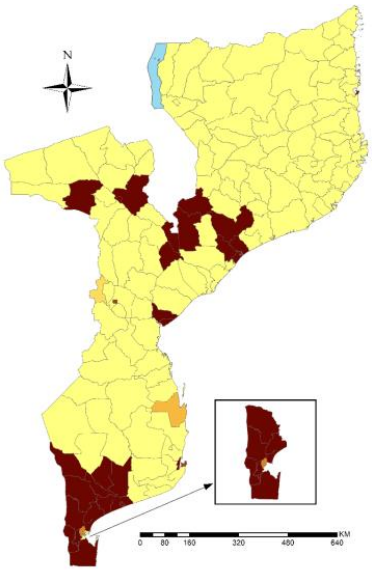
Indoor residual spraying (IRS) in 2005-2006



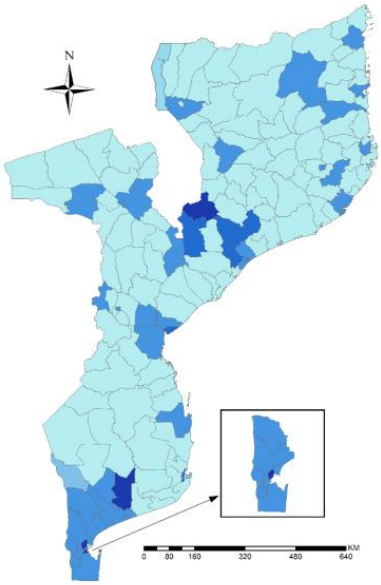


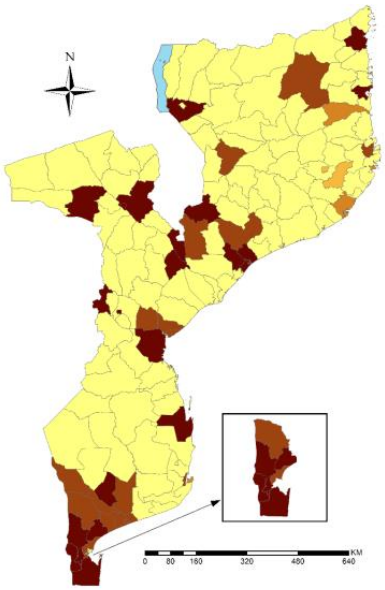
Indoor residual spraying (IRS) in 2006-2007



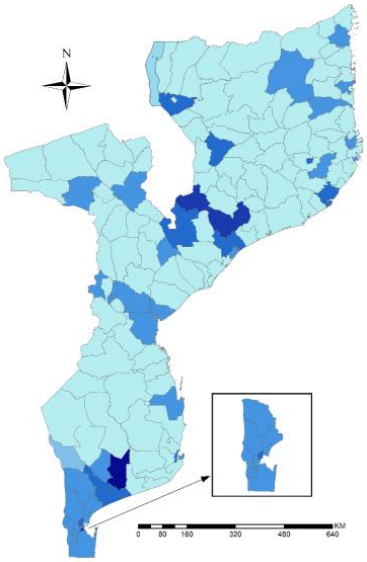


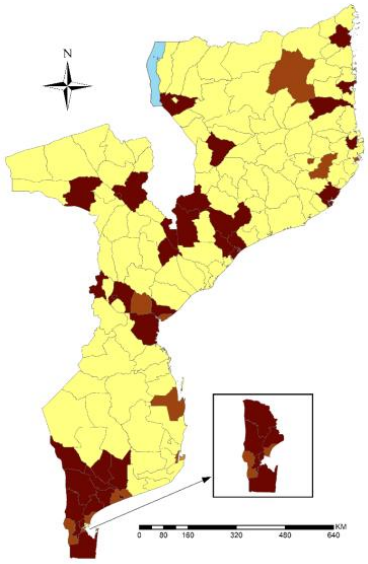
Indoor residual spraying (IRS) in 2008



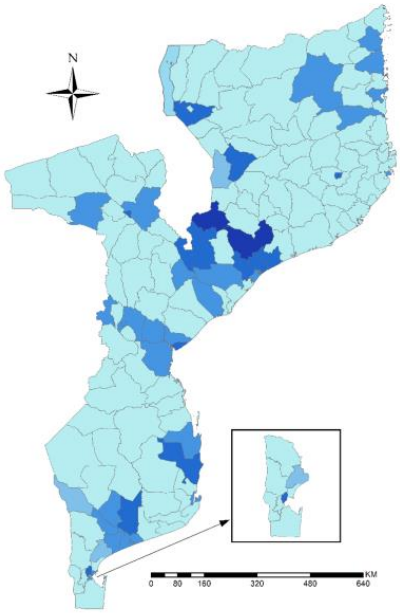


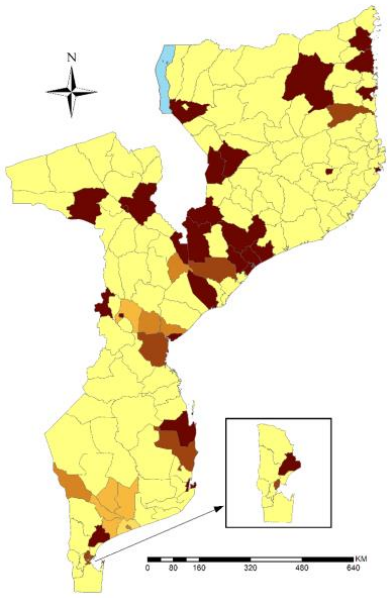
Indoor residual spraying (IRS) in 2009



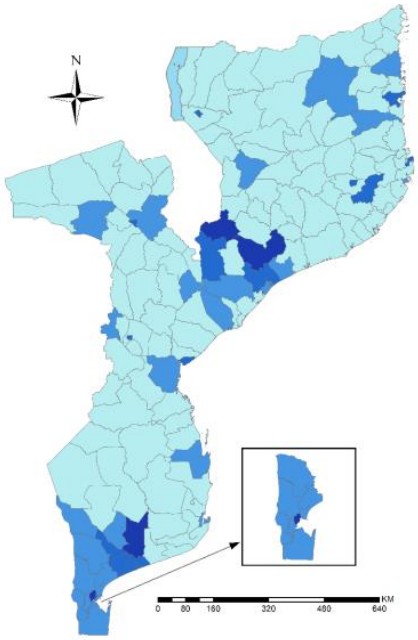


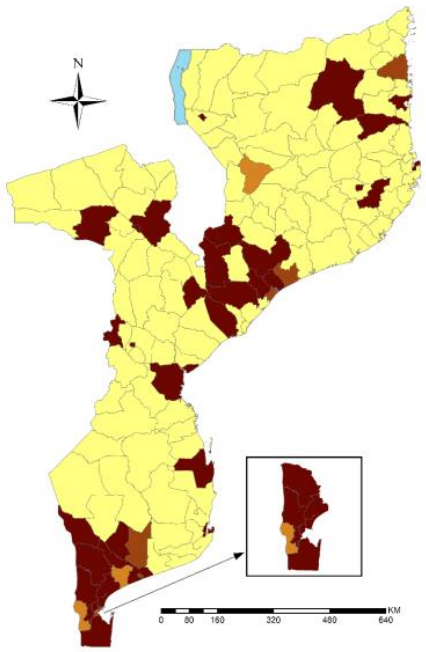
Indoor residual spraying (IRS) in 2010



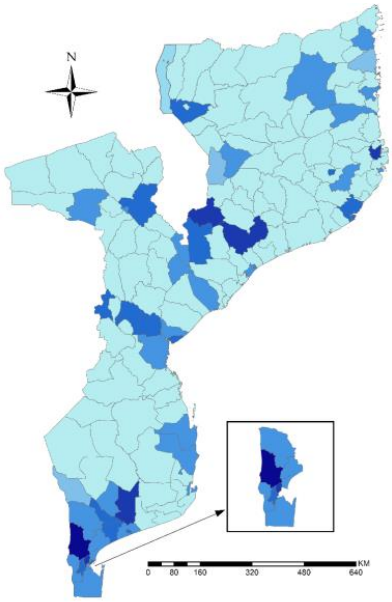


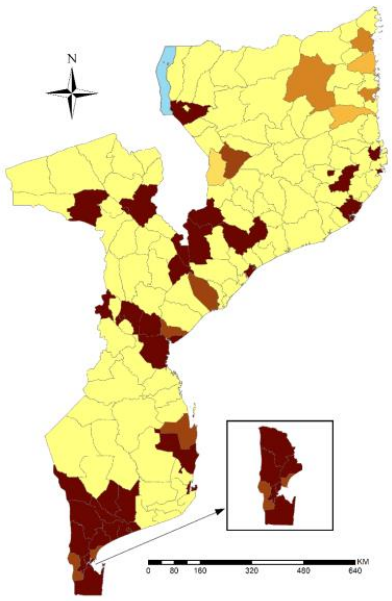
Indoor residual spraying (IRS) in 2011-2012



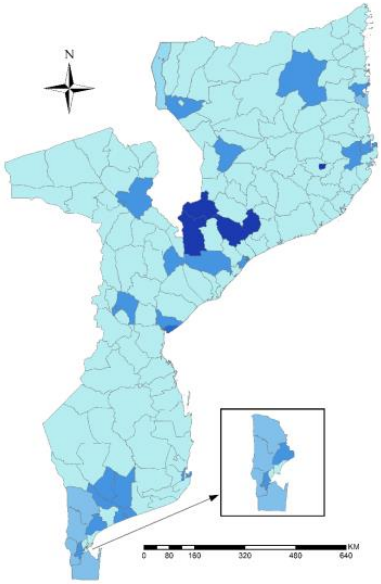


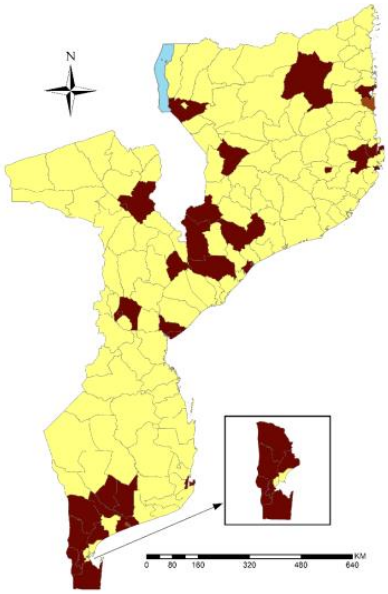
Indoor residual spraying (IRS) in 2013-2014





Indoor residual spraying (IRS) in 2014





Number of households under IRS

- 0
- 1 to <10,000
- 10,000 to <50,000
- 50,000 to <100,000
- 100,000 to <200,000
- 200,000 to 300,000

Percentage IRS coverage

- 0%
- >0% to <20%
- 20% to <40%
- 40% to <60%
- 60% to <80%
- 80% to 100%

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