

SIERRA LEONE: A PROFILE OF MALARIA CONTROL AND EPIDEMIOLOGY



DECEMBER 2015



INFORMATION FOR MALARIA

LONDON
SCHOOL of
HYGIENE
& TROPICAL
MEDICINE



Dados para informar decisões sobre malária



ACKNOWLEDGEMENTS

We acknowledge all those who have generously assisted with collecting and collating information, providing access to unpublished data, and reviewing the products, especially: Astrid Knoblauch, Edward Magbity, Mark Divall, Matthew Burns, Maru Aregaqi, Musa Sillah-Kanu, Samuel Juana Smith, Thomas Ansumana

The report was prepared by the LINK Programme Team at the London School of Hygiene and Tropical Medicine (David Schellenberg, Sarah Saleheen, Debora Miranda), the Information for Malaria (INFORM) team at the KEMRI-Wellcome Trust programme, Nairobi (Abdisalan Mohamed Noor, Robert Snow, Lukio Olweny, David Kyalo, Peter Macharia, Paul Ouma, Ezekiel Gogo, Joseph Maina, Stephen Oloo, Thomas Gachie and Fridah Karimi) who assembled the data and performed the analyses and modeling and the National Malaria Control Programme of Sierra Leone

The authors acknowledge the support and encouragement of Alastair Robb of the UK government's Department for International Development (DFID).

This work was supported by funds provided by DFID-UK to the LINK programme and by grants from The Wellcome Trust, UK to Professor Bob Snow (#079080) and Prof Abdisalan Mohamed Noor (#095127).

Suggested citation: NMCP, INFORM and LSHTM (2015). Sierra Leone: A Profile of Malaria Control and Epidemiology.

ABBREVIATIONS

ACT	Artemisinin Combination Therapy
ADB	African Development Bank
AL	Artemether-Lumefantrine
ANC	Ante-Natal Clinic
AQ	Amodiaquine
AQ-SP	Amodiaquine – Sulphadoxine pyrimethamine
AS	Artesunate
AS-SP	Artesunate – Sulphadoxine pyrimethamine
BIC	Bayesian Inference Criteria
CBP	Community-based practitioners
CBS	Chromosome Banding Sequence
CDC	Centers for Disease Control
CHAI	Clinton Health Access Initiative
CHW	Community Health Worker (APE)
CI	Confidence Interval
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
DHMT	District Health Management Team
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
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
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
IPT	Intermittent Presumptive Treatment
IRS	Indoor Residual Spraying
ITN	Insecticide Treated Nets
LLINs	Long Lasting Insecticidal Nets
LMIS	Logistics Management Information System
MAPE	Mean Absolute Prediction Error
MARA/ARMA	Mapping Malaria Risk in Africa
mASL	Metres Above Sea Level
MBG	Model Based Geo-Statistics
MDA	Mass Drug Administration
MDG	Millennium Development Goals
MeSH	Medical Subject Headings
MICS	Multiple Indicator Cluster Survey
MIS	Malaria Indicator Survey
MODIS	MODerate-resolution Imaging Spectroradiometer
MoHS	Ministry of Health and Sanitation
MPAC	Malaria Policy Advisory Committee
MPE	Mean Prediction Error
MPR	Malaria Programme Review
NFM	New Funding Model
NMCP	National Malaria Control Programme
NMSP	National Malaria Strategic Plan
NPPU	National Pharmaceutical Procurement Unit
OA	Open Access
ODA	Overseas Development Assistance
OR	Operational Research
PAPfPR ₂₋₁₀	Population adjusted PfPR ₂₋₁₀
PCR	Polymerase Chain Reaction
PDP	Product Development Partnership
PfPR ₂₋₁₀	Age-corrected <i>Plasmodium falciparum</i> parasite rate
PSM	Procurement and Supply Chain Management
R&D	Research and Development
RBM	Roll Back Malaria
RDTs	Rapid Diagnostic Tests
SD	Standard Deviations
SLMIS	Sierra Leone Malaria Indicator Survey
SP	Sulphadoxine-Pyrimethamine
SPA	Service Provision Assessment
SPDE	Stochastic Partial Differential Equations
SR	Sub-recipient (GFATM)
SRTM	Shuttle Radar Topography Mission
TFR	Total Fertility Rate
TPR	Test Positivity Rate
TSI	Temperature Suitability Index

U5MR	Under 5 Mortality Rate
UN	United Nations
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
VPP	Voluntary Pooled Procurement
WHO	World Health Organization

CONTENTS

1. INTRODUCTION	9
2. COUNTRY CONTEXT	11
• Location, geographic features and population	11
• Administration	15
• The health system	17
i. Health system structure	17
ii. Health context and priorities	20
• Malaria in Sierra Leone	21
• Structure and function of the National Malaria Control Programme	22
• Financing malaria control	23
• Data for malaria control	24
• Supply chain overview	26
• Drug & insecticide safety and efficacy monitoring	27
• Operational and implementation research	28
• Malaria mapping in Sierra Leone	29
• Ebola in Sierra Leone	30
3. A TIMELINE OF MALARIA CONTROL IN SIERRA LEONE	31
4. OVERVIEW OF TECHNICAL METHODS	39
• Space-time geo-statistical modelling	39
• Malaria prevalence survey data in Sierra Leone	41
• Malaria vector data in Sierra Leone	42
• ITN coverage mapping	42
5. MALARIA RISK MAPPING	45
6. ENTOMOLOGICAL PROFILE	49
7. INTERVENTION COVERAGE	53
• Insecticide treated mosquito nets	53
• Indoor residual spraying	58
• Mass drug administration	60
8. RECOMMENDATIONS	63
9. USB DRIVE CONTENTS	65

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. Over 50 years ago, the infection prevalence among children aged 2-10 years (PfPR2-10) was recognised as one important source of planning data and was used to define categories of endemic risk. These were used to guide and monitor progress toward 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 agenda for malaria control 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^{1,2} and over the last decade there has been enormous growth in spatial data on malaria and populations. This had not been available to malariologists or programme control managers 60 years ago. 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 Geo-Statistics (MBG)³.

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^{4,5}. 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.

The Sierra Leone Malaria Control Performance Review (MPR) of 2014 included the following action points:

- Conduct entomological studies preferably after the mass campaign in 2014 and regularly
- Update the malaria stratification in Sierra Leone
- Strengthen use GIS for routine mapping of morbidity, mortality and intervention coverage for decision making.

This epidemiological profile of malaria in Sierra Leone attempts to assemble a brief history of malaria control in the country and the epidemiological evidence base for a more targeted approach to malaria control. It draws together data on parasite transmission risk from household surveys, the distribution

¹ Snow RW, Marsh K, le Sueur D (1996). The need for maps of transmission intensity to guide malaria control in Africa. *Parasitology Today*, 12: 455-457

² Snow RW & Noor AM (2015). Malaria risk mapping in Africa: The historical context to the Information for Malaria (INFORM) project. Working Paper in support of the INFORM Project funded by the Department for International Development and the Wellcome Trust, Nairobi, Kenya June 2015; <http://www.inform-malaria.org/wp-content/uploads/2015/07/History-of-Malaria-Risk-Mapping-Version-1.pdf>

³ Diggle PJ & Ribeiro PJ (2007). *Model-based geostatistics*. New York: Springer

⁴ World Health Organization (2000). *The Abuja Declaration and the Plan of Action*. An extract from the African Summit on Roll Back Malaria, Abuja, 25 April 2000 (WHO/CDS/RBM/2000.17)

⁵ Snow RW, Amratia P, Kabaria CW, Noor AM, Marsh K (2012). The changing limits and incidence of malaria in Africa: 1939-2009. *Advances in Parasitology*, 78: 169-262

of dominant vector species and the coverage of insecticide-treated mosquito nets (ITN), Indoor Residual Spraying (IRS) and mass drug administration (MDA). 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.

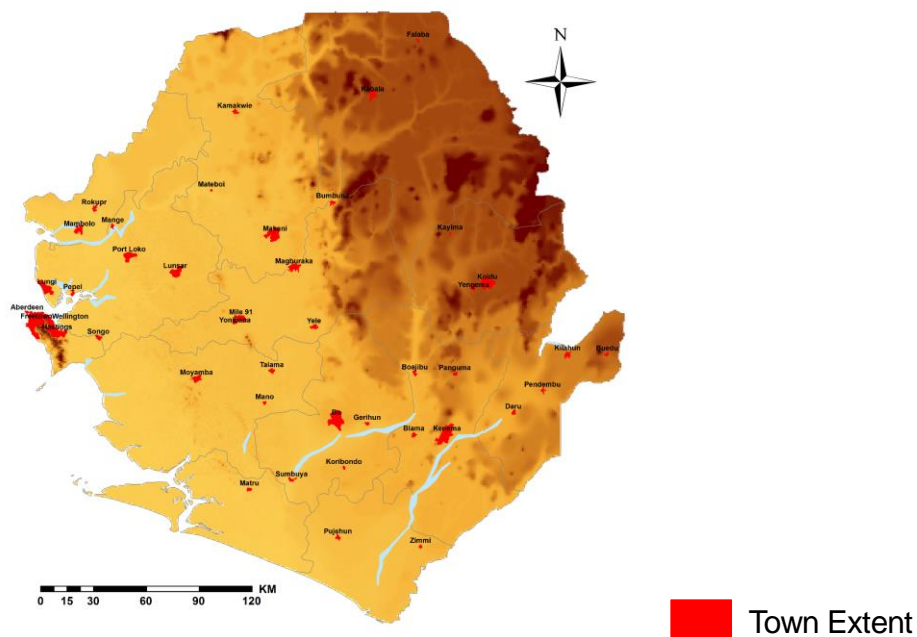
2. COUNTRY CONTEXT

LOCATION, GEOGRAPHIC FEATURES AND POPULATION

Situated on the west coast of Africa, Sierra Leone is bordered on the north and east by Guinea, on the south by Liberia, and on the west by the Atlantic Ocean.

The country can be divided into four distinct physical regions: the coastal swamp, the lowland plains, the interior plateau and the mountain region. The coastal swamp extends along the Atlantic for about 320 km. It is a flat, low-lying and frequently flooded plain composed mainly of sands and clays. Its numerous creeks and estuaries contain mangrove swamps. The Sierra Leone Peninsula, which is the site of Freetown, is a region of thickly wooded mountains that run parallel to the sea for about 40 km. The Peninsula Mountains rise from the coastal swamps and reach some 880 metres at Picket Hill.

FIGURE 1: EXTENTS OF MAJOR RIVERS, CITIES AND TOWNS AND THEIR ELEVATION IN SIERRA LEONE



Population distribution predictions for the year 2015 were derived from the population products shown in figure 3. The population distribution provided at 100m spatial resolution was resampled in ArcGIS (ver10.1 ESRI, USA) to obtain population density per km². A population density threshold of greater than 1000 persons per km² was used to identify urban settlements, a threshold found to significantly influence malaria prevalence [C Kabaria, personal communication]. Polygons covering an area greater than 5km² with population density across the polygon of ≥ 1000 people per km² were identified and matched to a place name gazetteer of Sierra Leone (www.geonames.nga.mil/gns/). This identified the 43 major urban settlements shown in figure 1. These are: Aberdeen, Blama, Bo, Boajibu, Buedu, Bumbuna, Daru, Falaba, Freetown, Gerihun, Hastings, Kabala, Kamakwie, Kayima, Kenema, Kilahun, Koidu, Koribondo, Lungi, Lunsar, Magburaka, Makeni, Mambolo, Mange, Mano, Mateboi, Matru, Mile 91, Moyamba, Panguma, Pendembu, Pepel, Port, Loko, Pujehun, Rokupr, Songo, Sumbuya, Taiama, Wellington, Yele, Yengema, Yonibana, Zimmi.

Digital elevation is represented from sea level (light brown) to a maximal elevation of 1,931 metres above sea level (dark brown).

References:

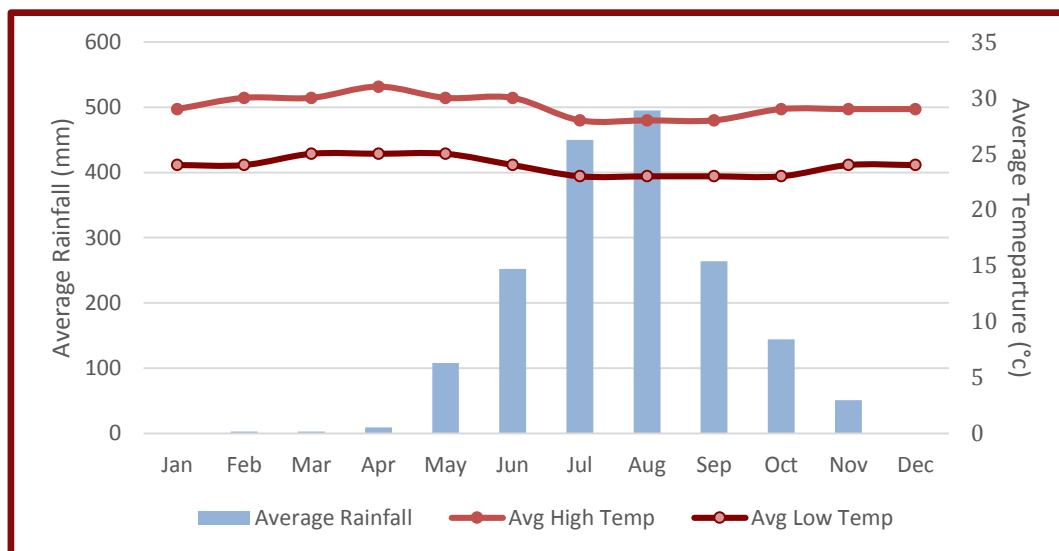
- 30m ASTER DEM: www.asterweb.jpl.nasa.gov/gdem
- Rivers from Global Lakes and Wetlands Database: GLWD; www.worldwildlife.org/GLWD

The climate is tropical and is characterized by the interchange of rainy and dry seasons. Conditions are generally hot and humid. The rainy season extends from May to October. Precipitation is greater on the coast than inland. The dry season, from November to April, is characterized by the harmattan, a hot, dry wind that blows from the Sahara. The rainy season has cooler (about 6 °C lower) daily maximum temperatures than the dry season; average monthly temperatures and precipitation are illustrated in [Figure 1](#) below⁶. The relative humidity may be as high as 90% for prolonged periods, particularly during the wettest months, from June to September⁷.

⁶ <http://www.worldweatheronline.com/Freetown-weather-averages/Western-Area/SL.aspx>

⁷ SM Sesay. Sierra Leone. Encyclopedia Britannica. 2014: <http://www.britannica.com/place/Sierra-Leone>

FIGURE 2. AVERAGE RAINFALL AND TEMPERATURE IN SIERRA LEONE (2000 - 2012)



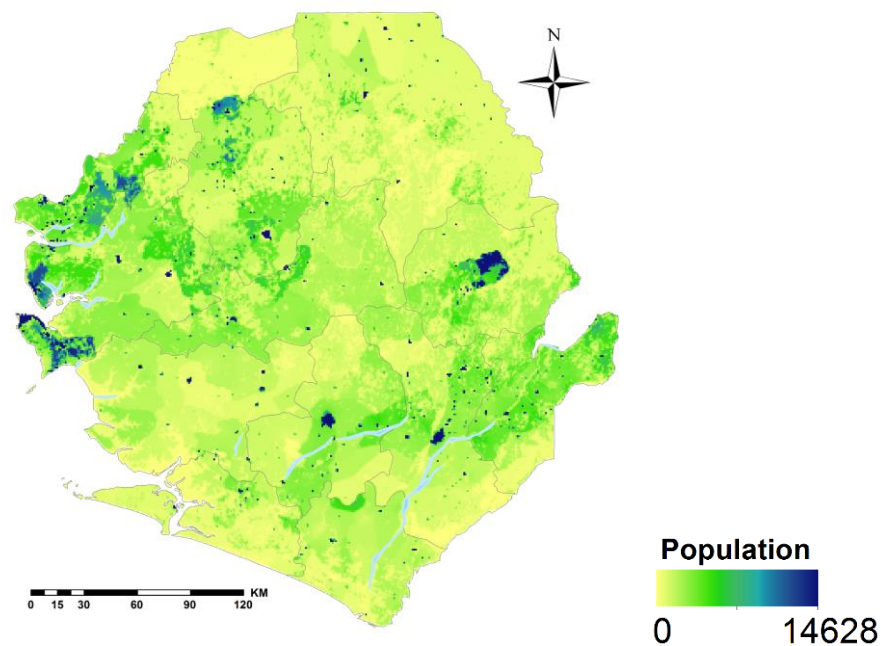
With an estimated population of 6.2 million in 2014, up from 5.5 million in 2008, Sierra Leone is growing rapidly; Figure 3 illustrates the population distribution across the country. The population density is 79 people per square kilometre, which ranks 114th in the world.

Sierra Leone remains among the world’s poorest countries with a Human Development Index for 2013 of 0.374— which is in the low category—positioning the country at 183 out of 187 countries and territories⁸. Decades of economic decline and 11 years (1991 – 2002) of armed conflict had dramatic consequences on the economy. Poverty remains widespread with more than 60% of the population living on less than USD 1.25 a day and unemployment and illiteracy levels remaining high, particularly among the youth. However, Sierra Leone has made considerable progress since the end of the civil war in 2002, consolidating peace, democracy and improving development indicators amid rising rates of economic growth⁹.

⁸ UNDP. Human Development Report. Sustaining Human Progress: Reducing Vulnerabilities and Building Resilience. Sierra Leone. 2014: http://hdr.undp.org/sites/all/themes/hdr_theme/country-notes/SLE.pdf

⁹ <http://www.sl.undp.org/content/sierraleone/en/home/countryinfo.html>

FIGURE 3: SIERRA LEONE POPULATION DISTRIBUTION AT 1 × 1 KM² IN 2010



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., 2010; 2012]. Population census size estimates, corresponding within chiefdoms used during the 2004 national census were acquired for Sierra Leone. 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 distribution datasets were projected to 2010 using United Nations (UN) national rural and urban growth rates and made to match the total national population estimates provided by the UN Population Division.

References

- Linard C et al. (2010). *GeoJournal*, **76**: 525–538; Linard C et al. (2012). *PLoS One*, **7**: e31743; Mennis J (2009). *Geography Compass*, **3**: 727-745

ADMINISTRATION

Sierra Leone emerged from over a decade of civil war in 2002 when more than 17,000 foreign troops disarmed tens of thousands of rebels and militia fighters. Over a decade on, the country has made progress towards reconciliation, but poverty and unemployment are still major challenges.

Sierra Leone is divided into four first-order administrative divisions - three provinces (Southern, Northern and Eastern provinces) and one area (Western Area). The provinces are sub-divided into 14 districts. The districts were the primary level of administration until 1920 when the four first-order administrative divisions were created. Each district is sub-divided into chiefdoms, governed by local paramount chiefs¹⁰. With the recent (2013) devolution of services to local communities, the country has now been divided into 19 local councils that have been further sub-divided into 392 wards. Each ward is headed by an elected councillor¹¹.

The Southern Province covers an area of 19,694 km² and has a population of 1,377,067 (2004 census). It consists of four districts (Bo, Bonthe, Moyamba, and Pujehun). Its capital and administrative centre is Bo, which is also the second largest and second most populated city in Sierra Leone after the nation's capital, Freetown. The population of the southern province is largely from the Mende ethnic group.

The Northern Province (commonly referred to as Northern Sierra Leone or simply the North) comprises the following five Districts: Bombali, Port Loko, Kambia, Koinadugu and Tonkolili. The Northern Province covers an area of 35,936 km² (13,875 sq mi) with a population of 1,718,240 (2004 census). Its administrative and economic centre is Makeni.

Eastern Province covers an area of 15,553 km² and has a population of 1,187,532 (2004 census). Its capital and administrative centre is Kenema.

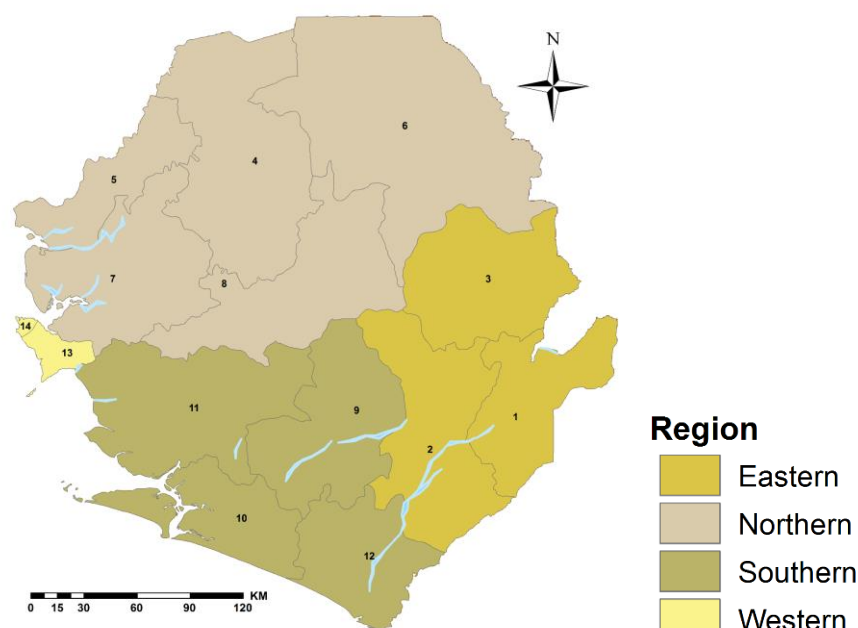
The Western Area or Freetown Peninsula (formerly the Colony of Sierra Leone) comprises the oldest city and national capital, Freetown, and its surrounding towns and countryside. It covers an area of 557 km² and has a population of 1,447,271. The Western Area is located mostly around the peninsula and is divided into two districts: the Western Area Rural and the Western Area Urban. The Western Area is the wealthiest region in Sierra Leone, having the largest economy, financial and cultural centre, as well as the seat of the country's national government. Unlike the other first order administrative areas of Sierra Leone, the western area is not a province. Freetown serves as the administrative headquarters of both the Western Area and the Urban District, and served as the capital of the Rural District until 2009 when it was formally moved to the city of Waterloo¹².

¹⁰https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/372364/Sierra_Leone_Administrative_Divisions_Oct2014.pdf

¹¹ Government of Sierra Leone, Ministry of Health and Sanitation. National Health Sector Strategic Plan 2010 - 2015. 2009

¹² <http://mic.gov.sl/AboutSL/Provinces>

FIGURE 4: SIERRA LEONE HEALTH ADMINISTRATION UNITS



Sierra Leone has four first order administrative divisions (Western, Southern, Eastern and Northern) and 19 local councils (14 district councils and 5 city councils). The district councils are responsible for managing the delivery of both primary and secondary health care services in the decentralised structure of the health system [Ministry of health and sanitation, 2012; Government of Sierra Leone, 2004]. To reconstruct the decision making units, we obtained second level shapefiles from global administrative units (GADM), which contained 14 district councils. We then aligned the external boundaries to match national boundaries from global administrative unit layers (GAUL).

References

- Global Administrative Areas (GADM) (2012). GADM database of Global Administrative Areas, version 2.0. Accessed June 11, 2014 at [www.gadm.org]
- Government of Sierra Leone (2004). The local government act: *Supplement to the Sierra Leone Gazette Extraordinary Vol. CXXXV, No. 14*. Accessed July 24, 2014 at [<http://www.sierra-leone.org/Laws/2004-1p.pdf>]
- Ministry of Health and Sanitation MoHS (2012). National Health Sector Strategic Plan 2010-2015: Joint Programme of Work and Funding (JPWF)

THE HEALTH SYSTEM

HEALTH SYSTEMS STRUCTURE

The Health Sector Steering Committee, chaired by the Minister of Health and Sanitation, is the supreme body that coordinates the health sector. It is supported by seven thematic groups reporting to the Health Sector Working group co-chaired by the Permanent Secretary and Chief Medical Officer. The health development partners' forum represents partners operating in the country. The UN agencies working in the health sector constitute the H+ partners which meet regularly to guide the Ministry. In addition, sub-regional organizations such as the West African Health Organization (WAHO) and MANO River Union (MRU) integrate inter-country initiatives in health and broader development areas^{13, 14}.

As part of the public sector reforms, which started in 2003, the Ministry of Health and Sanitation (MoHS) is organised into two main divisions at the central level: medical services and management services. Since the May 2004 local elections restored local government, decentralisation and devolution of authority have progressed rapidly with the aim of bringing service delivery and its management closer to the beneficiaries. The health sector was among the first three sectors that were scheduled for decentralisation of services to local councils from 2004 to 2008. The health sector was the only sector to devolve all the services as scheduled. The process started with devolution of primary health care services, followed by district hospitals in 2008.

With the devolution of services, the core functions of the MoHS remain as "Policy formulation; standards setting and quality assurance; resource mobilisation; capacity development and technical support; provision of nationally coordinated services, e.g. epidemic control; co-ordination of health services; monitoring and evaluation of the overall sector performance and training"¹⁵.

The responsibilities of the districts are implementation of national health policies; planning and management of district health services; provision of disease prevention, health promotion, curative and rehabilitative services; health education; ensuring provision of safe water and environmental sanitation; health data collection, management, interpretation, dissemination and utilisation.

Sierra Leone's health service delivery system is pluralistic with the Government, faith-based missions, non-governmental organisations and the private sector all providing services. There are public, private for profit, private non-profit and traditional medicine practices. The private sector is underdeveloped compared to other countries in the sub-region and involves mainly curative care for inpatients and outpatients on a fee-for-service basis. Private health facilities operate under the authority of individual owners and/or boards of directors and are mainly found in urban areas. Traditional healers and Traditional Birth Attendants (TBAs) are reported to provide a significant amount of health care, with TBAs attending almost 90% of deliveries at the community level¹⁶.

¹³ WHO Country Cooperation Strategy. Sierra Leone. 2014:

http://www.who.int/countryfocus/cooperation_strategy/ccsbrief_sle_en.pdf?ua=1

¹⁴ <http://manoriverunion.int/>

¹⁵ Government of Sierra Leone, Ministry of Health and Sanitation. National Health Sector Strategic Plan 2010 - 2015. 2009

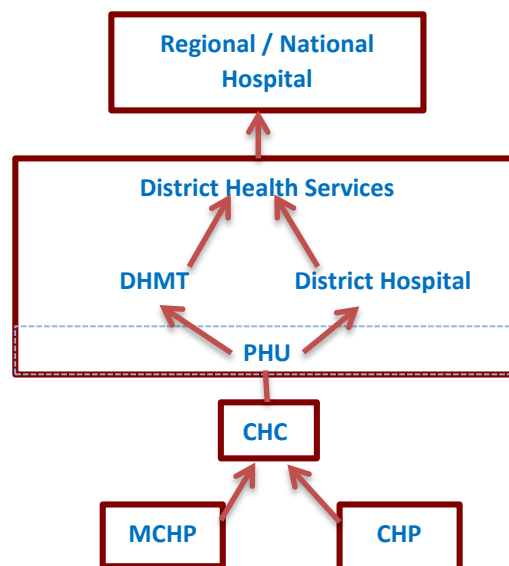
¹⁶ Government of Sierra Leone, Ministry of Health and Sanitation. National Health Sector Strategic Plan 2010 - 2015. 2009

Sierra Leone’s health care delivery is organised in a three tier system. The health service organisation is based on the primary health care concept which was started in the 1980s. The public health delivery system comprises three levels (see Figure 5 and Figure 6 below):

- a) Peripheral health units (community health centres, community health posts, and maternal and child health posts), providing first line primary health care;
- b) District hospitals for secondary care; and
- c) Regional/national hospitals for tertiary care.

District health services form the core component of primary health care. They are composed of a network of peripheral health units (PHUs), the district hospital (DH) and the District Health Management Team (DHMT). The DHMT is responsible for the overall planning, implementation, coordination, monitoring and evaluation of the district health services under the leadership of the District Medical Officer (DMO)¹⁷.

FIGURE 5: HEALTH FACILITY STRUCTURE



The PHUs are the first line of health services, and are further sub-classified into three levels:

- 1) The maternal and child health posts (MCHPs) are situated at village level and cater for populations of up to 5,000. They are staffed by Maternal and Child Health (MCH) Aides who are trained to provide a range of services: antenatal care, supervised deliveries, postnatal care, family planning, growth monitoring and promotion for under-five children, immunisation, health education, management of minor ailments, and referral of cases to the next level. The MCH Aides are supported by Community Health Workers (CHWs) who are community based and play a complementary role in health promotion and counselling of caregivers to improve health status and access to care. The CHW is an essential part of the

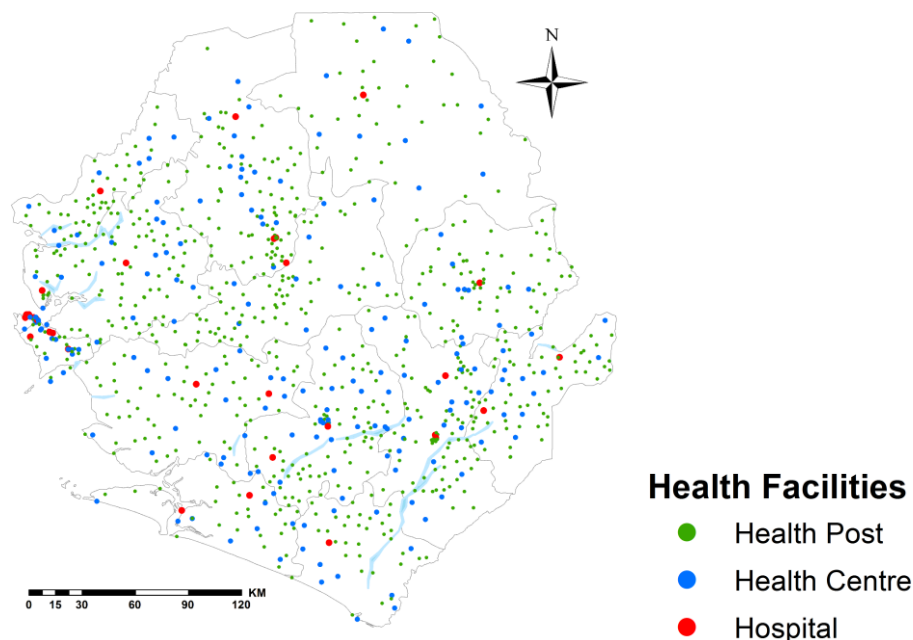
¹⁷ Government of Sierra Leone, Ministry of Health and Sanitation. National Health Sector Strategic Plan 2010 - 2015. 2009

continuum of care from the community to health facility and referral level, and for counter referrals¹⁸.

- 2) Community Health Posts (CHPs) are at 'small town' level with populations between 5,000 and 10,000 and are staffed by State Enrolled Community Health Nurses (SECHNs) and MCH Aides. In addition to the services provided at the MCHPs, CHPs include services relating to prevention and control of communicable diseases, such as vaccination programmes, and rehabilitation. They refer more complicated cases to the next level.
- 3) Community Health Centres (CHCs) which are located at Chiefdom level, usually covering a population ranging from 10,000 to 20,000 and staffed with a community health officer (CHO), SECHN, MCH Aides, an endemic disease control unit (EDCU) assistant and an environmental health assistant. They provide all the services provided at the CHP level in addition to environmental sanitation and supervise the CHPs and MCHPs within the Chiefdom.

The district hospital is a secondary level referral facility for the PHUs. It provides the following services: outpatient services for referred cases from PHUs and the population living within its immediate environs, inpatient and diagnostic services, accidents and emergencies, and technical support to PHUs¹⁹.

FIGURE 6: DISTRIBUTION OF AVAILABLE PUBLIC HOSPITALS (RED), HEALTH CENTERS (BLUE) AND HEALTH POSTS (GREEN)



¹⁸ Government of Sierra Leone, Ministry of Health and Sanitation. Policy for Community Health workers in Sierra Leone. June 2012

¹⁹ National Health Sector Strategic Plan 2010 - 2015. Ministry of Health and Sanitation. Sierra Leone. 2009

Health facility mapping

A geo-coded Health facility list assembled in 2010 by the Ministry of Health and Sanitation was provided by Dr. Edward Magbity, Principal Monitoring and Evaluation Officer, on August 17, 2012. The database contained 1,097 records with information on facility name, type (hospital, community health centre, community health post, maternal child posts), ownership (government, parastatal, private-for-profit, faith-based, and NGO), and location (district, chiefdom). Anomalies in the file included duplicated coordinates (n=8), fields with only facility type but no name, misspelt facility types and initialised names. These were systematically corrected by re-positioning duplicated coordinates, assigning chiefdom names to facilities without names, correcting spellings and completing names from initials. Facilities providing specialised care such as leprosy clinics, eye clinics, mental health centers, military and police clinics were excluded from the map (n=107) as these do not often provide routine curative care. The remaining 990 facilities, all with coordinates, were mapped.

References:

- Ministry of Health and Sanitation MoHS (2012). National Health Sector Strategic Plan 2010-2015: Joint Programme of Work and Funding (JPWF)

HEALTH CONTEXT & PRIORITIES

The health status of the people of Sierra Leone is still among the worst in the world with very high infant and maternal mortality rates. According to the 2008 Sierra Leone demographic and health survey (DHS), life expectancy is 47 years, the infant mortality rate is 89 per 1000 live births, under-five mortality rate is 140 per 1000 live births and the maternal mortality ratio is 857 per 100,000 births. Fertility rates are high and contraceptive prevalence rates are low²⁰.

The majority of causes of illness and death, especially of children, are preventable in Sierra Leone. Most deaths are attributed to nutritional deficiencies, pneumonia, diarrheal diseases, anemia, malaria, tuberculosis and HIV/AIDS. Malaria remains the most common cause of illness and death in the country, accounting for about 50% of outpatient visits and 38% of hospital admissions and 41% of all hospital deaths among children aged under 5 years²¹.

²⁰ Statistics Sierra Leone and ICF Macro. 2009. Sierra Leone Demographic and Health Survey 2008: Key Findings. Calverton, Maryland, USA: SSL and ICF Macro

²¹ African Health Observatory. World Health Organization. Sierra Leone – Health Status and Trends. http://www.aho.afro.who.int/profiles_information/index.php/Sierra_Leone:Analytical_summary_-_Health_Status_and_Trends

The National Health Sector Strategic Plan (NHSSP) 2010-2015 details the health policy of the government. It aims to make health services available, accessible and affordable to everyone, especially mothers, children and the poor. The plan describes three key priority areas²²:

- To move progressively towards universal coverage for mothers and infants;
- To reduce the burden of communicable and non-communicable diseases and
- To improve the quality of services.

MALARIA IN SIERRA LEONE

Malaria is endemic in Sierra Leone with stable and perennial transmission in all parts of the country. The entire populace is at risk of the disease. It is estimated that about 2,240,000 outpatient visits are due to malaria every year, of which about 1,000,000 patients are under five years old. Pregnant women and children under five years old constitute 4.4% and 17.7% of the total population, respectively, and are the most vulnerable groups²³.

The 2013 MIS revealed that 33% of children under 5 years old had fever during the two weeks preceding the survey, with a higher proportion of rural children (37%) than urban children (32%) having fever and 46% being found to be RDT positive²⁴. Analysis of the blood smears by microscopy revealed 43% of children under 5 years tested positive for malaria.

Plasmodium falciparum is the dominant parasite responsible for all severe cases and over 95% of uncomplicated cases. However, there are also cases of clinical malaria caused by *Plasmodium malariae* and *ovale*, or a mixture of these and *P. falciparum*.

The new National Malaria Control Strategic Plan, 2016-2020, was developed following recommendations from the Malaria Programme Review (MPR) conducted from February to July 2013. The MPR used a participatory approach leveraging the Programme's multi-Sectorial partnerships with various in-country technical resources.

The 2016 – 2020 National Malaria Strategic Plan aims to reduce the current levels of malaria morbidity and mortality by 40% by 2020 through:

- Promoting, co-ordinating and supporting the delivery of effective malaria control interventions that will prevent and reduce morbidity, mortality and disability due to malaria, and its socio-economic consequences;
- Using new technologies to improve diagnosis, ensure rapid and prompt treatment for malaria and establish selective malaria vector control activities;

²² Government of Sierra Leone, Ministry of Health and Sanitation. National Health Sector Strategic Plan 2010 - 2015. 2009

²³ DRAFT National Malaria Strategic Plan 2016-2020, National Malaria Control Programme. Ministry of Health & Sanitation. 2015

²⁴ National Malaria Control Programme (NMCP) Sierra Leone, Statistics Sierra Leone, University of Sierra Leone, Catholic Relief Services, and ICF International. 2013. Sierra Leone Malaria Indicator Survey. Freetown, Sierra Leone: NMCP, SSL, CRS and ICF International.

- Developing decentralised multi-sectorial, harmonised partnerships for malaria control in Sierra Leone, from the national down to the community level.
- Strengthening management and implementation capacity of the National Malaria Control Programme through effective coordination of partners.
- Strengthening surveillance, monitoring, evaluation and operational research for effective programme management

Key malaria control interventions currently employed by the NMCP include vector control efforts consisting largely of ITN distribution and targeted IRS, case management of malaria through parasitological diagnosis, using rapid diagnostic tests (RDTs), and artemisinin-based combination therapy (ACT) using artemether-lumefantrine as the first line drug, and intermittent preventive treatment of malaria in pregnancy with sulphadoxine-pyrimethamine. Injectable artesunate is the drug of choice for severe malaria, to be substituted by artesunate suppositories as pre-referral treatment where injectable artesunate cannot be administered.

STRUCTURE & FUNCTION OF THE NATIONAL MALARIA CONTROL PROGRAMME

The National Malaria Control Programme is the first point of contact in the Ministry for all technical matters relating to malaria and is responsible for the coordination of malaria control activities in the country²⁵.

As per the NMSP 2011-2015, the NMCP is responsible for taking the lead in strengthening malaria control efforts and coordinating all activities implemented by the various partners. This includes advocacy for malaria within the Ministry of Health and Sanitation to ensure malaria control is fully integrated into the overall development plans. **Figure 7** below illustrates the organisational structure of the NMCP with clear reporting lines²⁶.

Supported by other members of the RBM partnership, including WHO, the NMCP provides guidance, technical support and supervision to ensure that agreed strategies and guidelines are followed. A Technical Working Group (TWG) involving all partners has been formed whose primary responsibility is to develop or update malaria related policies, strategies and guidelines as the need arises. Detailed annual work plans are developed and progress monitored during quarterly coordination meetings.

The specific roles of the NMCP are to:

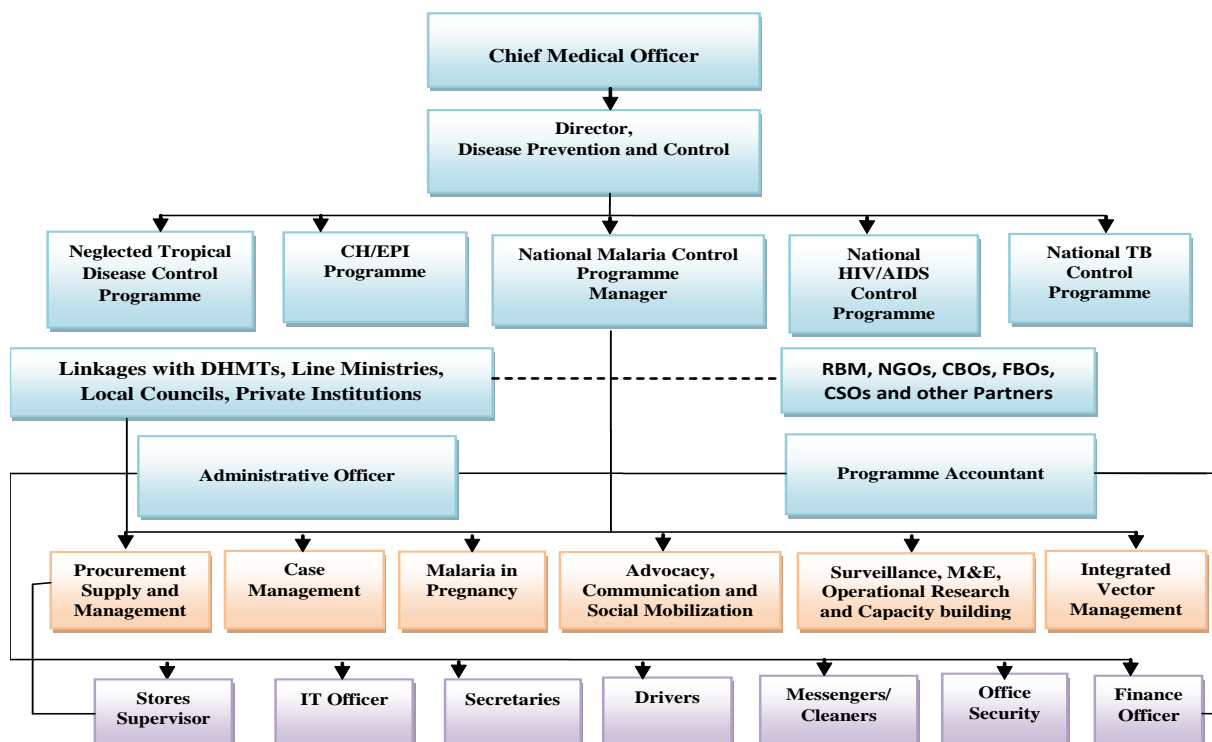
- Provide Leadership
- Devise standardised policies and guidelines
- Provide health services
- Supervise and coordinate

²⁵ http://www.who.int/profiles_information/index.php/Sierra_Leone:Analytical_summary_-_Malaria

²⁶ <http://www.rollbackmalaria.org/files/files/countries/sierra-leone2011-2015.pdf>

- Mobilise resources
- Monitoring & Evaluation
- Direct and review research agenda
- Provide commodities & supplies
- Guide private health care providers
- Human resource development.

FIGURE 7. NMCP ORGANOGRAM



FINANCING MALARIA CONTROL

The Ministry of Health and Sanitation National Health Sector Strategic Plan consists of six main pillars through which to deliver and finance health care.

Health care funding is requested from the consolidated MoHS fund and development partners. The health sector is substantially dependent on external resources for funding. The estimated cost to implement the Free Health Care Initiative policy, introduced in 2010 and targeting pregnant and lactating mothers and children under 5 years of age, was USD 35,840,173, of which 86.5% was

provided by partners, mainly the African Development Bank (ADB) (USD 1.5 million), World Bank (USD 1.5 million), GFTAM (USD 3 million) and DFID (USD 12.9 million)²⁷.

The major mechanism for pooling funds is provided through collaboration between the Government of Sierra Leone and development partners, as expressed by the Joint Programme of Work and Funding²⁸.

Both Government and donor expenditure on health has declined over the past decade and in 2007 Government expenditure was only 22% of the total basket, the remainder being externally funded. The percentage of Government expenditure on health - as a percentage of the total health expenditure - continued to be around 8%^{29,30}. Thus, the health sector has been grossly underfunded in the past and has never reached the Abuja Declaration target of 15% of total government allocation³¹.

While allocation for health in the National budget is less than 15%, government allocation to the National Malaria Control Programme, as per the 2010 – 2015 NMSP, is only 0.3% of the total health budget. However, the Malaria Programme receives funds from other partners supporting poverty alleviation in the country, including:

- The Global Fund; Since 2006, Sierra Leone has been awarded four GFATM malaria grants over three funding rounds to a total committed value of USD 62,120,726
- National Commission for Social Action (NaCSA)
- Social Action for Poverty Alleviation (SAPA)
- International Monetary Fund (IMF) approved an economic programme in the context of the Emergency Post Conflict Assistance Facility in December 1999
- The World Bank's Economic Rehabilitation and Recovery Credit to assist Government in restoring protective and economic security
- The Integrated Health Sector Investment Project (IHSIP), which is now Health Sector Reconstruction and Development.

DATA FOR MALARIA CONTROL

Routine health data in Sierra Leone are collected through a network of some 1,200 peripheral health units (PHUs) and 35 hospitals, unevenly distributed across the country's 13 health districts, coordinated by monitoring and evaluation and disease surveillance officers³².

²⁷ http://www.who.int/profiles_information/index.php/Sierra_Leone:Analytical_summary_-_Health_financing_system

²⁸ National Health Sector Strategic Plan 2010–2015 Joint Programme of Work and Funding (JPWF) 2012–2014. Government of Sierra Leone, Ministry of Health and Sanitation, 2012

²⁹ Leigh B. Child survival and development mid-term review report for the programme 2008–2010. Sierra Leone, United Nations Children's Fund, 2009

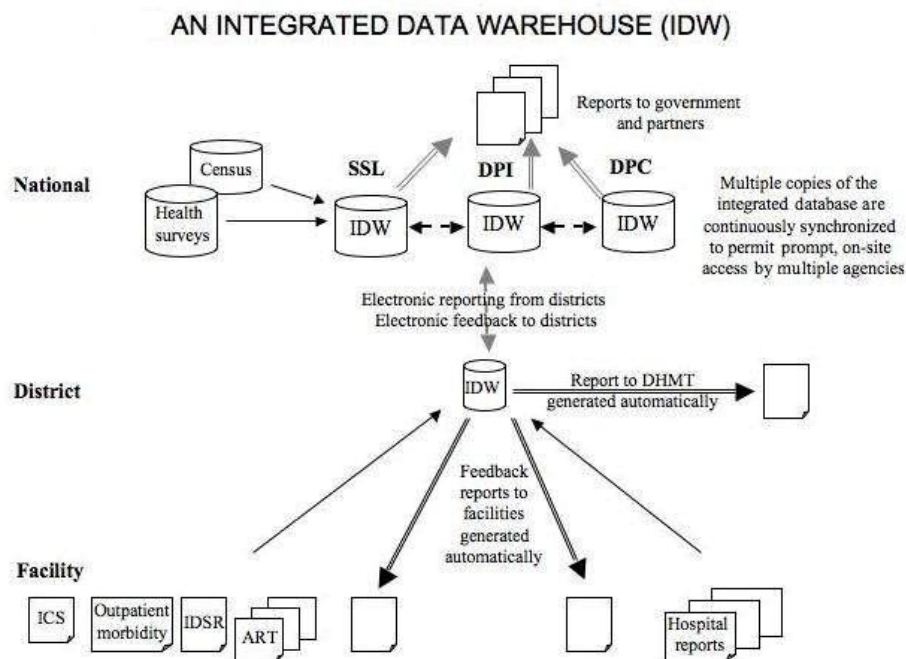
³⁰ Ensor T, Lievens T, Naylor M Review of financing of health in Sierra Leone and the development of policy options. Final report. Oxford Policy Management, 2008

³¹ http://www.who.int/profiles_information/index.php/Sierra_Leone:Analytical_summary_-_Health_financing_system

³² National Health Sector Strategic Plan 2010 - 2015. Ministry of Health and Sanitation. Sierra Leone. 2009

As part of the process of strengthening the Health Information Systems (HIS) of the ministry, a district-based electronic data management system, known as the district health information system (DHIS) was developed in 2008 to integrate and improve the quality and efficiency of data storage, transfer, analysis and dissemination. Data is currently captured in electronic form at district level and entered into an integrated data warehouse (IDW), as shown in Figure 8³³ below. This enables the production of reports for the DHMTs, at national level and for feedback to all levels, including PHUs and the community level. It is also utilised by stakeholders during review meetings and for decision-making at all levels.

FIGURE 8: SIERRA LEONE HEALTH INFORMATION SYSTEM



Notwithstanding the achievements so far, the HIS still needs to strengthen data collection capability at all levels, improve the quality of data collected and enhance district analytical capabilities. Challenges identified include³⁴:

- Inadequate financial and human resources for implementing HIS plans
- Weak capacity for data analysis, reporting, dissemination and use
- Weak hospital information and vital registration systems
- Poor engagement of the private sector and community groups in data collection
- Lack of standards and guidelines for data collection, analysis and reporting
- Lack of feedback at all levels
- Weak relationship between HIS and programme management
- Catchment area population not well defined
- No maintenance plan for existing ICT infrastructure both at national and district level.

³³ National Health Sector Strategic Plan 2010 - 2015. Ministry of Health and Sanitation. Sierra Leone. 2009

³⁴ National Health Sector Strategic Plan 2010 - 2015. Ministry of Health and Sanitation. Sierra Leone. 2009

The MoHS requires that all facilities, both public and private, report monthly on all services provided. Community Health Workers report at their regular monthly meeting with the Health facilities to which they are attached.

Health Facility summaries (PHU F1 to F8) are completed and verified by the in-charges and submitted to the DHMTs. Districts enter the data received from the health facilities into DHIS2. This data is transmitted electronically to DPPI. However, as part of the process for NMCP to integrate malaria data into the National HMIS, a customised DHIS2 database is currently installed at the NMCP. As the malaria database at NMCP is yet to be linked with the National HMIS, a transitional arrangement is made for the DHMTs to complete NMCP district summary forms which are then transmitted manually (paper based) to the NMCP for data entry. Hospital summary forms (HF1 and HF2) are submitted to DHMTs for onward transmission to the DPPI manually. In addition, NMCP hospital and laboratory summary forms are completed by the hospital M&E Officer and submitted to DHMT for onward, paper-based transmission to the NMCP. Data from districts, DPPI and partners are collated, analysed, disseminated and used for decision-making.

Despite multiple national household surveys over the last 10 years (MICS 2005, DHS 2008, MICS 2010), no information on malaria parasitaemia was collected until the Sierra Leone Malaria Indicator Survey (SLMIS) in 2013.

Six sentinel sites have been identified to be assessed for suitability for undertaking antimalarial drug efficacy and safety studies (three in Western Area, one in Bombali, one in Bo and one in Kenema).

SUPPLY CHAIN OVERVIEW

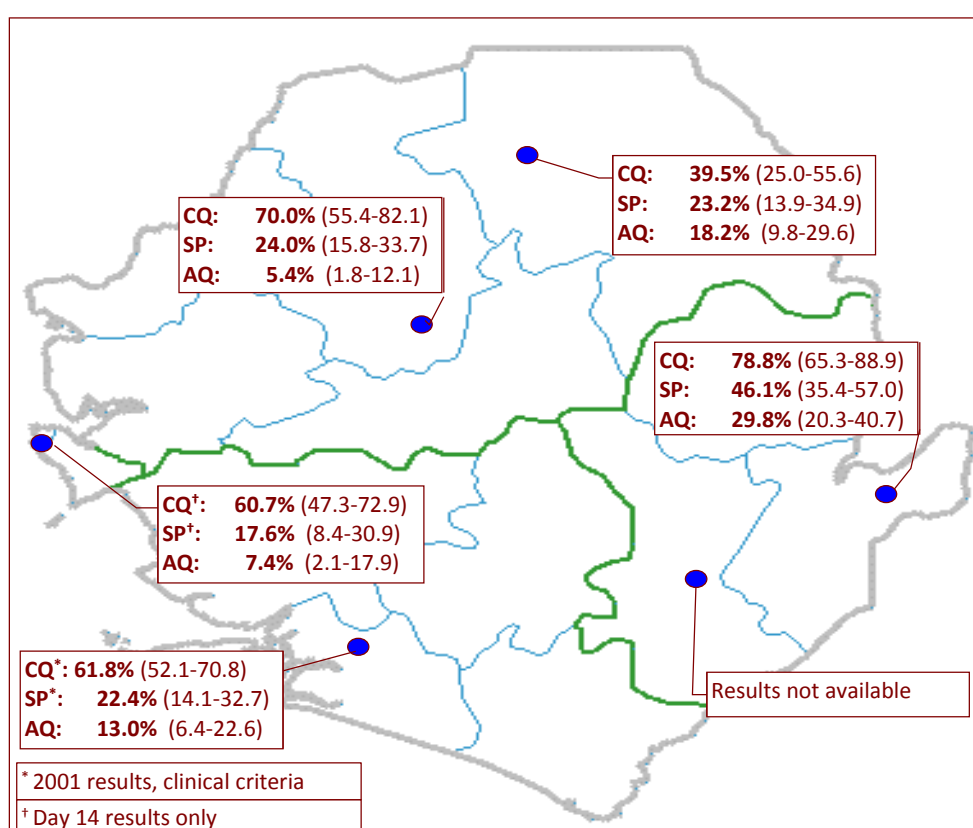
All antimalarial health commodities are presently procured through the Global Fund Voluntary Pooled Procurement (VPP). As an interim measure, the distribution of malaria commodities for Global Fund grants is currently undertaken by UNICEF. The Ministry of Health and Sanitation and the National Malaria Control Programme prepare a distribution plan every quarter in accordance with the risk distribution matrix developed in collaboration with partners. All anti-malarial commodities are distributed through the existing system and full accountability of the commodities is captured through the current health information system and logistics information system. The distribution network of health commodities consists of Central level Stores, 17 District and Regional level Stores, 1,200 PHUs, 35 Public and Private Hospitals/Clinics and 6670 Community Health Workers.

It is anticipated that The National Pharmaceutical Procurement Unit (NPPU) will be appointed as a sub-recipient to the Global Fund grant. In this role they will be responsible for the implementation of all component activities related to the Procurement and Supply Chain Management (PSM) including custom clearance, storage, distribution and LMIS of anti-malaria commodities in Sierra Leone. They will also be responsible for ensuring the timely delivery of all anti-malarial health commodities from the central level to the district level and that this distribution is integrated with the supply chain set up for the free healthcare initiative.

DRUG & INSECTICIDE SAFETY AND EFFICACY MONITORING

One of the earlier studies detailing resistance to widely used antimalarials in Sierra Leone was undertaken by Checchi *et al* in 2005³⁵. Chloroquine failure rates of 38 – 78% were reported and SP efficacy was also disappointing, with failure rates from 23 - 46%. AQ resistance was more moderate, ranging from 5 - 29%, with almost no early failures. The study was instrumental in providing evidence to inform anti-malarial policy in the country. Figure 9 illustrates the study sites and the failure rates.

FIGURE 9: MULTI-DRUG EFFICACY STUDY IN SIERRA LEONE



In 2010, insecticide susceptibility tests were undertaken by the NMCP on the following insecticides - Bendiocarb, Malathion, DDT, Permethrin, Deltamethrin and Lamdacyhalothrin – all were found to be efficacious at the sites in Bo, Kono, Makeni and Western Rural.

³⁵ F. Checchi *et al*. Evidence basis for antimalarial policy change in Sierra Leone: five *in vivo* efficacy studies of chloroquine, sulphadoxine-pyrimethamine and amodiaquine. American Journal of Tropical Medicine. 2005

OPERATIONAL AND IMPLEMENTATION RESEARCH

In the past five years there have been a number of studies undertaken whose findings are key to policy and decision making for malaria in Sierra Leone.

In 2011, a study was conducted by NMCP in collaboration with WHO to assess the therapeutic efficacy and safety of fixed-dose Artesunate Amodiaquine and Artemether Lumefantrine in four sentinel sites, in the treatment of uncomplicated *P. Falciparum* malaria among children under five years who present with confirmed uncomplicated malaria. A study revealed that a 100% (95% CI) Adequate Clinical and Parasitological Response was obtained for both ACTs in all four study sites when corrected for PCR. Results from this study indicated that both ASAQ and AL combination remain highly efficacious in Sierra Leone with presently no observed emergence of resistant strains to both drugs.

A recent study on presumptive treatment of self-diagnosed malaria by Ansumana *et al*, in 2013 found that the majority of febrile illnesses in Bo are self-diagnosed without clinical examination or laboratory testing, including more than half of suspected malaria cases that are treated presumptively without any clinical diagnostics³⁶.

On the vector control side, a pilot of indoor Residual Spraying (IRS) was conducted in selected Chiefdoms in Bo, Bombali, Kono and Western Rural districts in 2011 and 2012. Districts were selected on the basis of the availability of reliable malaria morbidity and incidence rate data; human resource and logistical capacity to manage IRS; infrastructure; stakeholder participation; economic activity and availability of sentinel sites for monitoring insecticide efficacy. The objective of the pilot program was to assess the feasibility, acceptability by communities, and effectiveness of IRS under local conditions and then scale up the intervention to reduce the country's malaria burden.

In November 2010, Sierra Leone distributed over three million long-lasting insecticide treated nets (LLINs) with the objective of providing protection from malaria to individuals in all households in the country. A study was undertaken to measure household possession and use of LLIN in Sierra Leone six months after a national mass distribution campaign³⁷. The study included 4,620 households with equal representation in each of the 14 districts.

Six months after the campaign, 87.6% of households were found to own at least one ITN and 36% of households were found to possess at least one ITN per two household members; rural households were more likely than urban households to have 1:2 ITN to household members, but there was no difference by socioeconomic status or household head education. Among individuals in households possessing 1 ITN, 76.5% slept under an ITN the night preceding the survey. The study concluded that the mass distribution campaign was effective at achieving high coverage levels across the population, notably so among rural households where the malaria burden is higher. These important gains in equitable access to malaria prevention will need to be maintained to produce long-term reductions in the malaria burden.

As an emergency response to the Ebola epidemic, the Government of Sierra Leone and its partners implemented a large-scale mass drug administration (MDA) with artesunate-amodiaquine (AS-AQ) covering >2.5 million people in the districts hardest hit by Ebola during December 2014 - January 2015 and with high malaria transmission. WHO collaborated with the NMCP in the evaluation of the impact of the MDA on malaria morbidity and the number of Ebola alerts at health facilities.

³⁶ R. Ansumana *et al*. *Presumptive self-diagnosis of malaria and other febrile illnesses in Sierra Leone*. The Pan African Medical Journal. 2013

³⁷ A. Bennett *et al*. *Household Possession and Use of Insecticide-Treated Mosquito Nets in Sierra Leone 6 Months after a National Mass-Distribution Campaign*. 2012. PLoS ONE 7(5)

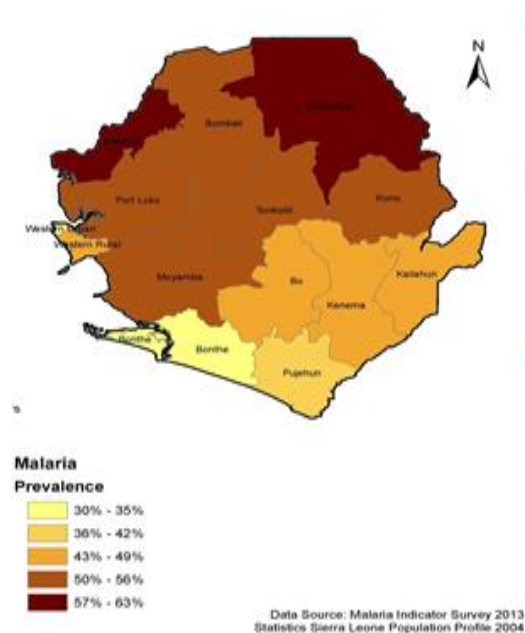
The study revealed that the number of suspected malaria cases tested with RDT decreased by >42% (95% CI) starting week 1 after the first MDA; RDT positive cases decreased by >46% starting week 1; and the RDT test positivity rate (TPR) declined by 25% starting week 2 after the first MDA. The total malaria (clinical + confirmed) cases decreased by 45% and the proportion of confirmed malaria cases among all outpatient consultations fell significantly by >33%. On the contrary, the trends of non-malaria outpatient cases did not change. The Ebola alerts (reported to a “117 hotline”) in the district Ebola Command Centres covered by MDA decreased by 30% in the first week and decreased even more strongly (>40%) in the four weeks after the second MDA. The non-MDA chiefdoms also saw moderate but significant changes in key malaria indicators but Ebola alerts increased during the same periods. [NMCP, personal communication, November 2015].

The study concluded that MDA implementation as a temporary measure helped in reducing malaria morbidity and febrile cases that would be potentially diagnosed as suspected Ebola cases, increasing the risk of nosocomial infections. The intervention also helped reduce patient case-load to the health services that were overloaded at the peak of the Ebola outbreak. The effect of the MDA waned in a matter of weeks and malaria intensity returned to the pre-MDA levels. Hence, the MDA was an appropriate public health intervention in the context of the Ebola epidemic even in the high malaria transmission areas of Sierra Leone involved, but the study also showed the relatively short-time impact of MDA in high transmission areas when deploying medicines with intermediate half-life.

MALARIA MAPPING IN SIERRA LEONE

Until very recently, maps were not used in Sierra Leone for malaria programming with the exception of [Figure 10](#) which was used in the draft 2016 – 2020 NMSP and uses prevalence data from the 2013 MIS.

FIG. 10: PREVALENCE OF MALARIA IN CHILDREN 6-59 MONTHS BY MICROSCOPY MIS 2013



EBOLA IN SIERRA LEONE

The Ebola outbreak in West Africa was first reported in March 2014, and has rapidly become the deadliest occurrence of the disease since its discovery in 1976. The first Ebola case in Sierra Leone was confirmed on 25 May 2014 when a young woman treated at the government hospital in Kenema tested positive for Ebola Virus Disease (EVD). This first case was traced to the funeral of a respected traditional healer who had treated sick patients travelling from neighbouring prefectures in Guinea³⁸.

The epidemic was concentrated in the Bombali and Port Loko districts in the Northern province and rural and urban zones of the Western Area province.

The EVD outbreak disrupted malaria case management. This was partly because of its impact on the health system and work force, but also due to overlapping initial symptoms between malaria and EVD: potential malaria patients became afraid to seek treatment for fear of being diagnosed with EVD. As part of the malaria response to the EVD outbreak, almost 3.5 million LLINs were distributed in June 2014.

On 7 November WHO declared that Ebola virus transmission had been stopped in Sierra Leone. The country then entered a 90-day period of enhanced surveillance, which is scheduled to conclude on 5 February 2016. Sierra Leone reported a total of 14,122 cases and 3,955 deaths attributable to Ebola³⁹.

³⁸ WHO, "Ebola at 6 months: Sierra Leone: a traditional healer and a funeral", 2014, <http://www.who.int/csr/disease/ebola/ebola-6-months/sierra-leone/en/>

³⁹ World Health Organisation. Ebola Situation Reports. 2015. <http://apps.who.int/ebola/ebola-situation-reports>

3. A TIMELINE OF MALARIA CONTROL IN SIERRA LEONE

It was in Sierra Leone, 100 years ago in 1899, that human malarial parasites were first observed in wild-caught *Anopheles gambiae* and *An. funestus*, the principal vectors of malaria in Africa. In the same year, Ronald Ross initiated the first anti-larval measures for malaria control⁴⁰.

Structured documentation of breeding sites for anophelines⁴¹, the establishment of 'Anopheles gangs' for larval control⁴² and efforts specifically to control malaria in pregnancy⁴³ go all the way back to the early 1900s. Efforts have intensified since 2000 as the government, internal and external partners worked to achieve the Millennium Development Goals (MDGs). This section attempts to capture key initiatives across the main intervention areas.

Early efforts to control malaria in Sierra Leone focused primarily on vector control, the two key activities from 1900 to the 1950s being environmental management for larval control and Indoor Residual Spraying (IRS) using a range of insecticides: pyrethroids, gammexane, dichloro-diphenyl-trichloroethane (DDT) and benzene hexachloride (BHC). Malaria prophylaxis with mepacrine was first documented in troops and school children in 1939. The Malaria Control Unit was established in 1944 and coordinated many of these activities until 1964 when its staff were integrated into other sanitary departments.

The period between the early 1960s and early 1990s saw very limited activities such as trials and use of chloroquine (CQ) in school children (1967) and selected communities in Bombali district, including Makeni city (1978).

With the establishment of the NMCP in 1994, activities began to pick up again with a surge of comprehensive and coordinated activity from 2000. The first National Malaria Strategic Plan (NMSP) (2004-2008) was launched in 2004 and changed first-line treatment policy from CQ to artemisinin-based combination therapy (ACT): CQ failure rates of 39.5% (in Kabala) to 78.8% (Kailahun)⁴⁴ had been reported⁴⁵. Free distribution of insecticide treated nets (ITNs) through expanded programme on immunisation (EPI) and ante-natal consultations (ANC), as well as small-scale campaigns, started in 2003 and continue to the current day. Intermittent preventive treatment of malaria in pregnancy (IPTp) was introduced in 2004 and rapidly rolled out nationally. In 2005, Sierra Leone won their first GFATM malaria grant (USD 6.9 million) which was instrumental in supporting the continued rollout of many of the activities described above.

In 2009, the second NMSP (2009 – 2015) was launched and Sierra Leone received its second GFATM malaria grant the following year, 2010 and the third malaria grant in 2012. This allowed a lot more flexibility and the roll out of mass ITN campaigns as well as pushing the agenda for adopting the test

⁴⁰ MJ Bockarie *et al.* *It all began with Ronald Ross: 100 years of malaria research and control in Sierra Leone (1899-1999)*. *Annals of Tropical Medicine Parasitology*. 1999

⁴¹ DB Blacklock & AM Evans. *Breeding places of anopheline mosquitos in and around Freetown, Sierra Leone*. *Annals of Tropical Medicine and Parasitology*. 1925.

⁴² SR Christophers & JW Stephens. *Further reports to The Malaria Committee of The Royal Society*. 1900

⁴³ DB Blacklock & RM Gordon. *Malaria infection as it occurs in late pregnancy; it's early relationship to early labour and early infancy*. *Annals of Tropical Medicine & Parasitology*. 1925

⁴⁴ F. Checchi *et al.* *Evidence basis for antimalarial policy change in Sierra Leone: five in vivo efficacy studies of chloroquine, sulphadoxine-pyrimethamine and amodiaquine*. *American Journal of Tropical Medicine*. 2005

⁴⁵ ON Nnedu *et al.* *Syndromic Diagnosis of Malaria in Rural Sierra Leone and Proposed Additions to the National Integrated Management of Childhood Illness Guidelines for Fever*. *American Journal of Tropical Medicine* 82(4), 2010

and treat policy for suspected malaria cases following the introduction of a policy to use RDTs or microscopy for the confirmation of malaria. This was also the beginning of more prominent role of CHWs in community case management of malaria (CCM).

In 2013 Sierra Leone carried out its first MIS collecting data on malaria parasitaemia for the first time. The Ebola outbreak in 2014 temporarily impaired malaria control but the NMCP responded exceptionally well temporarily suspending the test and treat policy, launching MDA campaigns for malaria and continuing with LLIN distribution while also undertaking the Malaria Programme Review on which basis a third NMSP (2016-2020) has now been developed.

It is anticipated the 2016-2020 NMSP will be launched early in 2016 with a vision of the entire population having access to malaria control and a specific goal to reduce malaria morbidity and mortality by at least 40% by 2020 compared with 2015.

MALARIA MILESTONE DATES

1827	Fourah Bay College, oldest university in West Africa, started
1899	Sir Ronald Ross of the Liverpool School of Tropical Medicine visited Freetown Human malarial parasites were first observed in wild-caught <i>Anopheles gambiae</i> and <i>An. funestus</i> in Sierra Leone
1900	Christophers & Stevens visited Freetown to make recommendations on mosquito control, including segregation
1901	“Anopheles gangs” established to drain the pools and puddles in the streets and the backyards of the houses, in which Anopheles breed "Culex gangs" established to collect from private houses all the broken bottles and buckets, empty tins, old calabashes, and similar unconsidered vessels in which mosquitoes of the genera Stegomyia and Culex breed
1920	Liverpool School established Tropical Laboratory in Freetown, Alfred Lewis Jones Lab functioning through to 1945
1930	Environmental management and drainage in Freetown and surrounding areas expanding with time though to end of Second World War Possible epidemic increase in malaria in Freetown and in 1931-1932
1939	Freetown important strategic port during war; reports of mepacrine prophylaxis used for troops and local school children through to 1944
1940	Pyrethrum spraying in Western Freetown
1943	Malaria Control Unit (MCU) established

1946	Trials of Gammexene IRS SW of Freetown and Marampa
1947	DDT, IRS and larviciding in Freetown reported though to 1960; within 3km radius of Lungi Airport
1951-1952	Use of BHC for IRS in Freetown area
1952	Bonthe, Sherbo Island targeted for BHC IRS but not clear if executed
1961	Independence of Sierra Leone
1963	No reports of IRS from this date
1964	MCU staff integrated into other sanitary departments
	WHO-19 pre-elimination project in Freetown and Western Region starting with detailed epidemiological surveys and capacity review; vector control not initiated, focus on increasing access to CQ for fevers and by 1967 limited CQ prophylaxis in school children
1979-1982	CQ chemoprophylaxis of communities in Bombali & Makeni northern districts
1980s	No reported national vector control strategies until trials in 1993
1982	Ndogbowusoi War in Pujehun district, southern province
1991	Civil war resulted in large scale population displacement and lack of any coordinated malaria control
1993	Trials of ITN and malaoprim (dapson + pyrimethamine) in area near Bo
1994	NMCP established
2002	Civil war officially comes to an end
2003	CQ and SP d28 clinical failure rates 39–78% and 17-46% respectively
	Insecticide treated tarpaulins piloted for refugee camps in Kenema province
2004	First, national malaria strategic plan launched through to 2008
	Global Fund approved Round 4 malaria financing
	IPTp policy introduced
2005	5% of children slept under an ITN
2006	AS-AQ replaced CQ as first line treatment after policy decision in 2004
	Mass free ITN campaign mounted by MSF in Bo and Pujehun districts distributing 65,000 nets

- November, national free mass LLIN distribution alongside measles vaccine campaigns distributed over 1.1 million nets
- 2008 600,000 ITN distributed routinely through ante-natal and EPI clinics since 2002
- 26% of children slept under an ITN
- 2009 Global Fund approved Round 7 malaria financing
- 2010 Lambda-cyhalothrin IRS only in selected chiefdoms of Bo (5/8 chiefdoms), Bombali (4/7 chiefdoms), Kono (5/8 chiefdoms), and Western Area Rural districts (12/20 communities); 87% household coverage protecting *circa* 302,000 people
- Bendiocarb, Malathion, DDT, Permethrin, Deltamethrin and Lamdacyhalothrin susceptible at Bo, Kono, Makeni and Western Rural
- 30% of children slept under an ITN
- December, mass free distribution of *circa* 3.2 million ITN
- Introduction of RDT test-treat policy
- 2011 National malaria strategy (2011-2015) launched, to reduce by 50% and 75% by 2015, mortality and morbidity due to malaria by 2015
- Post-LLIN distribution campaign survey suggests 72% of children were sleeping under an ITN
- Lambda-cyhalothrin IRS in four districts reaches 97% household coverage
- 2012 Global Fund approved Round 10 malaria financing
- National policy to expand community health workers launched to support a Basic Package of Essential Health Services (BPEHS) including Community Case Management of Malaria (CCMm)
- IRS continues in selected areas of four districts
- ACT efficacy (AQ-AS and AL) above 94% in four sentinel sites (Bo, Kenema, Rokupa and Makeni)
- 2013 45% of children slept under an ITN
- Training of 6,515 CHWs in community based malaria RDT use and treatment
- 2014 May, Ebola outbreak disrupts malaria control effort through to 2015

June, over 320,000 LLIN distributed nationally despite Ebola epidemic

IPTp 3 dose SP policy adopted but problems rolling out during epidemic

December, Mass Drug Administration (MDA) for malaria with AS+AQ targeting population of 2.4 million residents over 6 months of age in selected chiefdoms in the Bombali, Kambia, Koinadugu, Moyamba, Port Loko, Tonkolili and in all Wards in the Western Urban and Rural Areas

2015 January, MDA for malaria with AS+AQ targeting population of 3.04 million residents over 6 months of age in selected chiefdoms in the Bombali, Kambia, Koinadugu, Moyamba, Port Loko, Tonkolili and in all Wards in the Western Urban and Rural Areas

References used to develop timeline

Beltran O (1964). Malaria pre-eradication project Sierra Leone-19, second quarterly field report. April-June 1964; World Health Organization Archives, Geneva

Beltran O (1967). Malaria pre-eradication project Sierra Leone-19, second quarterly field report. April - June 1967; World Health Organization Archives, Geneva

Bespiatov VF, Sarr M, Rasoloniana L de G, Schuddeboom J (1983). Rapport de mission en Sierra-Leone du 22 Nov au 21 Dec 1983. Project ICP/MAL/001. World Health Organization Archives, Geneva

Blacklock DB (1941). Malaria in and around Freetown Harbour: final report on the work of the malaria investigation unit, from September 1940 to August 1941. pp. 18; UK National Archives, Kew, London

Bockarie MJ, Gbakima AA, Barnish G (1999). It all began with Ronald Ross: 100 years of malaria research and control in Sierra Leone (1899–1999). *Annals of Tropical Medicine & Parasitology*, 93: 213–224

Burns M, Rowland M, N'Guessan R, Carneiro I, Beeche A, Ruiz SS, Kamara S, Takken W, Carnevale P, Allan R (2012). Insecticide-treated plastic sheeting for emergency malaria prevention and shelter among displaced populations: an observational cohort study in a refugee setting in Sierra Leone. *American Journal of Tropical Medicine & Hygiene*, 87: 242–250

Colony of Sierra Leone (1949). Annual report of the Medical & Health Services for the year 1949. Government Printers, Freetown

Davidson G (1947). Field trials with Gammexane as a means of malaria control by adult mosquito destruction in Sierra Leone, II: the effect of treatments of houses with gammexane on the malaria rate in inhabitants. *Annals of Tropical Medicine & Parasitology*, 41: 210-214

Gerstl S, Dunkley S, Mukhtar A, Maes P, De Smet M, Baker S, Maikere J (2010). Long-lasting insecticide-treated net usage in eastern Sierra Leone - the success of free distribution. *Tropical Medicine & International Health*, 15: 480–488

Gordon RM & MacDonald G (1930). The transmission of malaria in Sierra Leone. *Annals of Tropical Medicine & Parasitology*, 24: 69-80

National Malaria Control Programme (NMCP) [Sierra Leone] (2009). Strategic Plan 2009-2015. Ministry of Health and Sanitation, Republic of Sierra Leone, May 2009

National Malaria Control Programme (NMCP) [Sierra Leone], Statistics Sierra Leone, University of Sierra Leone, Catholic Relief Services, and ICF International (2013). Sierra Leone Malaria Indicator Survey. Freetown, Sierra Leone: NMCP, SSL, CRS, and ICF International

National Malaria Control Programme (NMCP) [Sierra Leone] (2014). The National Malaria Control Programme Performance Review. Ministry of Health and Sanitation, Republic of Sierra Leone, April 2014

Petersen E, Marbiah NT, Magbiti E, Lines JD, Maude GH, Hogh B, Curtis C, Greenwood B, Bradley D (1993). Controlled trial of lambda-cyhalothrin impregnated bed nets and Maloprim chemo suppression to control malaria in children living in a holoendemic area of Sierra Leone, West Africa. Study design and preliminary results. *Parassitologia*, 35 (Suppl): 81-85

Ross R (1901). First progress report of the campaign against mosquitoes in Sierra Leone. Liverpool School of Tropical Medicine, Memoir 5, part 1, pp. 22

Statistics Sierra Leone (SSL) & ICF Macro (2009). Sierra Leone Demographic and Health Survey 2008. Calverton, Maryland, USA: Statistics Sierra Leone (SSL) and ICF Macro

Statistics Sierra Leone (SSL) & UNICEF-Sierra Leone (2007). Sierra Leone Multiple Indicator Cluster Survey 2005, Final Report. Freetown, Sierra Leone: Statistics Sierra Leone and UNICEF-Sierra Leone

Statistics Sierra Leone (SSL) & UNICEF-Sierra Leone (2011). Sierra Leone Multiple Indicator Cluster Survey 2010, Final Report. Freetown, Sierra Leone: Statistics Sierra Leone and UNICEF-Sierra Leone

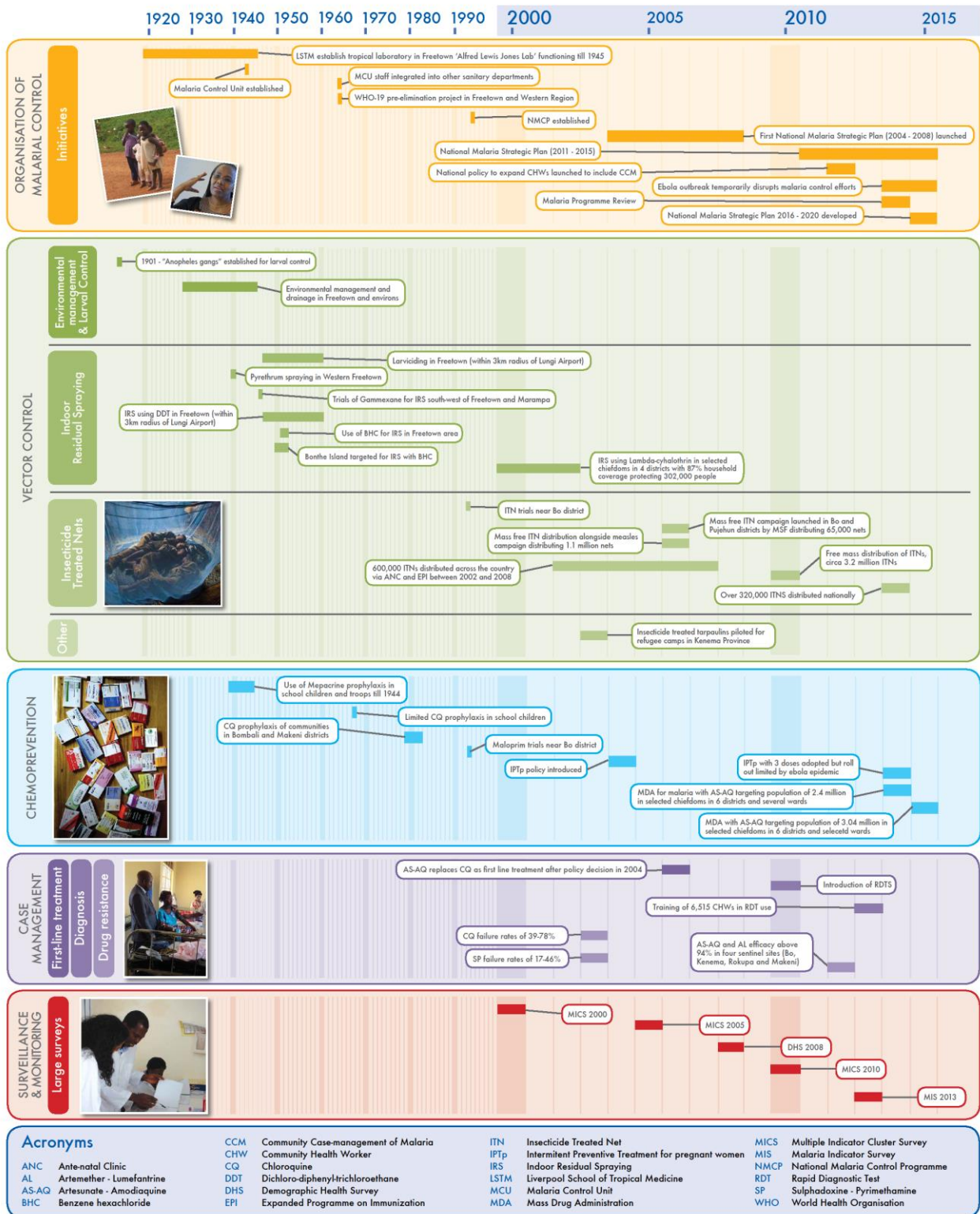
Stephens JWW & Christophers SR (1901). The proposed site for European residences in the Freetown Hills. Report to the Malaria Commission of Royal Society 5th Series, page 2-5

Storey J (1972). A review of malaria work in Sierra Leone 1900 to 1964. *West African Medical Journal*, 21: 57-68

Walton GA (1949). On the control of malaria in Freetown, Sierra Leone. II: control methods and the effects upon transmission of *Plasmodium falciparum* resulting from the reduced abundancy of *Anopheles gambiae*. *Annals of Tropical Medicine & Parasitology*, 43: 117-139

Zinyengere DT, Conteh P, Morovia M, Gbla AG (2010). Summary of the laboratory tests carried out to evaluate the susceptibility of the following insecticides for potential use in IRS pilot programme for four districts of Sierra Leone. Ministry of Health & Sanitation, Republic of Sierra Leone, July 2010

History of Malaria in Sierra Leone



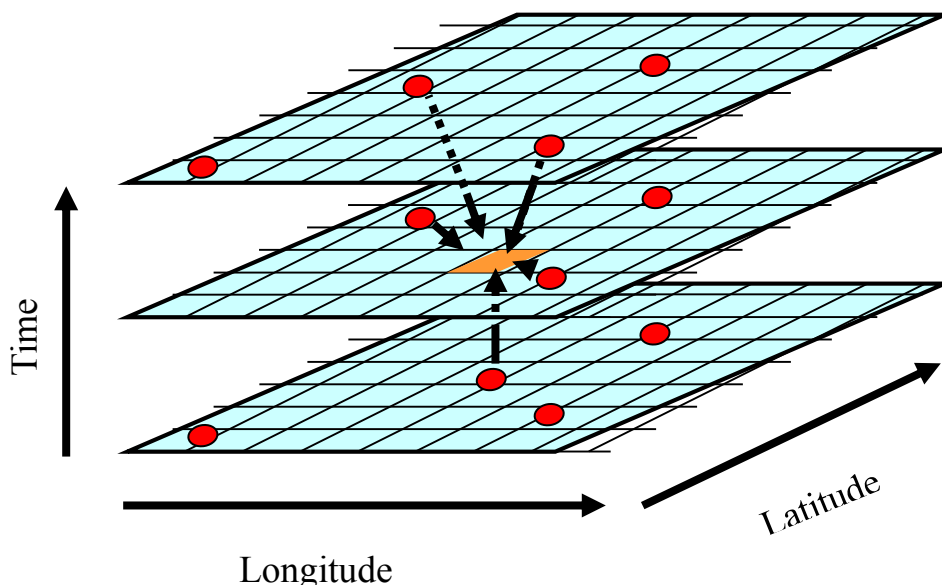
4. OVERVIEW OF TECHNICAL METHODS

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

SPACE-TIME GEO-STATISTICAL 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 do not exist. All model-based geostatistical (MBG) methods operate under Tobler's First Law of Geography (Figure 11) which states that things which are closer in space and time are more similar than those more spatially and temporally distal⁴⁶. When applied with a Bayesian inference framework, these methods are referred to as model-based geostatistical (MBG) methods. Bayesian inference allows better use of sparse data through the application of prior knowledge of an outcome in an iterative process. MBG allows robust estimation of uncertainties around the estimates of the outcome.

FIGURE 11: 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

⁴⁶ Tobler W (1970). A computer movie simulating urban growth in the Detroit region. *Economic Geography*, 46: 234-240

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, geo-code, 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 ($PfPR_{2-10}$) are described in Noor *et al* 2014 and Snow *et al* 2015. In brief, we used information (sample size and numbers positive) from available age-corrected survey data 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. We produced continuous maps of $PfPR_{2-10}$ for 2000 and 2010 at 1 x 1 km spatial resolutions within a Bayesian hierarchical space-time model, implemented through an adapted Stochastic Partial Differential Equations (SPDE) approach using Integrated Nested Laplace Approximations (INLA) for inference^{47,48}

Estimating Precision

A spatially and temporally de-clustered 10% of the $PfPR_{2-10}$ data was held out for model validation. Model accuracy was estimated by computing the linear correlation, the mean prediction error (MPE) and mean absolute prediction error (MAPE) of the observations and predictions of the holdout dataset. MPE is a measure of the bias of predictions (the overall tendency to over or under predict) whilst the MAPE is a measure of overall precision (the average magnitude of error in individual predictions).

The coefficient of variation (CV) is defined as the ratio of the standard deviation to the mean⁴⁹. 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. In Sierra Leone, there were no zero or near zero prevalence predictions.

⁴⁷ H. Rue *et al*. Approximate Bayesian inference for latent Gaussian models by using integrated nested Laplace approximations. *Journal of the Royal Statistical Society Series B*, 2009, **71**: 319–392

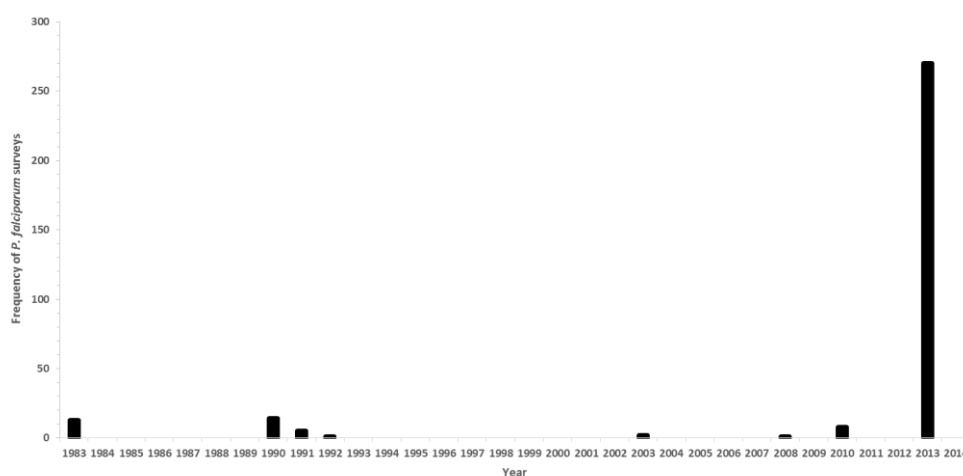
⁴⁸ R-INLA project. <http://www.r-inla.org/>. Accessed 10 April 2012.

⁴⁹ Kirkwood BL (1979). Geometric means and measures of dispersion. *Biometrics*, 35: 908–909

MALARIA PREVALENCE SURVEY DATA IN SIERRA LEONE

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 geo-code survey reports are presented elsewhere^{50,51}.

FIGURE 12: MALARIA PARASITE PREVALENCE 321 SURVEYS BY YEAR 1983-2013 IN SIERRA LEONE



A total of 321 time-space surveys undertaken since 1983 were identified through the data search. The earliest survey was undertaken in 1983 and the most recent survey undertaken in 2013. Six surveys were excluded because their sample sizes were less than 10 individuals. Of the remaining surveys, 270 were undertaken in 2013 during the Malaria Indicator Survey (MIS) and were used in the final analysis. Parasitaemia results were based on rapid diagnostic tests.

A complete excel database of all geo-coded surveys is provided for the NMCP as part of the support from the LINK project.

References

- MEASURE DHS: <http://www.dhsprogram.com/what-we-do/survey/survey-display-448.cfm>

⁵⁰ Noor AM, Kinyoki DK, Mundia CW, Kabaria CW, Wambua JM, Alegana VA, Fall IS, Snow RW (2014). The changing risk of *Plasmodium falciparum* malaria infection in Africa: 2000–10: a spatial and temporal analysis of transmission intensity. *Lancet*, **383**: 1739-1747

⁵¹ Snow RW, Amratia P, Mundia CW, Alegana VA, Kirui VC, Kabaria CW, Noor AM (2015). *Assembling a geo-coded repository of malaria infection prevalence survey data in Africa 1900–2014*. INFORM Working Paper, developed with support from the Department of International Development and Wellcome Trust, UK, June 2015; <http://www.inform-malaria.org/wp-content/uploads/2015/07/Assembly-of-Parasite-Rate-Data-Version-1.pdf>

MALARIA VECTOR DATA IN SIERRA LEONE

We used historical archives and published sources, and sourced more recent unpublished data from scientists and control agencies working in Sierra Leone, to assemble a database of malaria vectors in Sierra Leone. Full details of the data assembly, geo-coding methods and classifications of species according to their role in malaria transmission are provided elsewhere⁵². The database has been arranged as a site-specific, referenced inventory to capture details of species identification recorded since the earliest surveys in 1898 through to the latest records in 2012. 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 methods used to speciate each anopheline collection. “Y” was recorded if a species was identified and “N” was only recorded when the true absence of the species was reported. The database is therefore one of species presence, not absence or proportional presence of various vectors.

We have not assembled geo-coded information related to vector resistance: these data have been carefully curated, validated and mapped by the IRBase initiative⁵³.

ITN COVERAGE MAPPING

Typically, national household surveys are designed to be precise at national and regional levels and rarely at lower levels such as districts. Therefore, simply aggregating survey data to provide district level

estimates of an outcome of interest will lead to values of low precision. 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^{54,55}. We have used hierarchical Bayesian spatial and temporal SAE techniques using a geo-additive regression approach^{56,57} to estimate the proportion of the population in each health district sleeping under an insecticide treated net (ITN) the night before survey. This has been done by health district for the years

⁵² Snow RW, Amratia P, Mundia CW, Alegana VA, Kirui VC, Kabaria CW, Noor AM (2015). *Assembling a geo-coded repository of malaria infection prevalence survey data in Africa 1900-2014*. INFORM Working Paper, developed with support from the Department of International Development and Wellcome Trust, UK, June 2015; <http://www.inform-malaria.org/wp-content/uploads/2015/07/Assembly-of-Parasite-Rate-Data-Version-1.pdf>

⁵³ Knox TB, Juma EO, Ochomo EO, Pates Jamet H, Ndungo L, Chege P, Bayoh NM, N’Guessan R, Christian RN, Hunt RH, Coetzee M (2014). An online tool for mapping insecticide resistance in major Anopheles vectors of human malaria parasites and review of resistance status for the Afrotropical region. *Parasites & Vectors*, **7**: 76

⁵⁴ Rao JNK. Small Area Estimation. John Wiley & Sons, Inc., Hoboken, New Jersey, 2003

⁵⁵ BIAS (2007). Introduction to Bayesian Small Area Estimation, January 2007. <http://www.bias-project.org.uk/software/SAE.pdf>

⁵⁶ S Banerjee et al.. Hierarchical Modeling and Analysis for Spatial Data. Chapman & Hall, New York. 2004

⁵⁷ N Best et al. A comparison of Bayesian spatial models for disease mapping. *Statistical Methods in Medical Research*, 2005

2005, 2008 and 2010 and 2013. This method uses survey data from a health district and neighbourhood information from adjacent districts to smooth values at the health district.

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

5. MALARIA RISK MAPPING

Figure 13, below, shows the locations of the 270 *P. falciparum* parasite prevalence (PfPR) survey data points reported from 2013. The data were age-corrected to reflect the prevalence in 2 – 10 year olds (PfPR₂₋₁₀).

FIGURE 13: LOCATION OF 270 AGE-CORRECTED PARASITE PREVALENCE DATA (PfPR₂₋₁₀) IN 2013 IN SIERRA LEONE

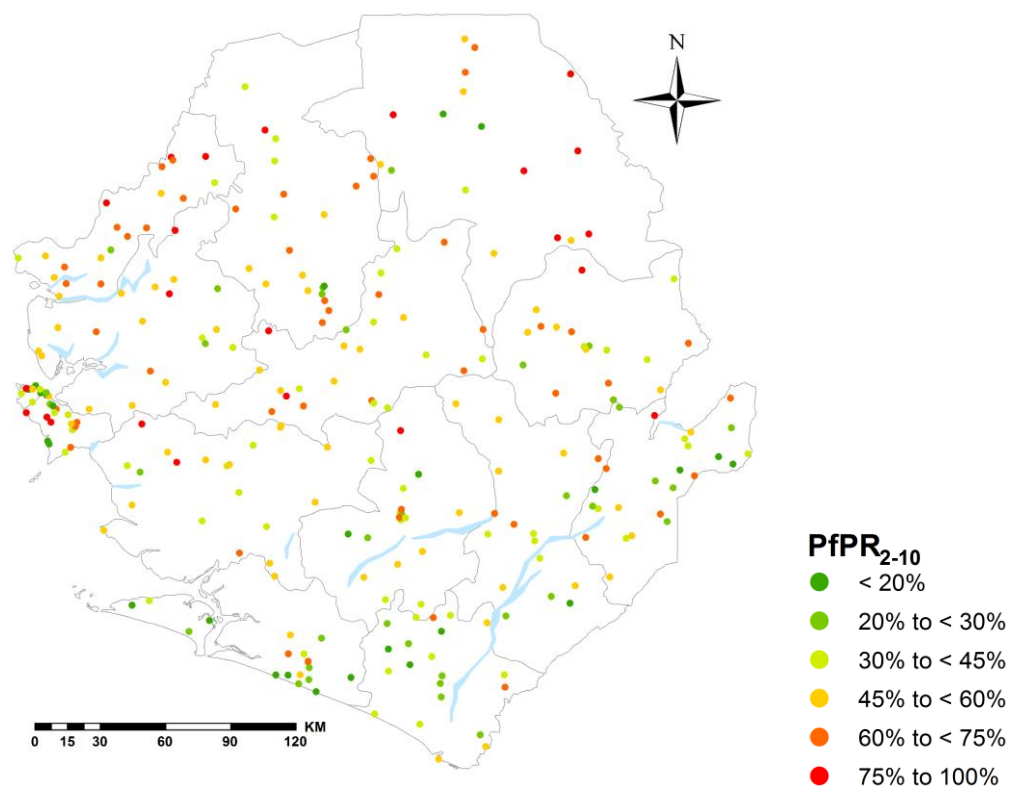
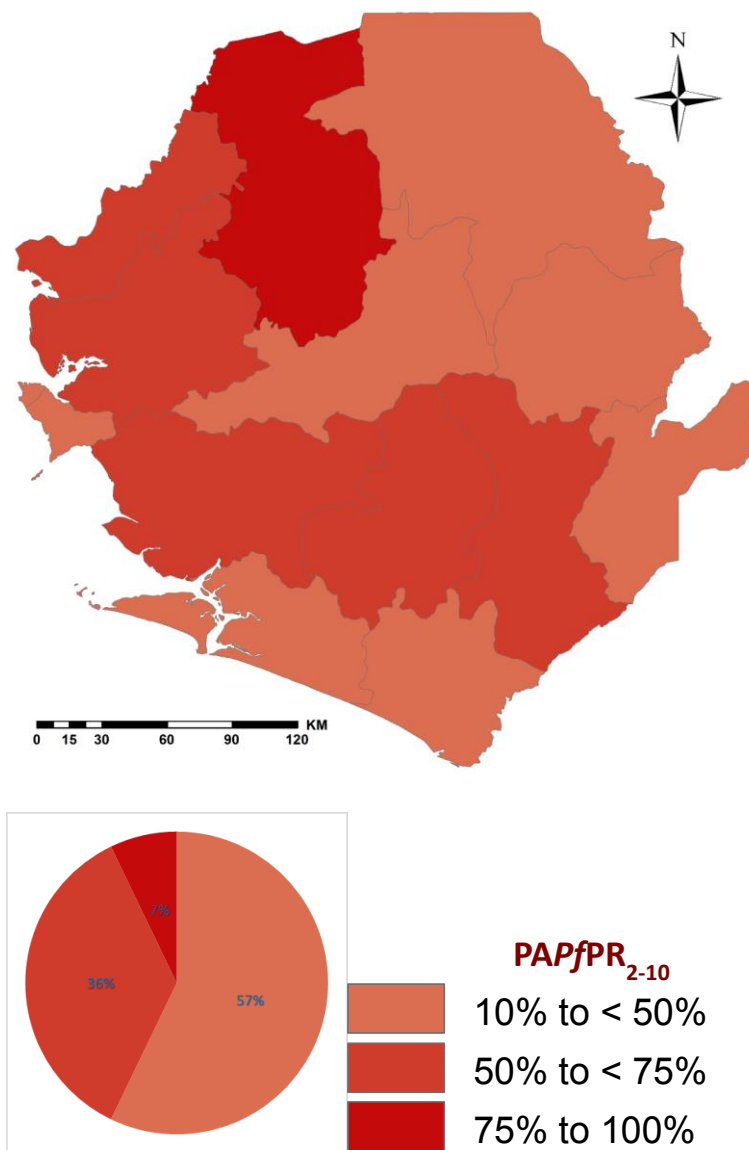


Figure 14 shows malaria risk, reflected by the PfPR₂₋₁₀, in 2013 by health district. A combination of population distribution and the PfPR₂₋₁₀ risk maps was used to compute a Population Adjusted PfPR₂₋₁₀ (PAPfPR₂₋₁₀) so that this reflects the underlying diversity of human settlement and malaria risk within a district.

The accompanying pie chart reflects the proportions of the population living at different levels of malaria risk.

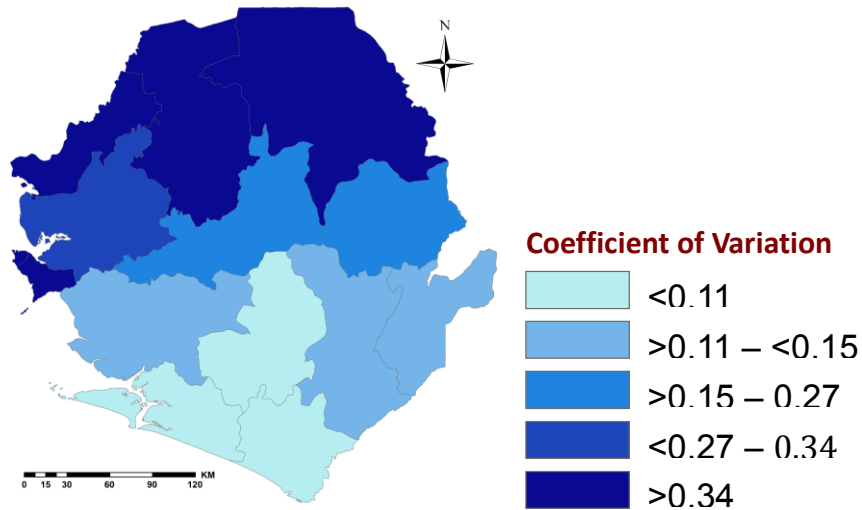
FIGURE 14: POPULATION ADJUSTED *PFPR*₂₋₁₀ PREDICTION 2013 BY HEALTH DISTRICT IN SIERRA LEONE



The precision of the model-based prevalence map is illustrated in Figure 15. Generally, low CV values suggest that the standard deviations around the mean are relatively small and high values may indicate increasing model uncertainty⁵⁸. The upper limit of the CV values is <0.5, indicating that in most districts predictions of *PAPfPR*₂₋₁₀ are of good precision. The highest CV values were in the high transmission but sparsely populated districts of the North. The precision of estimates in these districts could be improved in future surveys by either over-sampling survey clusters in these districts or supplementing household surveys with bespoke school parasitaemia surveys.

⁵⁸ AM Noor AM et al. Mapping the receptivity of malaria risk to plan the future of control in Somalia. *British Medical Journal Open Access*, 2012

FIGURE 15: SIERRA LEONE 2013 *PfPR*₂₋₁₀ MODEL PRECISION. POPULATION ADJUSTED COEFFICIENT OF VARIATION (RATIO OF STANDARD DEVIATION TO MEAN) IS USED AS A MEASURE OF UNCERTAINTY OF PREDICTIONS.



The population adjusted 2013 *PfPR*₂₋₁₀ model was validated as described earlier (“Estimating Precision” in Section 4: Space-Time Geo-Statistical Modelling).

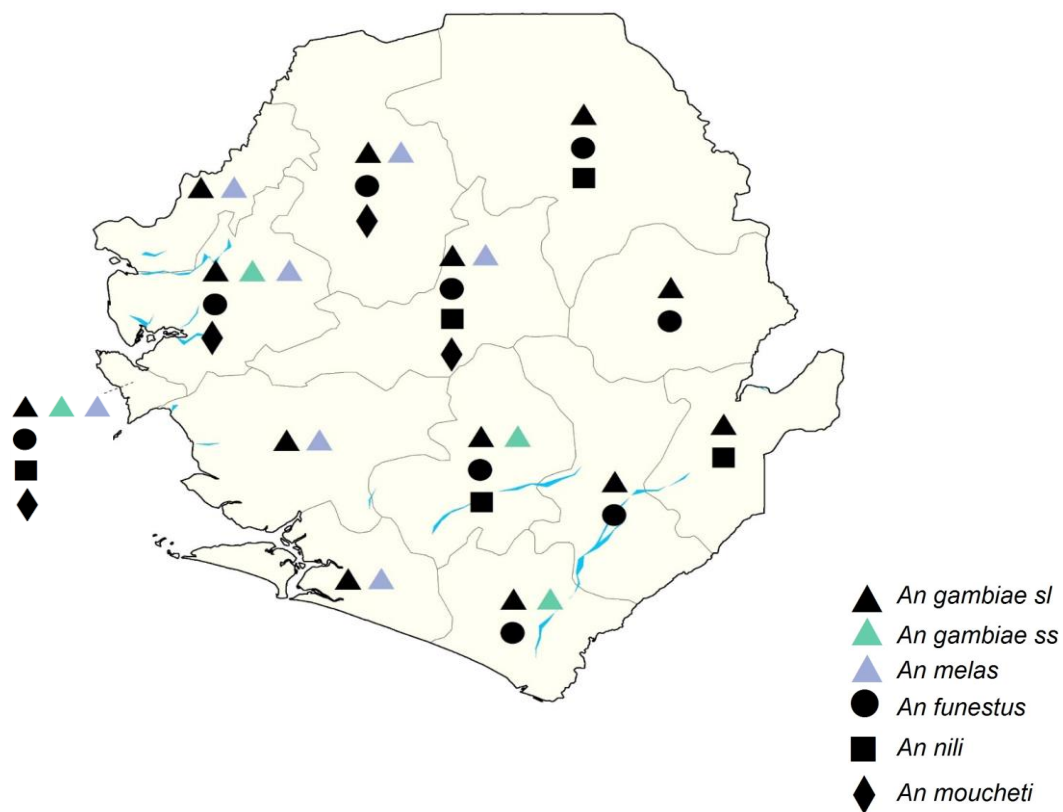
Estimates were computed from a comparison of the predictions and observations for a 10% “hold out” dataset. The precision parameter estimates were a Linear Correlation of 0.68, a Mean Percentage Error (MPE) of 1.9%; and a Mean Absolute Percentage Error (MAPE) of 8.2%.

6. ENTOMOLOGICAL PROFILE

The final entomological database contained 189 site/time specific reports of anopheline vectors in Sierra Leone, reported between 1898 and 2012 and for which the survey site was geo-located. We were unable to geo-locate only 1 (0.5%) of the survey sites.

The database includes site-specific records of some of the earliest malaria vector maps, developed by Christophers and Stevens (1900)⁵⁹, and reported vectors from different sites during Sir Ronald Ross's visit in 1901⁶⁰

FIGURE 16: RECORDED MALARIA VECTORS BY DISTRICT IN SIERRA LEONE



⁵⁹ SR Christophers & JWW Stephens. Further reports to the Malaria Committee of the Royal Society. London, Harrison & Sons, 1900. pp. 22

⁶⁰ R Ross. First progress report of the campaign against mosquitoes in Sierra Leone. Liverpool School of Tropical Medicine, 1901, Memoir 5, part 1, pp. 22

An. gambiae complex is ubiquitous across the country and members of the *An. funestus* group have been recorded across the country except for south-west and Port Loko district in the east.

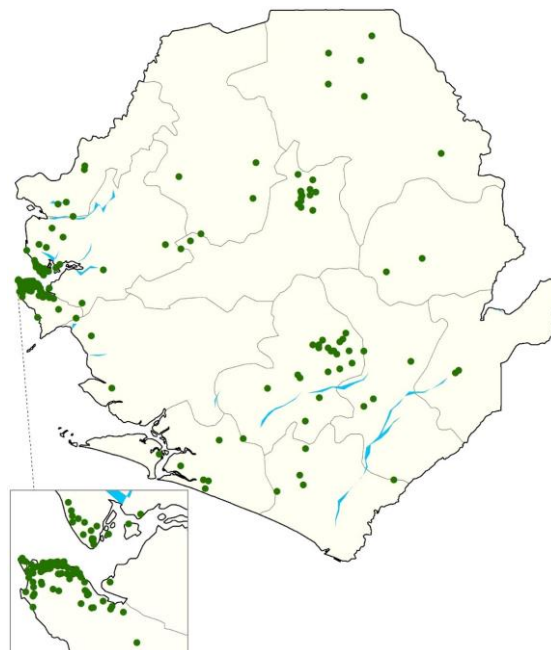
Among the *An. gambiae* complex, only *An. gambiae* ss (both M (*An. colluzzi*) and S forms) and *An. melas* have been recorded in Sierra Leone. There are no reports of *An. Arabiensis* in Sierra Leone.

The furthest inland *An. Melas* has been reported is along the Rokel river⁶¹.

An. nili group, *An. moucheti* group and *An. hancocki* have also been described in Sierra Leone, but only in small numbers.

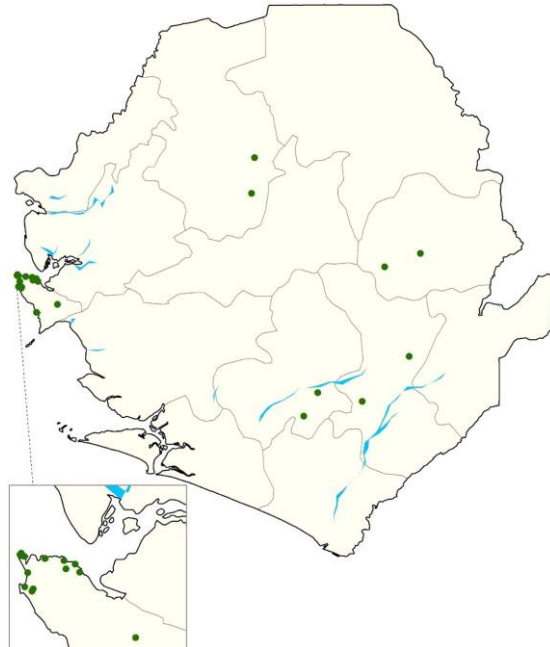
Records since 1898 of other anopheline species, either non-vectors or considered incidental vectors of malaria in Sierra Leone identify the following species: *An. barberellus*, *An. cinctus*, *An. coustani*, *An. domicolus*, *An. freetownensis*, *An. hargreavesi*, *An. marshalli*, *An. mauritanus*, *An. obscurus*, *An. paludis*, *An. quadriannulatus* (of the *An. gambiae* complex), *An. rhodesiensis*, *An. rufipes*, *An. smithii*, *An. squamosus*, *An. tenebrosus*, *An. theileri* and *An. Ziemanni*.

FIGURE 17: SITE LOCATIONS OF MOSQUITO SAMPLING SITES FOR 189 SURVEYS UNDERTAKEN BETWEEN 1898 AND 2012



⁶¹ RCM Thomson. Studies on the Breeding Places and Control of *Anopheles gambiae* and *A. gambiae* var. *melas* in Coastal Districts of Sierra Leone. Bulletin of Entomological Research, 1946 36: 185-252

FIGURE 18: SITE LOCATIONS OF MOSQUITO SAMPLING SITES FOR 25 SURVEYS UNDERTAKEN SINCE 2005



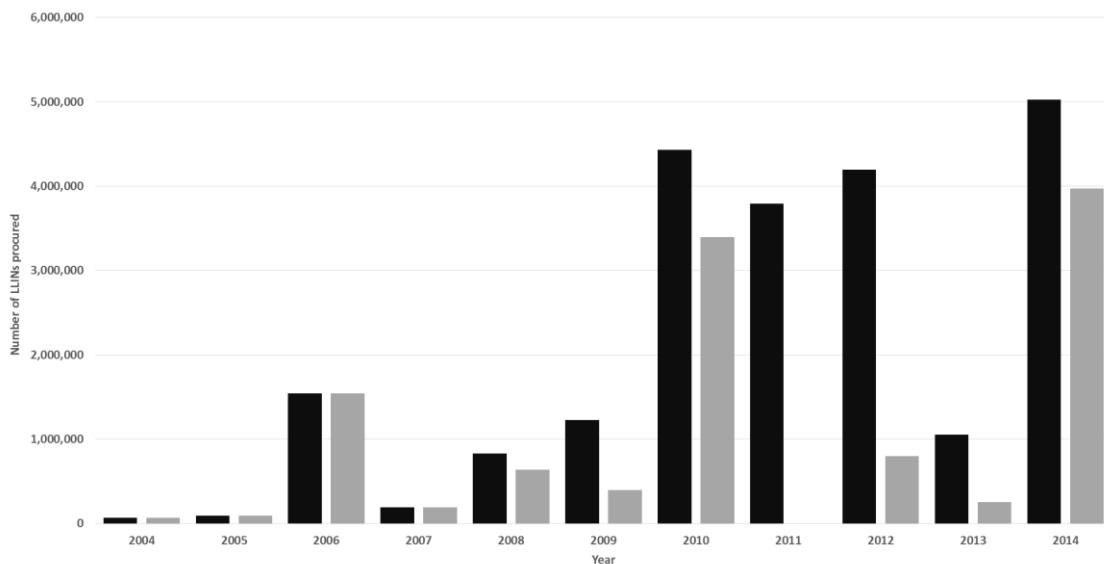
An entomological data gap exists between 1993 and 2009, when no anopheline surveys were carried out. This period largely overlaps with the Civil War. Between 2005 and 2014 a total of 25 survey locations have been sampled.

7. INTERVENTION COVERAGE

INSECTICIDE TREATED MOSQUITO NETS

Data on distribution of ITNs by district were obtained from the NMCP for the period from 2004 to 2014. Over this period LLIN's were distributed through both routine and mass distribution channels.

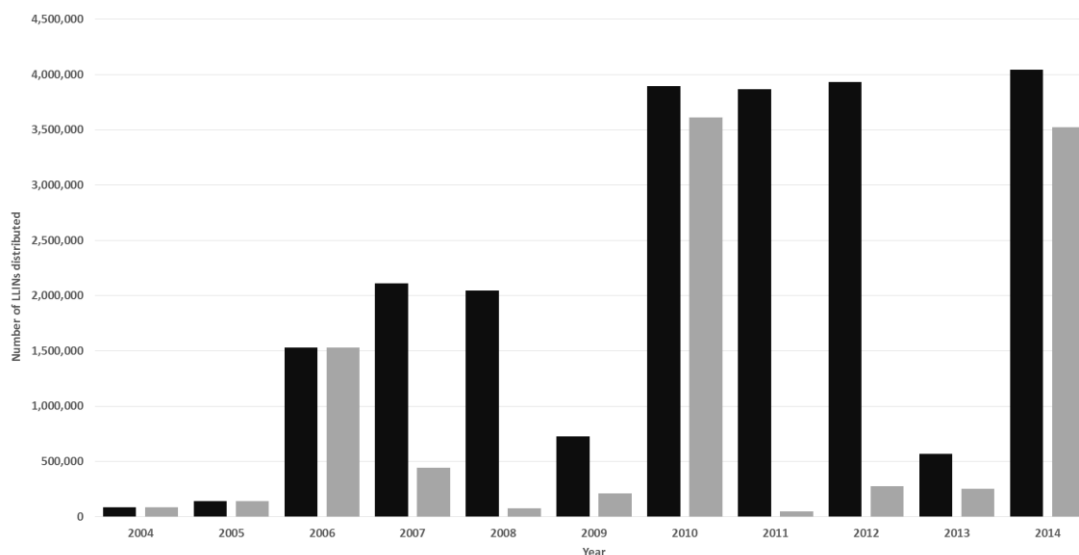
FIGURE 19: ANNUAL NATIONAL (GREY) AND EFFECTIVE CUMULATIVE (BLACK) PROCUREMENT OF ITNS/LLINS



Data on national procurement of ITN (up to 2006) and LLIN 2006 onwards were provided by the ALMA-RBM harmonization working group that maintain careful data on years and numbers of nets delivered to each country [Melanie Renshaw, personal communication, 2015]

Data have been arranged as follows, nets delivered in 2004 and 2005 (assumed to be ITN only) would have lasted for one year in absence of re-treatment. LLIN we have assumed would remain effective in year delivered and for three years afterwards when they would have lost efficacy. The graph shows therefore a cumulative “in-country” net availability. This is not usage or coverage which are modelled from household surveys in subsequent slides.

FIGURE 20: ANNUAL NATIONAL (GREY) AND EFFECTIVE CUMULATIVE (BLACK) DISTRIBUTIONS OF ITNS/LLINS



Data on distribution of ITNs for the period 2004-2014 was obtained from the NMCP. Cumulative ITN/LLIN distribution were computed by assuming an effective ITN lifespan of 1 year (up to 2006) and 3 years (2007-2014) after which they were assumed lose efficacy. This graph shows distribution in country and does not reflect actual use of the nets or their ownership by households.

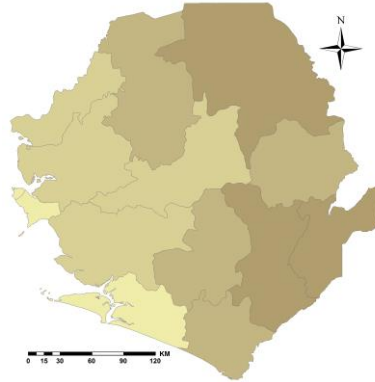
FIGURE 21: TOTAL NUMBER OF ITNs DISTRIBUTED FROM 2004-2014



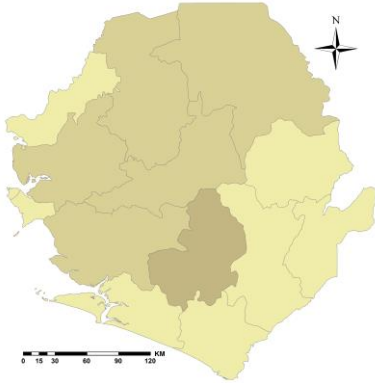
2006



2007



2008



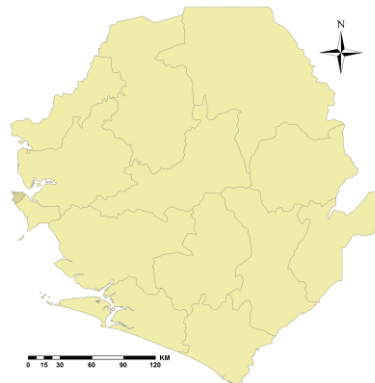
2009



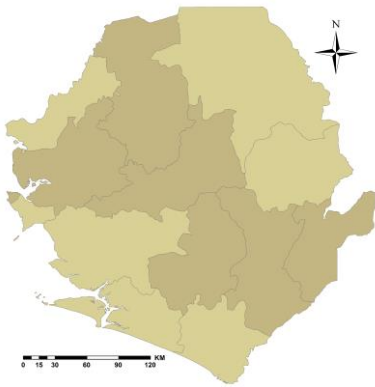
2010



2011



2012



2013



2014



Number of LLINs Distributed

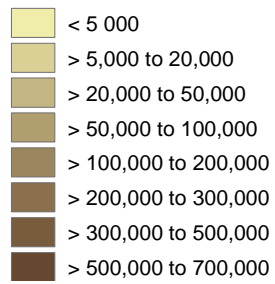
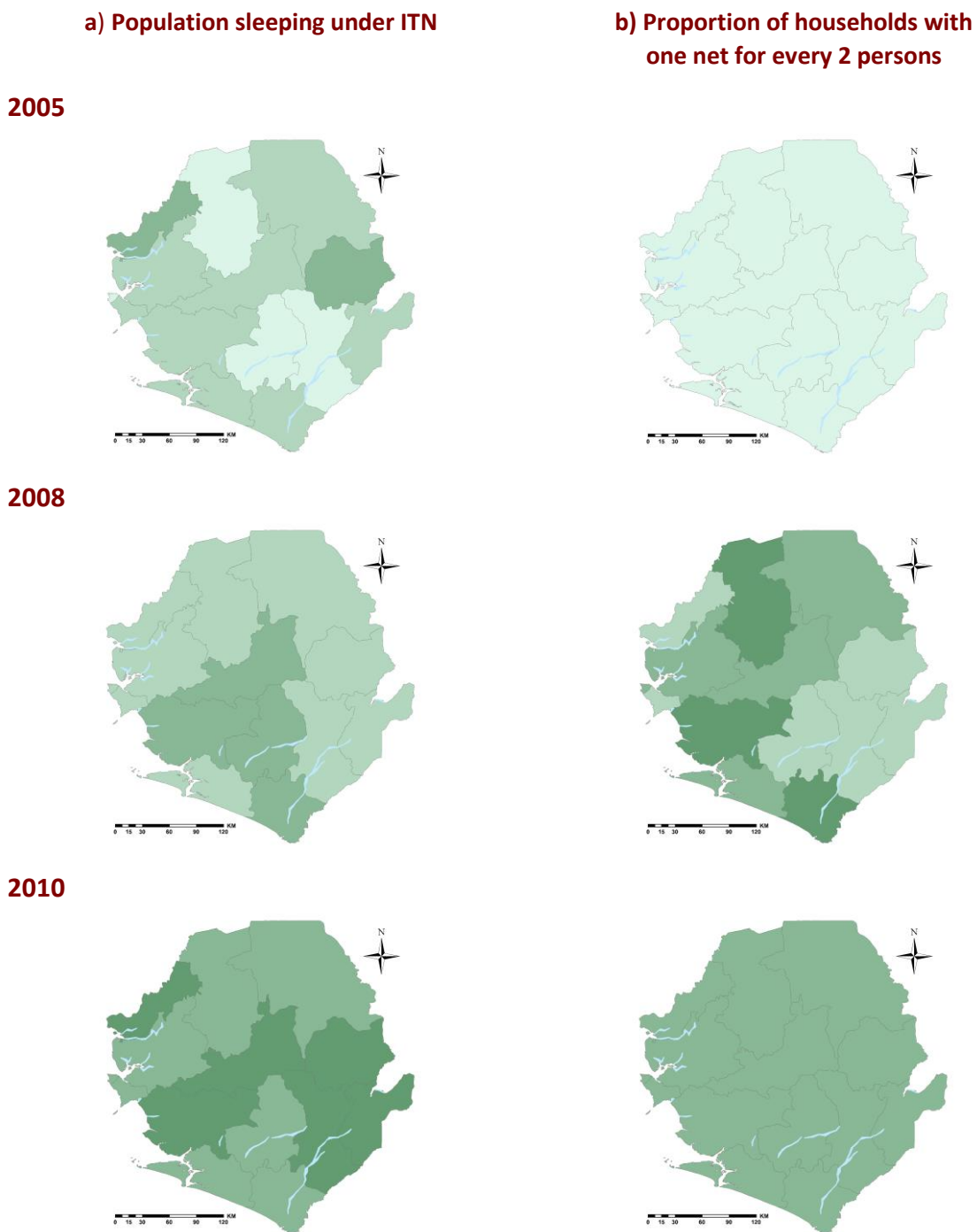


Figure 22 presents two indicators of ITN coverage – ITN use and an indicator of ‘universal coverage’ - by health district, between 2005 and 2013.

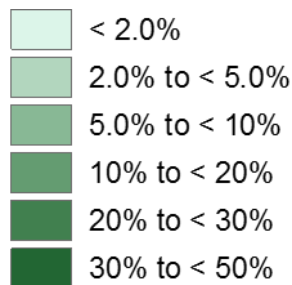
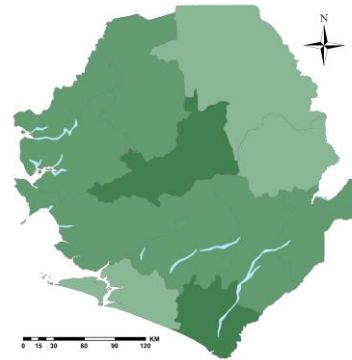
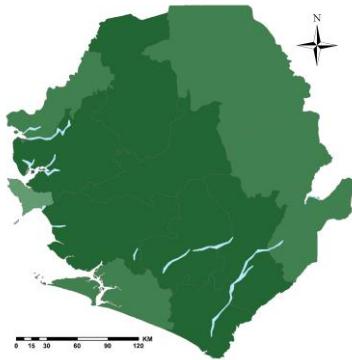
FIGURE 22: PROPORTION OF POPULATION SLEEPING UNDER AN ITN AND HOUSEHOLDS WITH AT LEAST ONE ITN PER TWO PEOPLE



a) Population sleeping under ITN

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

2014



INDOOR RESIDUAL SPRAYING

IRS has a long history in Sierra Leone with trials being document as early as 1940 and IRS programmed being deployed through till the early 1950s. More recently a pilot of indoor Residual Spraying (IRS) was conducted in selected Chiefdoms of Bo, Bombali, Kono and Western Rural districts in 2011 and 2012 (see Operational Research section, above).

Figure 23 illustrates those districts targeted for IRS since 2011 using Lambdacyhalothrin. Figure 24 depicts those that received IRS between 2010 and 2012.

FIGURE 23: DISTRICTS (YELLOW) TARGETED FOR INDOOR RESIDUAL SPRAYING (IRS) SINCE 2011 IN SIERRA LEONE

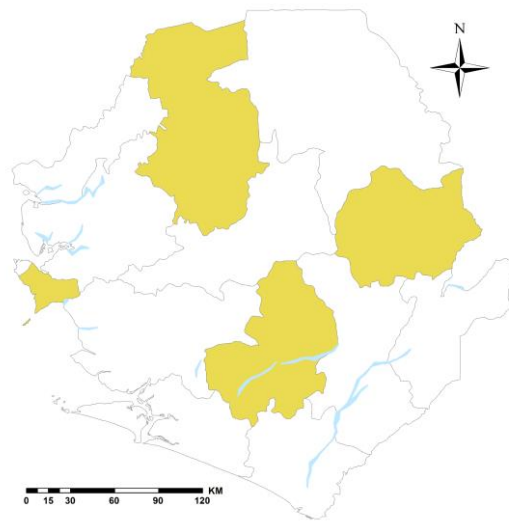
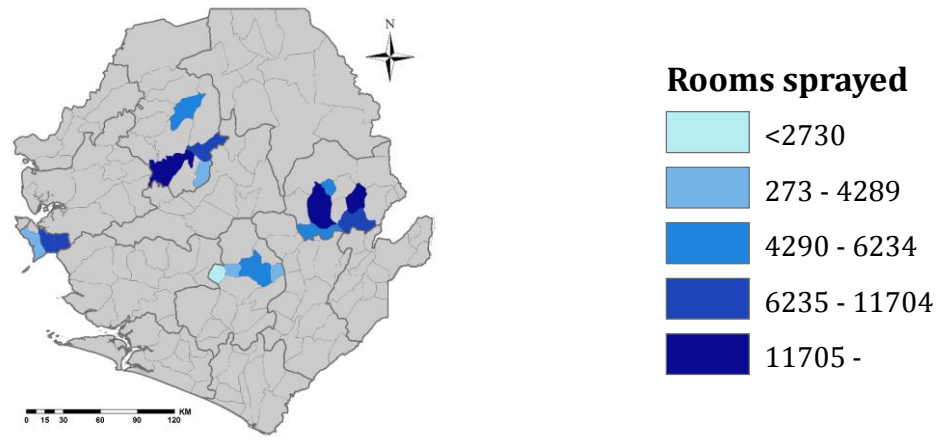
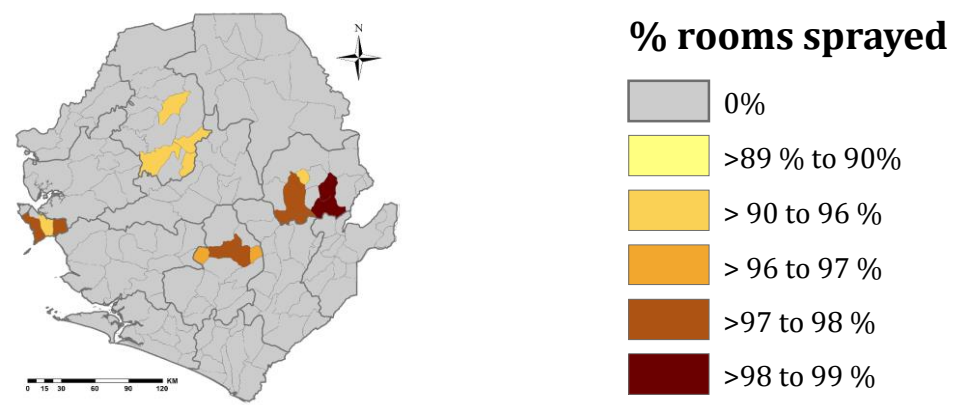


FIGURE 24: INDOOR RESIDUAL SPRAYING (IRS) IN 2010-2012 IN SIERRA LEONE

Rooms sprayed



Coverage



Selected Chiefdoms were targeted in each IRS district: Bo (Badjia, Gbo, Bagbwa); Kono (Nyawa Lenga, Selenga, Fiama, Gbaneh, Nimikoro, Kamara, Gorama); Bombali (Safroko Limba; M/ Ndohahun, Makari Gbanti, Paki Masabong); Western Area Rural (Malambay, Lumpa(Partial), Macdonald, Crossing, Masorie, Newton, Kent, York, John Thorpe, Songo, Waterloo(Partial), Kissy town).The last district, Western Area Rural, had 12 Chiefdoms which had to be merged to the existing chiefdoms for mapping. Freetown5 (Crossing, Kissy town, Masorie, Newton and Songo), Freetown3 (John Thorpe Lumpa (Partial) Macdonald Malambay and Waterloo (Partial) and Freetown (Kent and York). For each Chiefdom data on the number of rooms sprayed and coverage achieved was computed.

Reference:

- National Malaria Control Programme (2012). *The implementation of IRS in Sierra Leone in 2010-2012*. Ministry of Health and Sanitation, Government of Sierra Leone, Draft Report, 2012.

MASS DRUG ADMINISTRATION

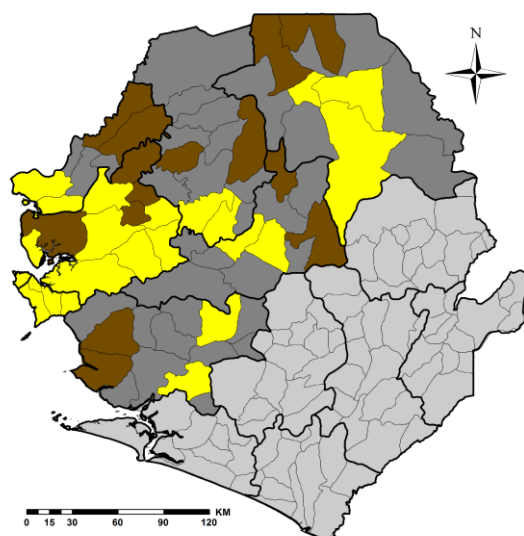
A pilot study on the potential effects of MDA during the malaria outbreak, using the first line treatment of artesunate-amodiquine (AS-AQ), was implemented in EVD hotspots. Two cycles of MDA were implemented: 5-8 December 2014 and 16-19 January 2015.

Figure 25 shows the districts targeted for MDA. These districts were Bombali, Kambia, Koinadugu, Moyamba, Port Loko, Tonkolili, Western and Rural Western Urban/Freetown) and are shaded in dark grey.

**FIGURE 25: MASS DRUG ADMINISTRATION (MDA)
FOR MALARIA DISTRICTS (DARK GREY) IN SIERRA LEONE**



FIGURE 26: MDA CHIEFDOMS – CONTROL (BROWN) VERSUS INTERVENTION (YELLOW)



Within MDA districts (dark grey) MDA Chiefdoms are shown in yellow and Non-MDA controls in brown (Figure 26).

In the NMCP report⁶² the Western Area is divided into Urban and Rural. 10 zones and 20 zones were captured in the Report for Rural and Urban Districts respectively. In mapping these chiefdoms, the two were merged and zones considered to have covered the entire districts. This is because of the lack of updated zones map for the Western Area.

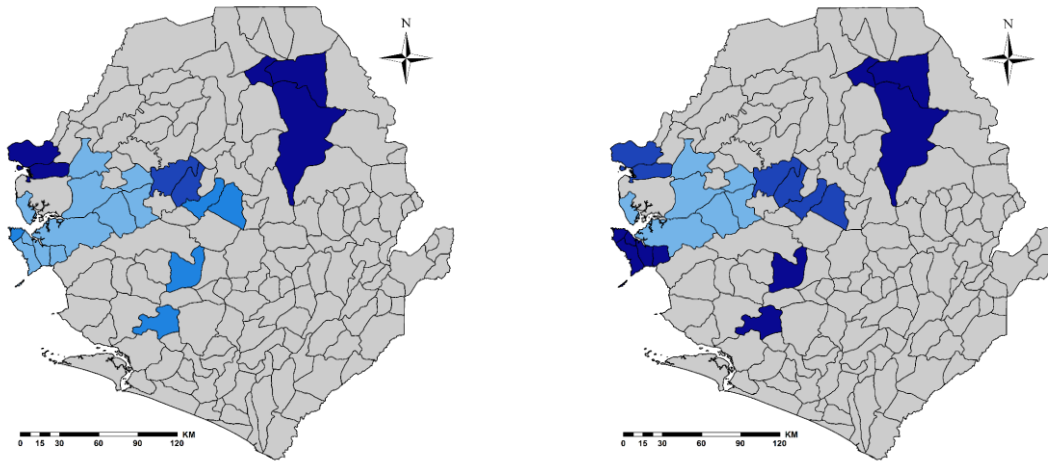
⁶² National Malaria Control Programme (2015). *Rapid Impact Assessment of Mass Drug Administration (MDA) for malaria in response to the Ebola outbreak in Sierra Leone*. Ministry of Health and Sanitation, Government of Sierra Leone, Final Report, May 2015.

Figure 27 shows MDA coverage estimates in target chiefdoms in the two rounds.

FIGURE 27: MDA COVERAGE IN TWO CYCLES OF MDA IN SIERRA LEONE

Cycle 1 (5-8 December 2014)

Cycle 2 (16-19 January 2015)



Percentage Coverage

- 0 %
- > 75 to < 79 %
- > 79 - to 85 %
- >85 to 90 %
- > 90 to 95 %
- > 95 to 101%

8. RECOMMENDATIONS

9. USB DRIVE CONTENTS

1. Profile

- Sierra Leone epidemiological profiles
- Sierra Leone districts mapping summary
- Sierra Leone health facility database
- Sierra Leone PR database
- Sierra Leone vectors
- Health districts shapefile
- Images

2. Library

3. Policies & Strategies

4. Implementation & Survey Reports

5. Sierra Leone: A Profile of Malaria Control and Epidemiology