TDR For research on diseases of poverty
UNICEF • UNDP • World Bank • WHO

Annual Report 2018

Vectors, Environment and Society

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List of abbreviations

ACMAD	African Centre of Meteorological Application for Development
AFRO	WHO Regional Office for Africa
ASEAN NDI	ASEAN Network for Drugs, Diagnostics, Vaccines, Traditional Medicine Innovation
ASEAN	Association of Southeast Asian Nations
CDC	Centers for Disease Control, USA
CNM	Cambodian National Center for Parasitology, Entomology and Malaria Control
COMBI	Communication for Behavioural Impact
EIR	Entomological inoculation rate
ENACTS	Enhancing National Climate Services
EWS	Early warning system
GIS	Geographic information system
GPW13	WHO's General Programme of Work 2019–2023
IAEA	International Atomic Energy Agency
IDRC	International Development Research Centre (Canada)
IRI	International Research Institute for Climate and Society at Columbia University
IRS	Indoor residual spraying
IVM	Integrated vector management
JOOUST	Jaramogi Oginga Odinga University of Science and Technology
LANDSAT	Space-based moderate-resolution land remote sensing data
LLIN	Long-lasting insecticidal net
LMICs	Low- and middle-income countries
MAFM	Multisectoral Action Framework for Malaria
MODIS	Moderate Resolution Imaging Spectroradiometer
NMAIST	Nelson Mandela African Institute of Science and Technology, Arusha, Tanzania
NTD	Neglected tropical disease
PI	Project investigator
RMT	Residual malaria transmission
RVF	Rift Valley fever
SACEMA	South African Centre of Excellence in Epidemiological Modelling and Analysis
SDF	Strategic Development Funds
SDG	Sustainable Development Goal
SESR	Socioecological systems and resilience
SIT	Sterile insect technique

STPH	Swiss Tropical and Public Health Institute
SU	Sokoine University, Morogoro, Tanzania
TDR	UNICEF/UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases
TDR/IIR	TDR unit on Intervention and Implementation Research
TDR/VES	TDR unit on Vectors, Environment and Society
UHC	Universal health coverage
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
VBD	Vector-borne disease
WHO/GMP	WHO Global Malaria Programme
WHO/NTD	WHO Neglected Tropical Diseases Programme
WIN	Worldwide Insecticide Resistance Network
WMO	World Meteorological Organization

Introduction

Three broad global objectives were defined in the WHO's *13th General Programme of Work 2019-2023: Promote health, keep the world safe and serve the vulnerable (GPW13)*. These are:

- Achieving UNIVERSAL HEALTH COVERAGE: One billion more people with Universal Health Coverage (UHC);
- Covering for HEALTH EMERGENCIES: One billion more people better protected from health emergencies; and
- Achieving HEALTHIER POPULATIONS: One billion more lives made healthier.

These objectives are tracked through specific indicators, including those related to infectious diseases of poverty in low- and middle-income countries (LMICs). Half of the neglected tropical diseases (NTDs) are vector-borne diseases (VBDs) which, together with malaria, account for 17% of the global burden on health. Moreover, for most of these diseases, only limited tools are available, either for prevention or control. Consequently, research on VBDs and their transmission patterns are an essential requirement to achieve the GPW13 goals.

In 2011, the Special Programme for Research on Tropical Diseases (TDR) created a unit to specifically address issues across diseases and sectors to improve the health and well-being of the most vulnerable populations affected by VBDs – Vectors, Environment and Society (TDR/VES). The unit supports research on new vector control interventions and their implementation and builds related research capacity and networks. These activities are in line with the new GPW13 strategic priorities, which include a broad scope of work on: i) the health of women, children and adolescents; ii) HIV, tuberculosis, malaria, hepatitis, NTDs, antimicrobial resistance and polio; iii) noncommunicable diseases, mental health, substance use, road traffic injuries; and iv) the health effects of climate change and the environment.

The TDR/VES workstream, established in 2014, addresses most of these priorities, with research topics focused on the most vulnerable populations. Activities specifically address research on the vectors of VBDs (with, but not limited to, vector ecology, biology and control technologies); community-based interventions; environmental and climate change impacts; and cross-cutting gender issues. The unit's objectives and activities were re-organized in 2018 into four main working areas as defined by the TDR 2018–2023 Strategy.[1] All VES expected results (ERs) are now included in one of these working areas and implemented through a holistic and integrated approach, as they are interdependent and have strong cross-cutting links. The four main categories are:

- Research for policies
- Research for implementation
- Research for innovation
- Research for integrated approaches

This report covers TDR/VES activities and achievements in 2018 and the ERs within each working area. Progress is presented on ERs and outcomes according to specific objectives, as summarized in Table 1. Information on the VES budget and financial implementation is summarized in Annex Table A1. Proposals for the 2020–2021 biennium and the associated TDR/VES programme and budget are presented in Annex Table A2. TDR funding by contributor is found in Annex 2. The recommendations of the Scientific Working Group (SWG) for Research for Implementation held from 18–19 September 2018, are presented and addressed in Annex 3. A full list of TDR contract implementation is presented in Annex 4. Annex 5 presents a list of the publications resulting from the TDR/IDRC Research Initiative on VBDs and Climate Change; and Annex 6 lists the advanced degrees of students supported by the TDR/IDRC Research Initiative on VBDs and Climate Change.

[1] The Strategy is available at https://www.who.int/tdr/publications/about-tdr/strategy/strategy-2018-23/en/.

Objectives

TDR/VES activities align with the four main objectives cited above and the expected results (ERs) are grouped into these workstreams. All activities have the overall goal to achieve tangible impact on policies and recommendations to improve the health of the most vulnerable.

Objective 1 – *Research for Policies*: The aim of this objective is to provide evidence that can be used to draft policies that will decrease VBD transmission. The ERs included in this objective are:

- **ER 1.3.3** – Population health vulnerabilities to vector-borne diseases (VBDs): Increasing resilience under climate change:
  - analyse and mitigate the impact of environmental change on the transmission of infectious diseases, in particular VBDs; and
  - advise and implement recommendations and policies that prevent adverse effects and increase resilience of populations.
- **ER 1.3.7** – Environmental prevention and control of VBDs and infectious diseases in South-East Asia:
  - provide evidence on impact of environmental changes on VBD transmission;
  - test innovative community-based solutions to control VBD transmission; and
  - coordinate multisectoral joint action and community empowerment.

Objective 2 – *Research for Implementation:* This objective includes activities to improve the implementation of already recognized tools, and focuses on gender-intersecting inequalities that influence vulnerability to, and the impact of, particular health conditions associated with infectious diseases in LMICs. This objective has two ERs:

- **ER 1.3.8** – Develop, pilot test and replicate an innovative training course for capacity building on gender-based analysis in VBD research and other infectious diseases of poverty:
  - develop a training course with an innovative global classroom approach;
  - pilot test the course and evaluate the feasibility of its implementation; and
  - improve on the design and delivery of such a course and explore possibilities to replicate the course in other universities.
- **ER 1.3.12** – Strategies to promote gender-responsive health interventions on prevention and control of infectious diseases.

Objective 3 – *Research for Innovation:* This objective includes activities on new tools. More than 50% of the world's population currently lives in cities which have experienced a 36% rise in population since 2000 (an increase of 1.02 billion people in urban areas). This upward trend is expected to continue and by 2050, around three-quarters of the global population will be living in urban conglomerations, mainly in LMICs. Mobility, poverty, inequality and climate change are some of the drivers of health risks in urban settings, including infectious diseases such as dengue, influenza (avian and swine flu), tuberculosis-AIDS, urban malaria, leishmaniasis, lymphatic filariasis, rabies and water-borne diseases. In recent years, disastrous dengue and chikungunya virus epidemics in urban settings were accompanied by a breakdown in social services and health care delivery. In the context of the new vector control tools that are currently in the pipeline, a collaboration is developing with WHO/NTD and the International Atomic Energy Agency (IAEA) to work on the sterile insect technique (SIT).

The ER under this objective focuses on VBDs and urban health interventions:

- **ER 1.3.10** – Urban health interventions for the prevention and control of vector-borne and other infectious diseases of poverty; with the objective of generating evidence on urban health interventions for the prevention and control of vector-borne and other diseases of poverty.

Objective 4 – ***Research for Integrated Approaches*:** This objective focuses on developing and implementing new approaches at the interface of relevant disciplines, all related to transmission patterns and control of VBDs. This objective includes support to research activities to increase understanding of the challenges faced by elimination programmes, and additionally supports country networks to prevent and better respond to infectious disease emergencies. The development of networks is supported under this objective for: emerging arboviruses in the Caribbean; resistance of the vectors of arboviruses worldwide; and on prevention and control of epidemic arboviral diseases in Western Africa. The two research ERs associated with this objective are:

- **ER 1.3.6** – Study of the impact of insecticide resistance on long-lasting insecticidal nets (LLINs) and indoor residual spraying (IRS) efficacy, and studies of the burden and causes of residual malaria; and
- **ER 1.3.11** – Multisectoral approach for prevention and control of malaria and emerging arboviral diseases

Key achievements in 2018

Research Initiative on VBDs and Climate Change

- **New knowledge and evidence** generated on the impact of VBDs in the context of climate change (see publications listed in Annex 5).
- **Decision support processes and tools developed.** Several methodologies were developed using remote sensing to monitor climate variability and environmental conditions, and their impacts on the dynamics of VBDs. The research initiative demonstrated how remotely sensed data can be accessed, analysed and integrated into research, decision-making processes for mapping risks, creating early warning systems (EWS), and evaluating the impacts of disease control measures.

Research on causes and the burdens of residual malaria

Research projects on residual malaria and impact of insecticide resistance on LLIN efficacy demonstrate that persistent malaria transmission in many settings is not residual but due to an inadequate coverage and use of the tools (LLINs and IRS).

Environmental prevention and control of VBDs in South-East Asia

Research supports a proof-of-concept that the release of super-sterile male mosquitoes can reduce the natural populations of *Aedes aegypti* in one village in eastern Thailand.

Urban Health

Scoping reviews were published in a special issue of the *Journal* of *Infectious Diseases of Poverty* on urban health, VBDs and other infectious diseases of poverty.

Multisectoral Approaches

The activities on multisectoral approaches for prevention of VBDs has produced six commissioned reviews, the framework for which was discussed at a workshop, resulting in the preparation of a guidance document.

Gender

- **Strengthened interdisciplinary research collaboration.** This collaboration will guide the design and implementation of gender-responsive interventions to prevent and treat infectious diseases – but also to strengthen researchers' capacities to incorporate intersectional gender analysis.
- **Informed strategic approach on gender and intersectionality.** In the context of infectious diseases of poverty, TDR will incorporate an intersectional gender lens in research and training in line with the GPW13.
- **Gender-based analysis.** Research capacities will be strengthened on gender-based analysis in VBD and climate change research in LMICs.

One Health

TDR participated in a *Special Plenary Session on Neglected Zoonotic Diseases* at the One Health Congress 2018, held in Saskatoon, Canada, 22–25 June 2018 (see figure 3).

Networks

- A network on preventing emerging VBDs in the Caribbean has been established and is now self-sustainable.
- A network on insecticide resistance distribution and mechanisms for *Aedes* mosquitos was established and is now self-sustainable.
- A network on preventing emerging VBDs in West Africa was started and an assessment of needs has been finalized.

Summary progress description

Table 1. TDR/VES Expected Results workplan and overall progress

Ongoing expected results by outcome	Indicators and progress against targets
Expected Results and Strategic Development Funds (SDFs) ongoing in 2018	
1.3.3: Population health vulnerabilities to vector-borne diseases (VBDs): Increasing resilience under climate change • Complex socioecological conditions of water systems in African drylands identified and characterized by their potential impact on VBDs • VBD risks assessed under various environmental exposure conditions and vulnerability context • Decision support processes and tools for health impact assessment • Capacity and network built for better management of climate and environment-related health risks	Research evidence provided: • To date, more than 150 articles have been published • Policy briefs were shared with various stakeholders and decision-makers in the health and environment sectors in seven African countries (ministries of health and environment) and other partners (WMO, UNEP and ACMAD) • Special Issue in the *Journal of Infectious Diseases of Poverty* • Implementation of iterative processes for active community engagement and feedback Decision support processes and tools developed: • All projects have used disease surveillance data, vector data and climate observations to inform the development of mapping interfaces and tools that will be useful in decision-making processes for

Ongoing expected results by outcome	Indicators and progress against targets
	prevention and control of VBDs • Several methodologies were developed using remote sensing to monitor climate variability, environmental conditions, and their impacts on the dynamics of VBDs • The research initiative also demonstrated how remotely sensed data can be accessed, analysed and integrated into research and decision-making processes for mapping risks, creating early warning systems (EWS), and evaluating the impacts of disease control measures Community of practice established: • A web-based knowledge-sharing platform, VBD-environment.org, was launched in July 2015 and continues to be supported; at least 100 researchers and public health practitioners are part of this network • Participation and/or organization of several capacity building workshops and scientific fora • Advanced academic degrees for 59 students (MSc, PhD and postdoctoral programmes) • Communities actively contributed to the research process and participated in capacity- building activities for increased population resilience to VBDs and climate changes
1.3.6: Evaluation and improvement of malaria control policies through study of the impact of insecticide resistance on LLINs and indoor residual spraying (IRS) efficacy, and preliminary analysis of the burden and causes of residual malaria Deliverables by outcome: • Insecticide resistance mechanisms known • Impact of the resistance on malaria control • Burden and causes of residual malaria	• By 2018: Some recommendations and policies for better implementation of malaria control through LLINs and IRS, based on the results of the research project, are already available and published on an open website http://vbd-environment.org/ • By 2019: Implementation plans for deployment of tools that are adequate to the situation (vectors and human behaviours) developed for each project in collaboration with stakeholders
1.3.7: Environmental prevention and control of VBDs and infectious diseases in South-East Asia Deliverables by outcome: • Evidence on impact of environmental changes on VBDs transmission in the selected setting • Innovative solutions to control VBD transmission • Research uptake to coordinate multisectoral joint action and community empowerment	• By 2018: Two projects being implemented. New evidence demonstrated proof-of-concept that the release of super-sterile male mosquitoes can reduce the natural populations of *Aedes aegypti* in one village in eastern Thailand • By 2019: Innovative solutions for VBD control have been tested
1.3.8: Develop, pilot test and replicate an innovative training course for capacity building on gender-based analysis in VBD research and other potential infectious diseases of poverty Deliverables by outcome: Training course on gender-based data analysis delivered	• In 2017, training course on gender-based data analysis pilot tested, reviewed and evaluated for feasibility of implementation • In 2018, Pilot training course at the University of Ghana Medical School implemented and a second and final peer-reviewed evaluation completed

Ongoing expected results by outcome	Indicators and progress against targets
1.3.10: Urban health interventions for the prevention and control of vector-borne and other infectious diseases of poverty Deliverables by outcome: • Commissioned reviews • Workshop organized for discussion on research priorities. By 2017, commissioned reviews completed, and a workshop held in Colombia, March 2017	• In 2018, commissioned reviews completed and published in the peer-reviewed journal, *Journal of Infectious Diseases of Poverty*
Expected Results and SDF completed in 2018	
1.3.1: Promoting research for improved community access to health interventions in Africa Deliverables by outcome: • Research reports, publications and strategies to strengthen primary health care • Testing of the public health benefit of a treatment package for integrated Community Case Management (iCCM) of malaria and pneumonia, focusing on mortality • Knowledge generation and management on community-based interventions	• In 2016, systematic reviews published: Eight systematic reviews published • In 2017, recommendations available for countries participating in the studies • In 2018, studies published: More than 20 papers published
1.3.2: Improved Chagas and dengue disease control through innovative ecosystem management and community-directed interventions Deliverables by outcome: • Cross-disciplinary research framework for ecological-biological-social (EBS) studies and toolkit for EBS research • Evidence for EBS approach to strengthen VBD control	• In 2014, EBS framework developed in Latin America • In 2014, 15 studies completed and published
1.3.4: EBS research in support of the WHO Global Strategy for dengue prevention and control Deliverables by outcome: • Implementation research on productive dengue vector breeding sites and targeted interventions. By 2016, four country studies completed • Studies completed in three countries and final technical reports available	• In 2016, final joint meeting with TDR/IIR on "Innovative Tools and Strategies for the Prevention and Control of Arboviral Disease: A Research to Policy Forum", August 2016
SDFV.1: Improving the careers of women research scientists in infectious diseases of poverty (TDR-wide activity) Deliverables by outcome: • Research reports, publications and strategies to improve the careers of women scientists	• In 2015, nine case studies on how the careers of women scientists can be improved and funded • In 2016, reports with cross-site analysis on activity portfolio of nine sites • In 2017, final technical reports of the nine projects received, and cross-site analysis done by an intern

Ongoing expected results by outcome	Indicators and progress against targets
SDFV.2: Implementation of a regional network on surveillance, diagnostic and vector control of vector-borne emerging diseases in the Caribbean region Deliverables by outcome: • Organization of two workshops • Publication of proceedings • Official network launched	• Workshop held in Trinidad, December 2015 and in Saint Kitts and Nevis, May 2016 • Caribbean Network officially launched in August 2017 in Cuba (carivecnet.carpha.org). Financial sustainability achieved through the European Union, the Center for Disease Control and Prevention (CDC), and the Caribbean Community (CARICOM) funds • Four working groups established in 2017 on surveillance, clinical management, diagnostics and vectors. • By 2019, assessment of facilities and capacities for surveillance and diagnostic of emerging arboviruses available for Caribbean countries
SDFV.4: Development of an online platform for courses on vectors and VBDs for low- and middle-income countries (LMICs) Deliverables by outcome: • Commissioned review and organization of a workshop • Publication of proceedings • Platform launched. By 2016, commissioned review available and published, workshops held, proceedings of the workshops published	• Workshop held in Lisbon in February 2016 • Commissioned review published in *Memórias do Instituto Oswaldo Cruz (MIOC)* in November 2016 • By 2016, directory of courses available • No budget was available for the development of the platform
SDFV.5: Selection of a consortium of institutions for the organization of a workshop and commissioned reviews to develop an international network on surveillance of insecticide resistance and alternative methods of control for vectors of emerging arboviruses (Worldwide Insecticide Resistance Network, WIN) Deliverables by outcomes: • Commissioned reviews and organization of a workshop • Publication of proceedings • Publication of reviews • WIN launched and sustainable	• WIN website launched, May 2016 • Workshop held in Brazil, December 2016, with more than 73,000 Internet connections • Proceedings of the workshops published, February 2017 • By 2018, four commissioned reviews published in peer-reviewed journals • By 2019, insecticide resistance recommendations used in policies

Progress description and plans for 2019–2021

Objective 1: Research for Policies

ER 1.3.3: Population health vulnerabilities to vector-borne diseases (VBDs): Increasing resilience under climate change conditions in Africa

The TDR/IDRC Research Initiative on VBDs and Climate (Ramirez B et al., 2017), was focused on the particular health threat posed by VBDs in the broader development context of human vulnerability to climate change. The overall goal of this research initiative was to generate evidence to enable development of innovative strategies to reduce VBD-related human vulnerability and to increase resilience of African populations to VBD-related health threats. In addition, this work aims to broaden and extend knowledge, research capacity, collaboration and policy advice products that can be used throughout Africa and other regions. This portfolio is also expected to contribute to the WHO's Global Vector Control Response (2017–2030)[2] and the UN Sustainable Development Goals (SDGs) 2015–2030,[3] particularly in the areas of health and climate action.

To support a portfolio of research projects in this topical area, TDR collaborated with one of its long-standing contributors, Canada's International Development Research Centre (IDRC). Consequently, the TDR/IDRC Research Initiative on VBDs and Climate Change (2012–2017) was established to provide the opportunity to optimize resources and technical expertise in this area. The initiative focuses on addressing the need for transdisciplinary, multisectoral approaches for development of actionable strategies that address cumulative environmental and climate change effects on health. New knowledge and evidence generated from the research initiative will enable African health officials to better predict and respond to emerging health threats linked to climate change, and improve the effectiveness of climate change adaptation and health investments (see Table 2 for a list of supported research projects).

Table 2. List of climate-related research projects supporting ER 1.3.3

Project title	VBDs/countries in Africa	Principal Investigator
Project A: Social, environmental and climate change impact of VBDs in arid areas of Southern Africa	Malaria and Schistosomiasis Botswana, South Africa, Zimbabwe	Moses Chimbari, College of Health Sciences, University of Kwazulu-Natal (UKN), Durban, South Africa
Project B: Early warning systems for improved human health and resilience to climate sensitive vector-borne diseases in Kenya	Malaria and Rift Valley Fever (RVF) Kenya	Benson Estambale, Jaramogi Oginga Odinga University of Science and Technology (JOOUST), Bondo, Kenya
Project C: Predicting vulnerability and improving resilience of the Maasai Communities to vector-borne infections: an EcoHealth approach in the Maasai Steppe ecosystem	African trypanosomiasis Tanzania	Paul Gwakisa, Nelson Mandela African Institute of Science and Technology (NMAIST), Arusha, Tanzania

[2] This WHO publication is available at: https://www.who.int/vector-control/publications/global-control-response/en/.
[3] For more information on the SDGs, see https://una-gp.org/the-sustainable-development-goals-2015-2030/.

Project title	VBDs/countries in Africa	Principal Investigator
Project D: Human African trypanosomiasis, alleviating the effects of climate change through understanding the human-vector-parasite interactions	African trypanosomiasis Tanzania, Zimbabwe	John Hargrove, South African Centre of Excellence in Epidemiological Modelling and Analysis (SACEMA), University of Stellenbosch, South Africa
Project E: Vulnerability and resilience to malaria and schistosomiasis in northern and southern fringes of the Sahelian belt in the context of climate change	Malaria and schistosomiasis Côte d'Ivoire, Mauritania	Brama Kone, Centre Suisse de Recherches Scientifiques en Côte d'Ivoire, Abidjan, Côte d'Ivoire

Outputs

New knowledge and evidence on the impacts of changing VBD risks, environmental exposure and social vulnerabilities under climate change and associated health outcomes. These are assessed and characterized under various environmental, social and climatic conditions in Africa. New knowledge and evidence generated from the projects are detailed in scientific papers that have been published (see Annex 5). Additional information can be obtained from the online knowledge-sharing platform, http://vbd-environment.org/.

Decision-making and support processes and tools for VBDs and adaptation to climate change interventions have been developed, for example, *VBD and climate change adaptation interventions: Tools to enable access to and use of climate services for health were developed* (Ceccato P et al., 2018, and Thomson M et al., 2018).

For the research initiative, several methodologies using remote sensing to monitor climate variability, environmental conditions, and their impacts on the dynamics of VBDs were developed. The research initiative demonstrated how remotely-sensed data can be accessed and analysed, and how they can be integrated into research and decision-making processes for mapping risks, creating early warning systems (EWSs), and evaluating the impacts of disease-control measures.

This research initiative recognized that one of the most pressing needs for operational health agencies is the strengthening of current disease control efforts to bring down disease rates and manage short-term climate change risks. This may, in turn, increase resilience to long-term climate change.

To address this need, TDR collaborated with the International Research Institute for Climate and Society (IRI) at Columbia University to develop research tools and networks. Researchers, policy- and decision-makers, public health practitioners, and communities from lower- and middle-income disease-endemic African countries received capacity building and access to and use of climate services for health. The following is a brief list of some of the learning and capacity-building activities:

- Understanding and establishing the relationship between diseases and climate by creating spatial and temporal stratification of the diseases and population risk (i.e. risk mapping);
- Estimating the seasonality of the disease and timing of intervention; and
- Developing and implementing frameworks for EWSs for real-time monitoring real time and forecasting the risks of disease transmission based on climate and environmental factors.

When working with VBDs, researchers and decision-makers often face a lack of quality climate data required for optimal targeting of the intervention and surveillance. While raw climate data (station- and satellite-generated) can be accessed freely online, this is not always readily available, especially in Africa; and whenever data is available, processing the data appropriately requires technical skills.

Thus, ease of access should not be mistaken for ease of analysis since the datasets are highly complex and require complex analysis, especially when applied to decision-making. Various core tools have been developed to improve data accessibility and analysis for use by decision-makers and researchers across all projects supported under this research initiative.

Networks can support the development and use of decision-making and support systems for better management of VBD risks and vulnerabilities related to climate change in Africa. This networking engages cadres of young researchers from African countries and aims to increase skills development to identify appropriate research topics, and obtain, manage and use social, environmental and climate information in VBD research (see Annex 5 for a list of research published)**.**

A Climate Data Library as an integrated knowledge system, organized as a library, and containing a collection of both locally held and remotely held datasets for earth observations on:

- Precipitation – sourced from the Global Precipitation Climatology Project, Climate Prediction Center Merged Analysis Precipitation, CPC MORPHing technique, Tropical Rainfall Measurement Mission, Global Precipitation Measurement, African Rainfall Estimate, Enhancing National Climate Services (ENACTS) and Climate Hazards Group Infrared Precipitation with Station;
- Temperature and land-surface temperature – sourced from MODIS (Moderate Resolution Imaging Spectroradiometer) and ENACTS;
- Vegetation – sourced from Global Normalized Difference Vegetation Index and Terra MODIS Normalized Difference Vegetation Index (NDVI);
- Water bodies and inundation products – sourced from Terra MODIS and LANDSAT reflectance channels, remote-sensing observations from multiple satellite sources: European Remote-Sensing Satellite (ERS) scatterometer; Quick Scatterometer (QuikSCAT); Special Sensor Microwave/Imager (SSM/I); Advanced Microwave Scanning Radiometer – Earth Observing System (AMSR-E); and inundation fraction products;
- Others – sourced from a menu of maps and analysis used to monitor current global and regional climate as well as archived/historical data such as from: the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA) and the Goddard Institute for Space Studies, New York in the United States; the Climate Research Unit, University of East Anglia, the United Kingdom; the European Centre for Medium-Range Weather Forecasts (ECMWF) and the WMO;
- Online tutorials, and “how-to” guide on access and use of the Climate Data Library;
- Online map rooms provide easy access to point-and-click map-based user interfaces which are built into the Climate Data Library infrastructure. These are particularly suited to areas where connectivity and the Internet is slow and where downloading very large remotely sensed data images can be a problem;
- Data archiving within the Climate Data Library – a special automated software was used to update the near-real-time datasets as soon as they are available from the data sources (for example, MODIS satellite data is available in the Climate Data Library within one day after processing is complete at the NASA Data Center);
- Data analysis tools – time-series analysis for climate trends and anomalies; and
- An algorithm for use within the Google Earth Engine that can allow communities, researchers and public health practitioners to access Google’s high-performance computing resources to produce systematic data products or deploy interactive applications without needing to be an expert in application development, web programming or HTML. An example is the integration of trypanosomiasis data with eight LANDSAT satellite images of bodies of water in the Maasai villages in Simanjiro district, northern Tanzania.

Smartphone applications were developed for:

- Integrating satellite images on precipitation, temperature and water bodies with local data on habitats of tsetse flies and occurrence of cattle trypanosomiasis. This application allowed the Maasai community and local officials to access high-spatial resolution images and extract time-series analysis for mapping the risks of trypanosomiasis in the Maasai villages; and
- Collecting health data geo-referenced with pictures of the environment, data of vector breeding sites, data from socioeconomic and health surveys. This application is based on Open Data Kit (ODK)4 and can create decision support for researchers, communities and public health practitioners to build multimedia-rich customized mapping tools.

1. OTHER TOOLS DEVELOPED FOR DISEASE-SPECIFIC APPLICATIONS

Malaria

Use of ecological mapping of *Anopheles arabiensis* larval habitats for larval control programmes has been a focus of tool development. Indicators like floods and diversified breeding sites and their contribution to prolonged and prolific larval breeding, "short" aquatic vegetation, turbidity and water conductivity were useful as early warning indices for predicting larval numbers. The following are other tools related to malaria:

- *Malaria outbreak prediction tools,* based on data interactions between climate variables and malaria, are used for predicting outbreaks and for the design of preparedness interventions. This includes the analysis and use of clinical malaria transmission patterns and its temporal relationship with climate (rainfall, flood discharge and extent, mean minimum and mean average temperatures) which is then correlated with the incidence of clinical malaria cases.
- *The vector dynamics* tool is used to inform more effective strategies for IRS in malaria elimination programmes, using essential and relevant entomological indices that contribute to malaria transmission of the indoor-resting population of *Anopheles arabiensis*.
- *Disability-adjusted life year (DALY) metrics* are used to assess the burden of malaria and provide a better understanding of the impact of malaria in communities. It is important to estimate the malaria burden to assist policy-makers in formulating evidence-based decisions when planning resources for malaria control and prevention.
- *Mapping the spatial distribution of malaria incidence* was useful in improving the planning and implementation of malaria elimination programmes.
- A *tool to monitor malaria trends* and the association with climate variables in Zimbabwe determined that the period of high malaria risk is associated with precipitation and temperature at 1–4 months prior to the seasonal cycle. Intensifying malaria control efforts over this period will likely contribute to lowering the seasonal malaria incidence.
- A *time-series analysis tool* was used for exploring the relationship between climate variables, based on data gathered by the IRI and the Lamont-Doherty Earth Observatory (LDEO) climate databases to track and analyse malaria transmission dynamics and develop effective malaria control strategies.

[4] The Open Data Kit community produces free and open-source software for collecting, managing, and using data in resource-constrained environments. It allows the collection of data offline and submit the data, when internet connectivity is available.

- A *malaria hotspots mapping tool* for tracking changing climate conditions was useful in mounting focused interventions within Baringo county, Kenya and included integrated mosquito control and chemotherapy for infected individuals.
- A *malaria risk mapping tool,* which incorporates the seasonal and year-to-year correlations (period covered 2004–2015) between climatic factors (rainfall and temperature) and vegetation cover and related implications for malaria risks in Baringo county, Kenya was useful for planning malaria control.
- A *modelling tool* to investigate the relationship between climate and environmental conditions and *Anopheles gambiae* s.l. larvae abundance was useful in zone-specific malaria interventions, such as the one focused on a dry season vector control strategy in the riverine zone.
- A *framework for malaria control for communities* in Baringo county, Kenya based on trends and local knowledge of malaria, was used to minimize the impacts and enhance uptake of appropriate malaria management mechanisms.

Schistosomiasis

- The *Maximum Entropy (Maxent) modelling tool* was used for the analysis of spatial and seasonal distribution of suitable habitats for *Bulinus globosus* and *Biomphalaria pfeifferi* snail species (intermediate hosts for *Schistosoma haematobium* and *S mansoni,* respectively). It was determined as a robust model for determining snail habitat suitability and is also useful in informing the development of a vector control and management strategy for schistosomiasis.
- A *community-based malaria early warning system model* was developed using community indigenous knowledge systems (IKS) indicators (insects, plant phenology, animals, weather and cosmological characteristics).
- *Participatory methodological tools* were used to capture local knowledge of communities for memories of experiential impacts of and adaptation to key environmental and anthropogenic change events; differentiated memories of historical events by communities are complementary and necessary in developing a comprehensive adaptation strategy.

Rift Valley Fever Virus (RVFV)

- *Vector presence modelling* may be useful in predicting the distribution of RVF vector species under climate change scenarios to demonstrate the potential for geographic spread of RVFV and to develop a risk map for spatial prediction of RVFV outbreaks.

Trypanosomiasis

- *A mapping and analysis tool* showed that trypanosome prevalence is dependent on fly availability, and temperature drives both tsetse fly relative abundance and trypanosome prevalence. This tool is useful for designing community-wide vector and disease control interventions and planning sustainable regimes for reduction of the burden of trypanosomiasis- endemic pastoral areas, such as the Maasai Steppe in northern Tanzania.
- A *mathematical model* was used to track the transmission of Trypanosoma *brucei rhodesiense* by tsetse vectors to a multi-host population through application of insecticides to cattle, either over the whole body or to restricted areas of the body, known to be favoured tsetse feeding sites. The restricted application technique resulted in improved cost-effectiveness, providing a cheap, safe, environmentally-friendly and farmer-based strategy for the control of vectors and Trypanosoma *brucei rhodesiense* in humans.

- *Insecticide-treated screens*, called targets, that simulate hosts can be one of the most economical and effective methods of tsetse control.
- *Mapping tools* provide substantial potential benefits to bovine trypanosomiasis control and facilitate more effective cost analysis of different approaches. Five intervention approaches are: trypanocides, targets, insecticide-treated cattle, aerial spraying and the release of sterile males. Mapping the specific benefits of each approach helps decision-makers and planners to define strategies, assists in prioritizing areas for intervention, and helps identify the most appropriate intervention approach.
- *Geostatistical models* predict local-scale spatial variation in the abundance of tsetse vectors of human and animal African trypanosomes, which allow vector control managers to identify sites predicted to have relatively high tsetse abundance, and to design and implement improved surveillance strategies.

2. CAPACITY AND NETWORK BUILDING IN AFRICA

Community of practice (CoP) established**:**

- A web-based knowledge-sharing platform, VBD-environment.org, was launched in July 2015 and continues to be supported. At least 100 young researchers and public health practitioners from African countries are part of this network.
- The CoP promotes participation in and/or organization of several capacity-building workshops and scientific fora.
- The network is also involved in advancing academic degrees for 59 students (MSc, PhD and postdoctoral programmes).
- Through the CoP, communities and relevant stakeholders and partners actively contributed to the research process and participated in capacity-building activities.

For a list of students whose advanced degrees were supported by the TDR/IDRC Research Initiative, please refer to Annex 6.

- **A total of 59 students** were part of this research programme
  Project A: twenty; Project B: eight; Project C: five; Project D: fourteen; and Project E: twelve
- **Master's programme**: 23 students
  Project A: six; Project B: five; Project C: two; Project D: six; Project E: four.
- **PhD programme**: 30 students
  Project A: eleven; Project B: three; Project C: three; Project D: five; Project E: eight)
- **Post-doctoral programme:** Six students
  Three each from Project A and Project D.

Gender distribution of the 59 students:

- **33 students (55.9%) men:**
  Project A: eleven; Project B: five; Project C: two; Project D: seven; Project E: eight
- **26 students (44.1%) women:**
  Project A: nine; Project B: three; Project C: three; Project D: seven; Project E: four

Plans for 2019; 2020–2021

The activities planned are:

- Funding applications: Through the TDR Strategic Development Fund (SDF) to support/convene a consultation meeting for operationalizing a One Health approach for the control of VBDs in the context of climate change. If approved, the project will be implemented Q1/Q2–2019; and
- Engagement with partners (WHO/AFRO, the UN Environment, the IDRC, among others): This activity will leverage funding for a new portfolio of research projects that will build on the achievements of the TDR/IDRC Research Initiative aimed to strengthen research uptake and translation.
-

Partnerships and collaborations:

- IDRC, Canada
- International Research Institute for Climate and Society (IRI)
- WHO/PHE – Public Health, Environmental and Social Determinants of Health
- WHO/AFRO, Protection of Human Environment Unit
- WMO

Leverage created by this project:

An estimated 8 million Canadian dollars was designated funding from the IDRC.

Gender aspects and vulnerable populations:

- The Special Project Team members were comprised of 57% men (four experts), and 43% women (three experts).
- The project sites are located among vulnerable populations that are economically disadvantaged and have a high risk for VBDs.
- A gender perspective is embedded within the implementation of the research projects, including gender analysis to address gender disparities and differences in the communities.

Publications:

New knowledge and evidence generated from the projects are detailed in published scientific papers (see Annex 5). Additional information can be obtained from the online knowledge-sharing platform, http://vbd-environment.org/.

Related news:

Refer to http://vbd-environment.org/.

ER 1.3.7: Environmental prevention and control of VBDs and infectious diseases in South-East Asia

The overall goal of this research programme is to contribute to improving environmental public health through strengthening community-centred environmental health services for the control and prevention of priority VBDs.

The specific objectives are:

- Identify and characterize environmental public health concerns and risks, and assess their potential impact on priority infectious diseases in a community;
- Develop and implement a sustainable, community-centred adaptation strategy to access environmental health support services, promote improved monitoring of environmental parameters, encourage the use of environmentally-friendly health technologies; and
- Assess and monitor the benefits resulting from the use, uptake and adoption of a sustainable, community-centred adaptation strategy for access to environmental health support services for the control and prevention of priority infectious diseases.

This new initiative, entitled *Collaborative research on health and the environment in the South-East Asian and Western Pacific regions: Innovative socioecological strategies for the prevention and control of VBDs,* aims to stimulate collaborative research. The main focus is generating a positive, transformative impact on health outcomes for populations challenged by VBDs within the context of an ever-changing environment (including climate change) and within a framework of complex socioecological systems.

This research initiative further envisions a health-supportive environment that can adequately and appropriately address the challenges of VBDs in South-East Asia, especially those areas with inadequate health infrastructure. Building a health-supportive environment ensures that intervention approaches are developed through coordinated multisectoral joint action and community empowerment. The initiative supports and contributes to the use, uptake and adoption of VBD control and prevention products that are preventive and sustainable, such as innovative tools, solutions, delivery mechanisms, and approaches to significant VBD challenges.

Progress in 2018

Project 1. Impact of socioecological systems and resilience (SESR) strategies on dengue vector control in schools and neighbouring household communities in Cambodia (Project investigator: Dr Jeffrey Hii, Malaria Consortium, Thailand)

A multitude of epidemiological, ecological and socioeconomic factors influence infectious disease transmission and imply the need for transdisciplinary, integrated and context-sensitive initiatives to design adaptive control strategies capable of sustainably interrupting disease transmission. The SESR theory is a conceptual framework and operational platform that is ideal for such an endeavour and encompasses a range of conceptual and methodological attributes (i.e. ecosystem approaches to health, participatory methods, etc.) and values and principles (equity, sustainability, epistemological pluralism, etc.).

Using the SESR conceptual and methodological rationale, the project proposes the characterization of a community-based and contextualized Dengue Vector Control Protocol, as well as its implementation, assessment and refinement through field studies in dengue-endemic transmission areas in Kampong Cham, Cambodia. The objectives of the study are:

- Carry out community-based environment-friendly mosquito control methods;
- Carry out training on dengue and its prevention in schools, in support of teachers willing to play a role in increasing community awareness and action (by transferring messages to students, parents and the rest of the community); and
- Generate new knowledge and best practices for the control of dengue in the community.

Children are disproportionately exposed to mosquito bites due to their higher risk of exposure at peak mosquito biting times of dengue vectors at home and in school (where they are often surrounded by exposed water-filled jars and containers ideal for mosquito breeding). To reduce this risk, this project offers an elementary school-based dengue education programme combined with a community participation approach to vector surveillance and control, using guppy fish (larvivorous fish) distribution, autocidal traps and participatory activities. This programme provides an opportunity for a low-cost and integrated strategy for dengue control in the community.

This project is investigating the benefits of two disease-specific interventions: i) integrated vector management (IVM) reduction procedures; and the communication for behavioural impact (COMBI) health education approach.

The following is an update on activities completed under Project 1:

A. Multisectoral and intersectoral planning meetings were convened with the ministries of education and health to develop plans of action in line with *Health Promotion in Schools*. A project inception workshop and field visits to study sites were organized in Kampong Cham in June 2018. Around 50 representatives of various stakeholder sectors participated in the workshop and field visits. These included: school teachers; health centre staff from the target study areas; the operational district and provincial health authorities, officials from the National Malaria and Dengue Control Programme; officials from the Ministry of Education; international partner experts from WHO (TDR and WHO-Cambodia); Bournemouth University; the Global Health Asia Institute; the Institute of Tropical Medicine, Belgium; the Institut Pasteur, Cambodia; and the Malaria Consortium. Outputs during the workshop included the following: an agreement by stakeholders and partners on the project implementation strategy (project goal, objectives and deliverables), an agreement on the Year 1 action plan; and an agreement on partner roles and responsibilities during the research cycle.
B. Teachers, students and managerial staff were trained in guppy fish rearing and mosquito surveillance. This activity is integrated into the school health curriculum.
C. Teachers conducted science classes (including basic introduction to ecology), lab demonstrations and biology projects on mosquito identification, guppy rearing and setting up guppy banks. These classes are organized in semester cycles, with additional opportunities provided through refresher and remedial training.
D. The Malaria Consortium[5] engaged with the Cambodia Provincial Health Department (PHD) and the Cambodian National Center for Parasitology, Entomology and Malaria Control (CNM) for the development of school and household survey protocols for assessment of basic demographic information (household and school composition), characteristics of housing and availability of health services. Community knowledge, attitudes and practices (KAP) surveys related to dengue and other VBDs have been completed (analysis is under way). The School Dengue Project integrated: geographic information system (GIS) vector mapping and geo-referencing of household clusters; larval/pupal/adult mosquito surveys for use in households

[5] For more information on the Malaria Consortium, see https://www.malariaconsortium.org/.

and public spaces; the use of a social research toolkit with modules for qualitative methods to assess social context and gender; and a standard guide for ecosystem characterization for *Aedes* dengue vectors. The mapping of study sites was completed while the KAP and entomological surveys and studies were under way.

E. Parent-teacher discussion forums were conducted to facilitate community awareness for COMBI activities (including stakeholder mapping), for the development of culturally-appropriate COMBI education and materials for schools and family households.

F. Fully operational guppy banks were established in three health centres. Additional guppy rearing jars were purchased and will be set up in the other health centres. As part of a social innovation and entrepreneurship approach, the ovitraps were manufactured locally.

The following activities are planned for the next phase of the project:

A. Teacher-supervised simple mosquito larvae collections from key containers and other breeding sites will be established. The larvae samples will be brought to the School Dengue Project labs for preliminary mosquito identification (to be confirmed by the Cambodian PHD and CNM staff) with the preservation of samples in 80% alcohol. Vector distribution maps will be generated from data on larval collections to inform a community intervention plan and to conduct resource mobilization.

B. Communities and schools in the intervention arm of the project will introduce vector-source reduction activities, and guppy fish and/or pyriproxyfen distribution. Teachers and students will participate in monitoring and mapping the interventions.

C. Household and school-based entomological surveys, rearing and maintaining guppy fish tanks, and household satisfaction surveys will be conducted; including in-depth interviews and focus group discussions post-intervention (three times per year). Collaboration with CNM will aim to distribute ovitraps in schools and households and to monitor weekly adult mosquito densities.

D. A costing study for preventive action will be undertaken in collaboration with the Cambodian Department of Planning and Health Information, and the Ministry of Health.

E. Mid-term reviews to assess progress, gaps and challenges will be conducted. Feedback and research findings will be disseminated to stakeholders, civil society, and policy- and decision-makers from the education and health sectors.

F. The School Dengue Project will convene an independent review panel to conduct an impact evaluation.

Project 2. Innovative vector birth control and socioecological strategies for the prevention of dengue, chikungunya and Zika diseases in Thailand

South-East Asia is the most rapidly developing region in the world and home to the greatest concentration of cultural and biological diversity. At the same time, environmental change is occurring at an historically rapid rate, creating vulnerable populations and ecosystems, and contributing to the emergence of global hotspots of emerging infectious diseases. VBDs, such as dengue, chikungunya and Zika diseases, are becoming important public health problems and high economic burdens in South-East Asia. Controlling the major mosquito vectors, *Aedes aegypti*, by reducing their populations is currently the only measure used to reduce disease risk and incidence.
So far, chemical insecticides have been the major approach in vector control operations, but due to an increasing trend in insecticide resistance in mosquito vectors, as well as the residual effects of chemical insecticide on the environment, there is an urgent need for alternative and effective vector controls in South-East Asia. In addition, due to the complexity of disease emergence, transdisciplinary and socioecological strategies are needed to successfully implement such an alternative approach.

An innovative vector birth control strategy using the super-sterile mosquito technique, combined with sterile insect techniques (SITs) and the *Wolbachia*-induced incompatibility approach, was successfully developed and applied in a small-scale operation in Thailand. In this project, an attempt was made to apply transdisciplinary, socioecological strategies to implement this innovative vector control tool in Bangkok. Upon completion, the project is expected to deliver a proof-of-concept for successful application of this novel vector control tool to reduce disease vectors in other participating network countries in South-East Asia.

Following a consultative meeting of WHO/TDR and the International Atomic Energy Agency (IAEA) in Bologna, Italy in May 2018, the workplan for this project was modified to reflect the impact of the mosquito SIT programme on disease (i.e., dengue). This modification was based on preliminary results from a small-scale pilot study that demonstrated that the project's proof-of-concept was successful in significantly reducing natural populations of *Aedes aegypti* in a village in the Pleang Yao District, Chachoengsao Province, in eastern Thailand. This resulted in the following findings:

- Baseline data on sterility and mating competitiveness of irradiated male mosquitoes is needed to determine effective release ratios for planning the mosquito release strategy.
- Site selection and spatial mapping of the study areas and sampling of households are important steps in conducting field trials. This includes GIS mapping of pilot release sites and collection households for released sterile male mosquitoes.
- Community and public engagement are key to the success of a pilot trial.
- Tools for monitoring mosquito populations (MosHouse traps, MosVac aspirators, ovitraps, etc.) are important for project evaluation and demonstrating success.
- A mosquito mass-rearing facility is needed to scale-up the mosquito SIT programme in Thailand.
- Further research is needed to determine the impact of the mosquito SIT programme on dengue.

Priority for future work will be focused on the conduct of a study to assess the impact of the intervention on both vector and disease in an appropriate study site in Bangkok. Dengue prevalence and incidence data, obtained by passive surveillance, will be included in the study. An epidemiological assessment is in progress, through scoping/accessing data from the Thailand National Surveillance System on dengue. The entomological assessment on egg surveys (ovitraps) and adult surveys (estimating adult population density using MosHouse adult traps) is also in progress. The future site in Bangkok is currently being identified for the next experimental release of super-sterile *Aedes* male mosquitoes, taking into account the availability of dengue surveillance data and facilities to follow up on the epidemiological data.

Expected contribution to impact

- The project should generate sustainable public health solutions fostering community ownership, participation and empowerment.
- Implementation modalities will be identified to apply the adaptive VBD control strategies that address social and ecological drivers of disease emergence.
- Further alternative and effective vector control strategies will be identified and explored.

Remaining challenges

Effective research project management is a challenge, especially in projects that are transdisciplinary in nature.

Partnerships and collaborations:

- Malaria Consortium partners in Thailand, Cambodia and the United Kingdom
- Go Green
- ASEAN NDI

Leverage created by this project:

- The ASEAN NDI Secretariat has pledged collaboration and funding support for capacity-building activities, including training workshops and scientific fora.

Gender aspects and vulnerable populations:

- Special Project Team members were comprised of 57% men (four experts), and 43% women (three experts).
- The project sites are located among vulnerable populations that are economically disadvantaged and have a high risk for VBDs.
- A gender perspective is embedded within the implementation of the research projects, including gender analysis to address gender disparities and differences in the communities.

Objective 2: Research for Implementation

ER 1.3.8: Develop, pilot test and replicate an innovative training course for capacity building on gender-based analysis in VBD research and other infectious diseases of poverty

Incorporating gender analysis in VBD research requires technical capacity among researchers. This can be limited, especially in disease-endemic countries, and thus, capacity building is a gap that needs to be filled. TDR/VES proposed to manage and coordinate the development of a training course for capacity building on gender-based analysis in VBD research. The target audience are researchers and policy-makers from disease-endemic countries, following a learning delivery method that deviates from the traditional concept, and utilizes an innovative global classroom approach.

In the innovative global classroom approach, the use of online learning will include: the use of web conferencing, video conferencing, discussion fora, and blog use and moderation; and the use of social media for assignments, assigned reading and other class-related activities. The course modules were developed in collaboration with the University of Ghana and have already been pilot tested and undergone two rounds of peer reviews. The specific objectives are:

- Develop a training course on gender-based analysis based on an innovative global classroom approach;
- Pilot test the course and evaluate the feasibility of its implementation; and
- Improve on the design and delivery of such course and explore possibilities to replicate the course in other universities.

Plans for 2019–2021

Plans are in progress to integrate the training course on VBDs and climate change research into the curricula of the University of Ghana and to explore further possibilities of upscaling such training modules in other universities in Southern Africa.

ER 1.3.12: Strategies to promote gender-responsive health interventions on prevention and control of infectious diseases

This expected result recognizes that gender norms, roles and relations influence people's susceptibility to different health conditions, on access to and uptake of health services, and on health outcomes experienced throughout the life course. The WHO recognizes that it is important to be sensitive to different identities that do not necessarily fit into binary male or female sex categories. In this context, delivery and access to prevention and control approaches and products for infectious diseases should not be configured as one-size-fits-all solutions, but instead should benefit from approaches that take into account the complex interaction of several social stratifiers, and their influence on health outcomes.

There is growing recognition that gender roles, gender identity, and gender relations, apart from institutionalized gender inequality, influence the way in which an implementation strategy works (e.g. for whom, how and why). There is also emerging evidence that programmes may operate differently within and across sexes, gender identities and other intersectional characteristics under different circumstances and contexts. Research should inform implementation strategies to avoid ignoring gender-related dynamics that influence if and how an implementation strategy works. Therefore, scientists focusing on implementation research would benefit from adequately considering sex, gender and other intersecting social stratifiers within their research programmes. This will strengthen both the practice and science of implementation, and will contribute to improved health outcomes and the reduction of gender and health inequalities. In addition, relevant research uptake strategies are important in decision-making, communication, stakeholder engagement and policy level interventions.

TDR supports research on the impact of gender dynamics and inequalities to control infectious diseases of poverty, and it also promotes gender equality among supported researchers and committee and board members. While there is a growing body of evidence on gender and intersectionality, the applications for the prevention and control of infectious diseases remain limited and could benefit from generating further knowledge to inform policy and practice.

The initiatives under this expected result are expected to strengthen research capacities and inform a strategic approach around gender and intersectionality in the context of infectious diseases of poverty within TDR programmes as well as support WHO's mandate and the GPW13. In order to expand work in this area, a comprehensive TDR-wide strategy for an intersectional gender approach in research would strengthen and inform good practice and policy.

In 2018, TDR/VES produced a draft research guidance toolkit (to be finalized in first quarter of 2019) to build research capacities for conducting intersectional gender analysis in infectious disease research. An expert group meeting was held with global experts on gender research, infectious diseases and public health to inform and strengthen the design of the strategic path for TDR's intersectional gender approach in research. The meeting was also attended by representatives from other WHO departments, including the Gender, Equity and Human Rights unit (GEH); the Sexual and Reproductive Health Unit/Human Reproduction Programme; the Alliance for Health Policy and Systems Research; and the UNDP (co-sponsor).

Plans for 2019–2021

In 2019, it is planned to : i) finalize a toolkit for incorporating intersectional gender analysis in research on infectious diseases of poverty; ii) open a call for research proposals in 2020–2021 to generate new knowledge and evidence on the intersection of sex and gender with other social stratifiers to address power relations, social exclusion, marginalization and disadvantage in access to quality health services and iii) develop a TDR-wide strategy for an intersectional gender approach in research on infectious diseases of poverty.

▪ Objective 3: – Research for Innovation

ER 1.3.10: Urban health interventions for the prevention and control of vector-borne and other infectious diseases of poverty

Scoping reviews and research gap analyses on urban health interventions for the prevention and control of vector-borne and other diseases of poverty were conducted in collaboration with the University of Montréal on six topics. An overarching commentary, a study protocol, a research article and six scoping reviews were completed and submitted to a peer-reviewed journal in January 2018 and published in September 2018. Six different research teams of three to eight people each undertook the scoping reviews in four different institutions covering the following topics:

- Field validation and implementation of rapid diagnostic test for vector-borne and other infectious diseases of poverty in urban areas;
- Surveillance systems for VBDs in urban settings;
- Impact, economic evaluation and sustainability of integrated vector management in urban settings;
- Transmission dynamics, vector capacity and co-infection;
- Containment measures of emerging and re-emerging vector-borne and other infectious diseases of poverty in urban settings; and
- Interventions for vector control focused on housing and hygiene in urban areas.

1. SPECIAL ISSUE ON URBAN HEALTH AND INFECTIOUS DISEASES OF POVERTY

In September 2018 the open access *Journal of Infectious Diseases of Poverty* published a special issue on urban health and infectious diseases of poverty, featuring the above topics. The special issue included a commentary paper, a study protocol, a research article and six scoping reviews on urban health and vector-borne and other infectious diseases of poverty.

Some highlights of the scoping reviews are shown below.

- **Rapid diagnostics:** This scoping review is of particular interest to health-care providers that need to choose among several different rapid diagnostic options. More evidence on the performance or implementation of current tests or alternative tools to detect a range of infectious diseases is needed to improve clinical management and diagnosis of VBDs.
- **Surveillance systems:** This extensive literature review on disease surveillance systems presents research and practice priorities on: innovative research for new disease control tools; cost-effective technologies for surveillance, including the use of mobile phones; and the benefits of cross-sector collaboration between public health and urban services.
- **Impact, economic evaluation and sustainability of integrated vector management (IVM):** Scoping review authors cite a lack of robust studies on the economic evaluation of interventions, and a scarcity of countries with operational IVM. Community involvement was highlighted as key to vector control success.
- **Transmission dynamics, vector capacity and co-infection of infectious diseases:** This review focuses mainly on dengue transmission in Asia and the Americas, and malaria transmission in Africa. Policies and practices are recommended that target the most at-risk populations, including stronger disease surveillance measures and early warning tools. Key knowledge gaps on the role of asymptomatic individuals, the impact of co-infections and other environmental and social factors are identified.

- **Containment of emerging diseases:** This review focuses on outbreak response and containment experiences with the Ebola virus and dengue. Authors recommend that research should extend beyond reporting on the effectiveness of detection and control actions. They urge scientists, policy-makers and health practitioners to take into account the complexity of real-world settings and how these conditions affect policies, practice and outcomes.
- **Housing and hygiene interventions:** Authors report that community involvement in risk management of VBDs is particularly promising at the household level. They identify waste management and sanitation, the integration of ecological and sustainable vector control strategies, and implementation research as priorities.

Plans for 2019–2021

- The completion of briefs on policy recommendations will be finalized in a planned meeting/workshop in 2019.
- A project presentation will be given at the above-mentioned meeting at the Institut de recherche pour le développement (IRD), France in 2019.
- Funds will be sought to convene the same meeting to present and discuss research priorities and policy recommendations. Attendees will include participants of the e-Delphi exercise.

Publications:

- Campeau L, Degroote S, Ridde V, Carabali M, Zinszer K. Containment measures for emerging and re-emerging vector-borne and other infectious diseases of poverty in urban settings: a scoping review. *Infect Dis Poverty,* 2018.
- Dagenais C, Degroote S, Otmani Del Barrio M, Bermudez-Tamayo C, Ridde V. Establishing research priorities in prevention and control of vector-borne diseases in urban areas: A collaborative process. *Infect Dis Poverty*, 2018*,* 7:85.
- Degroote S, Zinszer K, Ridde V. Interventions for vector-borne diseases focused on housing and hygiene in urban areas: a scoping review. *Infect Dis Poverty*, 2018.
- Degroote S, Bermudez-Tamayo C, Ridde V. Approach to identifying research gaps on vector-borne and other infectious diseases of poverty in urban settings: scoping review protocol from the VERDAS consortium and reflections on the project's implementation. *Infect Dis Poverty*, 2018.
- Eder M, Cortes F, Teixeira de Siqueira Filha N, França GVA, Degroote S, Braga C, et al. Scoping review on vector-borne diseases in urban areas: Transmission dynamics, vectorial capacity and co-infection. *Infect Dis Poverty*, 2018.
- Fournet F, Jourdain F, Bonnet E, Degroote S, Ridde V. Effective surveillance systems for vector-borne diseases in urban settings and translation of the data into action: a scoping review. *Infect Dis Poverty,* 2018.
- Marcos-Marcos J, Olry de Labry-Lima A, Toro-Cardenas S, Lacasaña M, Degroote S, Ridde V, et al. Impact, economic evaluation, and sustainability of integrated vector management in urban settings to prevent vector-borne diseases: a scoping review. *Infect Dis Poverty*, 2018.
- Osorio L, Garcia JA, Parra LG, Garcia V, Torres L, Degroote S, et al. A scoping review on the field validation and implementation of rapid diagnostic tests for vector-borne and other infectious diseases of poverty in urban areas. *Infect Dis Poverty*, 2018.
- Otmani del Barrio M, Simard F, Caprara A. Supporting and strengthening research on urban health interventions for the prevention and control of vector-borne and other infectious diseases of poverty: scoping reviews and research gap analysis. *Infect Dis Poverty*, 2018*,*7:94.

- Objective 4: Research for Integrated Approaches

ER 1.3.6: Evaluation and improvement of malaria control policies through study of the impact of insecticide resistance on LLINs and IRS efficacy, and preliminary analysis of the burden and causes of residual malaria

***General objective**: Evaluation and improvement of malaria control policies through study of the impact of insecticide resistance on LLINs and IRS efficacy, and preliminary analysis of the burden and causes of residual malaria.*

1. PROJECTS UNDER ER 1.3.6

Six research projects are included in this expected result (see Figure 1), and all projects are focusing on better understanding how to support malaria control and elimination:

Project A: Understanding the impact of insecticide resistance on the efficacy of IRS and LLINs in three ecological settings in Mali, Benin and Nigeria (PI: N. Sogoba, Mali). Objectives are:

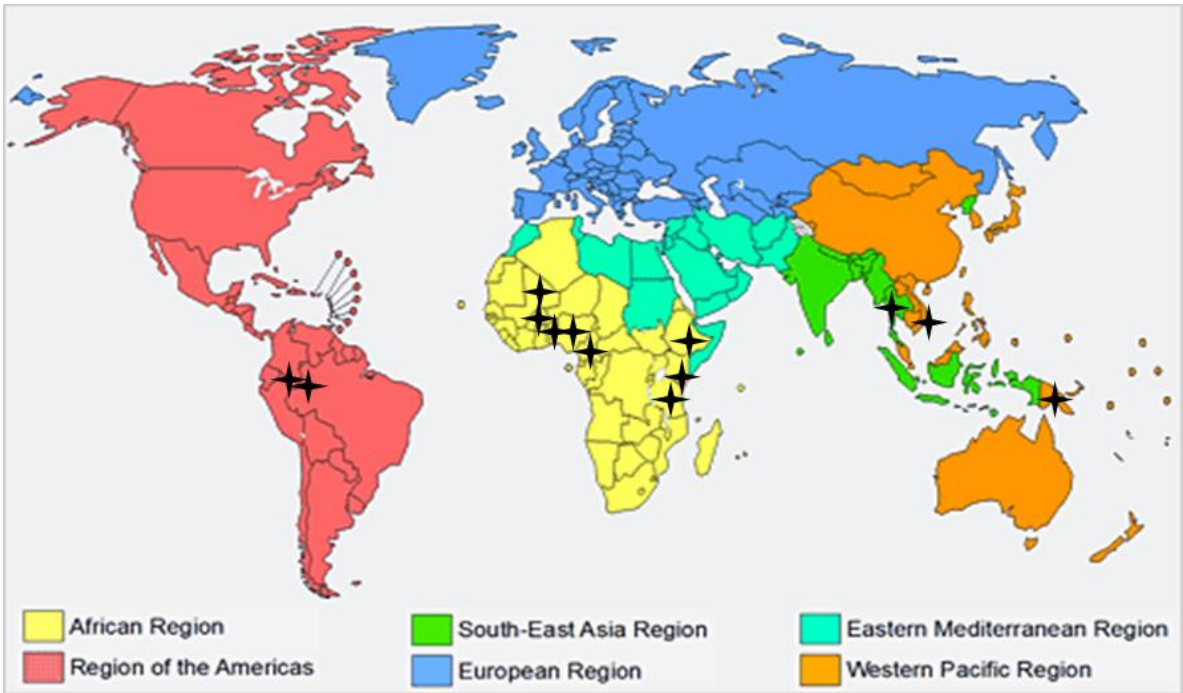
1. Update data on insecticide resistance and determine resistance mechanism(s) in the three target countries (Mali, Benin and Nigeria) in order to identify appropriate study sites with the knock-down and metabolic-based resistance mechanisms;
2. Monitor entomological, parasitological and socio-anthropological indices of LLINs/IRS efficacy in selected study sites with and without insecticide resistance; and
3. Compare the performances of LLINs or IRS on entomologic indices, e.g. vector longevity, Man Biting Rate (MBR) and the entomological inoculation rate (EIR) and malaria incidence according to different resistance mechanisms.

Project B: Residual malaria hotspots in Peru and Brazil: Setting the stage for testing improved (PI: D. Gamboa, study sites in Peru and Brazil). Objectives are:

1. Compare prevalence/incidence of parasitemia among households with and without bed net use (insecticide treated nets (ITNs)/LLINs)) and with/without Insecticide Residual Spraying (IRS);
2. Assess the socioeconomic, behavioural, and environmental determinants of residual malaria through a combination of household surveys and satellite imagery; and
3. Determine the vector biology metrics[6] quantification of environmental variables of aquatic mosquito habitats and genetic characterization of immature and adult *Anopheles darlingi* along the Mazán River (Loreto Department, Peru) and in Mâncio Lima (Juruá Valley, Brazil).

[6] These metrics include: human biting rate (HBR), malaria incidence rate (IR), entomological inoculation rate (EIR) and human blood index (HBI).

Figure 1. WHO Regions and countries included in the project on residual malaria



Project C: Residual Malaria Transmission (RMT) in the Greater Mekong subregion: Studies to examine its magnitude and identify its causes (PI: Jeffrey Hii, study sites in Thailand and Viet Nam). Objectives are:

1. Determine the magnitude of RMT relative to the overall burden of malaria in a number of different transmission settings in the Greater Mekong subregion;
2. Produce scientific evidence on the risk factors of RMT through an in-depth investigation of entomological, epidemiological, social and environmental determinants in a representative selection of specific transmission settings in one endemic province in Thailand and one endemic province in Viet Nam; and
3. Develop simple, cost-effective protocols and tools that can be used more widely by partner agencies across different ecological and epidemiological settings globally to investigate RMT and its various determinants.

Project D: Where and when is RMT taking place? Investigating magnitude and drivers of persistent Plasmodium infections in East and West Africa (PI: Fredros Okumu, study sites in Burkina Faso and Tanzania). Objectives are:

1. Estimate the proportions of ongoing RMT that occurs outside dwellings at different times of night, relative to proportions occurring indoors in high and low transmission settings;
2. Quantify levels of pyrethroid insecticide resistance in the selected study sites and estimate the potential contribution to ongoing residual transmission;
3. Identify common human outdoor activities and environmental factors associated with current RMT in the different sites; and
4. Develop a draft guideline for assessing exposure to RMT both indoors and outdoors, including peri-domestic and non-peri-domestic spaces in different ecological and epidemiological settings.

Project E: Understanding residual transmission for sustainable malaria control and enhancement of elimination efforts in Africa (PI: Joseph Mwangangi, study sites in Kenya, Cameroon and Ethiopia). Objectives are:

1. Characterize outdoor malaria transmission in focal points in different epidemiological settings with scaled-up coverage of LLINs/IRS. Test whether the vectors responsible for outdoor malaria transmission are different from those feeding indoors and whether malaria transmission is more prevalent outdoors than indoors in villages with high bed net coverage;
2. Determine the contribution of various mosquito behaviours to persistent malaria transmission despite high coverage of LLINs/IRS in different epidemiological settings. The *Anopheles* mosquito vectors displaying exophagy, exophily, zoophagy or resistant to pyrethroids are more likely to escape control measures compared to anthropophilic mosquitoes feeding and resting indoors; and
3. Investigate human behavioural/occupational factors associated with exposure to mosquito bites. Are residents who retire to bed early and regularly use insecticide treated nets less exposed to malaria transmission compared to others?

Project F: Understanding human, parasite, vector and environmental interactions driving RMT in Papua New Guinea (PI: Moses Laman, study sites in Papua New Guinea). Objectives are:

1. Investigate the distribution of malaria infection prevalence and clinical episodes across spatial clusters and population subgroups in order to identify the extent of residual malaria at the time of study;
2. Establish a clinical surveillance system, aligned with the National Health Information System procedures, in the health facilities of the study sites in order to validate routinely collected indicators for the identification of focal areas of RMT;
3. Investigate general human behavioural patterns with potential relevance for malaria transmission; and
4. Investigate the ecology and behaviours of local vector populations that enable them to sustain RMT in human populations in Papua New Guinea.

This activity was developed in collaboration with the WHO Global Malaria Programme (WHO/GMP). Current WHO/GMP guidelines recommend LLINs, IRS and larval source management interventions to control malaria vectors. However, resistance of the malaria vectors to insecticides threatens the success of malaria elimination. Nevertheless, malaria transmission can also persist even when LLINs and/or IRS are effectively implemented and malaria vectors are susceptible to the insecticides used. This may be due to a combination of vector and human behaviours/bionomics which compromise the effect of the control measures. The rationale of the project is, therefore, to provide information on: i) the impact of insecticide resistance on LLINs efficacy; ii) the magnitude of RMT in different epidemiological settings; and iii) utilizing standardized protocols identify the main factors driving that transmission, including social behaviours or activities, environmental changes, feeding preferences, or changes in mosquito species composition.

The *2017 World Malaria Report* shows that the number of malaria cases decreased in the last 16 years. However, the number of cases in 2016 was higher than the number of cases in 2015. Mortality due to malaria has decreased since 2010 and was about the same between 2015 and 2016, with about 445,000 deaths annually, mostly from the African region (90%) followed by South-East Asia (6%). The reasons for the 2015–2016 slow-down in the decrease of global malaria incidence are multiple, and include a lack of effectiveness in vector control. Resistance to insecticide of the malaria vectors, in particular, is of great concern. In Africa, for example, among the 61 countries performing insecticide resistance tests, 50 countries reported resistant mosquito strains to one or more products. Moreover, some malaria transmission is still in progress even when control measures are well in place and efficient, which is referred to as “residual transmission”.

2. PROJECT OUTPUTS UNDER ER 1.3.6

Projects A, B and C have already completed data collection and are finalizing data analysis. Projects D and E have also completed data collection, but the analysis of data is still in progress. Project F has recently completed data collection and the final technical report will be available in Q2/3–2019.

Project A Outputs:

- **In Mali,** *An. coluzzii* was the main *Anopheles* species constituting 95.5% of the *Anopheles* population in the different villages. Resistance to commonly used insecticides (pyrethroid) was very high in all sites, but the mosquito population was fully susceptible to pyrimiphos-methyl (organophosphate) used for IRS. Entomological transmission and parasitological parameters were all low in LLINs+IRS sites compared to LLINs-only sites. Consequently, malaria control with LLINs+IRS was found much more efficient then LLINs alone, despite some insecticide resistance.
- **In Nigeria,** with LLINs as the main vector control intervention, multivariate analysis found insecticide resistance was a main factor associated with non-usage or halt in LLINs usage. The data suggest that only the metabolic P450 mechanism of resistance appears to impair LLINs efficacy and performance in term of *Anopheles* monthly biting rates, parasites inoculation rates and malaria prevalence.
- **In Benin,** mosquitoes (*An. gambiae* and *An. funestus*) from most surveyed sites were found resistant to pyrethroid insecticides, with higher resistance recorded in the south. In the selected study sites, multidrug-resistance mechanisms (target sites and metabolic resistance) were recorded and it was observed that more severe malaria cases were recorded in the locality with a higher resistance level.

The main conclusion was that insecticide resistance developed by malaria vectors is one of the main factors affecting the efficacy of LLINs in communities.

Project B Outputs:

- **In Peru**, in Salvador, there is a very low EIR (0–0.25) and a relatively high number of malaria cases (107 in 2016). This suggests little local transmission or a highly mobile human population. Entomological indices suggest greater risk of malaria transmission in the Mazán district. Indoor *An. darlingi* EIR 0.25–3, together with indoor Pf incidence rates, suggests that IRS could be effective as part of an integrated intervention/eradication programme; little insecticide resistance in *An. darlingi* has been noted to date.
- **In Brazil,** the overall malaria incidence density high was 17.26 episodes per 1,000 person-years at risk; with the highest incidence among males aged 25–39 years. The distribution of malaria episodes was over-dispersed and there was no association between malaria incidence and rainfall. Characteristics from individuals show higher association with risk of infection vs. household characteristics. For example, going to sleep after 2200 hrs increased the risk of malaria infection (RR = 1.25, 95% CI 1.14–1.37) whereas waking time had no association. The use of bed nets was not associated with malaria infection. In addition, a high proportion of people (70.5%) reported using nets the night before interviews. A limited access to vector control tools (LLINs, IRS) was detected in Mâncio Lima. *An. darlingi* is the main malaria vector and probably most transmission is outdoors.

Project C Outputs:

- In **Thailand**, LLIN universal coverage has not been achieved in the study area. It has, nevertheless, been ascertained that primary biting vectors are active in early evening or late morning and between 20% and 38% of the bites are occurring when the people are not under the nets. Other contributing factors to RMT in the study site include: i) some members of the

population have different sleeping times, going to bed later or rising earlier, thereby increasing their risk or exposure to anopheline bites; ii) a large proportion of the population stay overnight in the farm huts or forest where sleeping times are different and where net use is low, iii) there were 25% to 50% of households with damaged nets, decreasing protective efficacy; and iv) some people do not use nets even if they are available, thereby exposing themselves to biting throughout the night. This is particularly important where the housing structure is very open and in farm huts. The key gaps that need to be addressed to reduce the current transmission in this region include: i) achieving universal coverage and usage of LLINs to remove risk from vectors biting during sleeping times; ii) achieving better maintenance of nets either through behavioural change or more frequent replacement of damaged nets; and iii) novel personal protection tools are required to protect people in the forest and from early evening biting and late morning biting.

- In **Viet Nam**, LLIN coverage in the study site is optimal, however 100% of biting from secondary vectors occurred before 2200 hours and around 26% of households had nets that were observed to have holes or tears, decreasing the protective effect. Further, a large proportion of the population stay for long periods of time in the farm field plots where their sleeping times are different, usually around 19:30 to 05:00h. This would mean they would be exposed to 28.7% of bites if they used LLINs during this time. However, net use in the farm huts was not observed to be universal and farm hut structures are open and offer little or no availability to hang nets. Nets are not used in the forest when people are working or sleeping outside and these people are thus exposed to about 4.73 bites per person per night. The following issues need to be addressed to reduce the current transmission in this region: i) achieve generalized coverage and usage of LLINs in the farm huts to reduce the risk from vectors biting during sleeping times (distribution of more nets per household to ensure coverage at both household and farm hut locations); ii) improve farm hut structures to offer more protection from mosquitoes; and iii) novel personal protection tools are required to protect people in the forest and from early evening and late morning biting.

Project D Outputs:

- In **Burkina Faso**, the EIR is very high with 255.45 infectious bites per person per year. A higher density of malaria vectors was observed indoors compared to outdoors. However, a change in the mosquito collection methodology, (from CDC traps to miniature double nets), demonstrated higher biting rates outdoors than indoors. High resistance of all malaria vectors to the pyrethroids commonly used in LLINs was reported with very low mortality rates when mosquitoes were exposed to bed nets collected from the households. Community members tended to spend most of the early night hours outdoors, only moving inside the houses at around midnight. Further, a significant proportion of people in the communities studied were observed to sleep outdoors at night during the dry season due to hot climate, with no protection against mosquitoes. Finally, surprising observations included the misconception that people could get malaria from eating certain fruit and food, or eating food that was contaminated by mosquitoes; mosquitoes being just one of the ways to contract malaria.
- In **Tanzania**, the EIR was much less, with 8.34 infectious bites per person per year, but surprisingly higher parity was observed in *Anopheles funestus* compared to *Anopheles arabiensis*. High resistance of all malaria vectors to the pyrethroids commonly used in LLINs was also reported again with very low mortality rates when mosquitoes were exposed to bed nets collected from the households. As in the other countries studied, community members were outdoors in the early night hours. There was also a misconception that mosquitoes carrying malaria parasites were not active except between midnight and 0200 hours.

Project E Outputs:

In Cameroon, Ethiopia and Kenya it was concluded that the usage of LLINs by the population in the equatorial forest, highlands and coastal regions was associated with a reduction in malaria transmission intensity. However, several factors related to mosquito species composition, biting and feeding behaviour, insecticide resistance and human behaviour affect the protective efficacy of LLINs. Malaria transmission in scaled-up interventions (LLINs and IRS) seems to be driven by more relaxed feeders which are less anthropohillic and more exophilic vectors, such as *An. funestus*, *An. arabiensis* and *An. moucheti* in the three sites. Some secondary vectors, such as *An. pretoriensis, An. coustani,* and *An. Squamosus*, also seem to be playing a role in outdoor malaria parasite transmission. These findings highlight the need to identify additional means to control malaria transmission and other related diseases in these foci where the population is particularly exposed to the risk of outbreaks due to the transmission of pathogens from primates to humans. The use of an integrated control approach to improve the performance of LLINs and limit the expansion of insecticide resistance could be indicated. In addition, more sensitization of the population is needed to emphasize the importance of using control measures regularly and avoiding risk activities which could increase their exposure and increase the transmission of malaria.

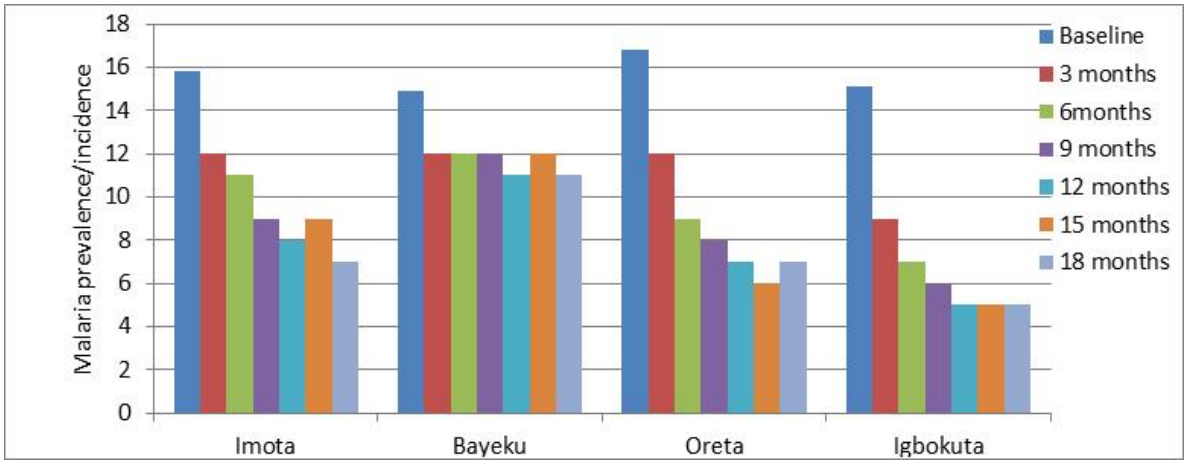
Project F Outputs:

The final technical report has not yet been provided.

Expected contribution to impact

For the impact of insecticide resistance on malaria incidence, the project has already delivered evidence showing an impact, due not only to mosquito survival, but also due to human behaviour associated with a lack of LLIN protective efficacy. Furthermore, the data show that LLIN efficacy is higher when there is no resistance in place (Figure 2) and the duration of protection is much longer, such as in the village of Igbokuta. In contrast, the efficacy is much less and of shorter duration when there is resistance and even when this resistance to products is due to more than one mechanism, such as in the village of Bayeku.

Figure 2. Malaria prevalence in children (aged 1–10 years) in Ikorodu area, Nigeria (figure extracted from the final technical report of project A).



Note: At baseline and three-month intervals, post-LLIN distribution.

For the residual malaria projects, it is clear from some projects that vector control tools are not implemented well, and consequently, the ongoing malaria transmission is not residual, but more an implementation problem. In other situations, such as in Brazil, Peru, and Thailand, the current tools are not efficient because of human or mosquito behaviour, and thus malaria transmission is not residual according to the current definition.

In situations where malaria can be considered residual, such as in Viet Nam, because of the very good coverage of LLINs, the persistence of malaria transmission has moved from villages to farm plots and forests, with secondary vectors. In such places, the deployment of LLINs needs new approaches, but other vector control tools are also needed. In African countries the persistence of malaria transmission is due to a combination of factors with local specificity. In Burkina Faso, the insecticide resistance of the vectors, as well as certain human behaviour, can be favourable to malaria transmission, but this transmission cannot be considered residual since there is an evident lack of efficacy of the recommended vector control tools. In Tanzania, insecticide resistance and human behaviour are also part of the problem, but another mosquito vector is emerging (*An. funestus*). Consequently, this transmission is partly not residual due to lack of efficacy of the tools, and partly residual due to a new vector species. In Cameroon, malaria transmission persists despite good implementation of the recommended tools through a high diversity of vector species exhibiting different biting behaviours. In Kenya, insecticide resistance was found to be one of the most important factors driving persistent malaria transmission. For all projects, a very strong research component was the study of human behaviour, including sleeping times, net use, activities, and also age and gender differences. These specificities should help in developing integrated malaria control approaches adapted to the local context.

An international workshop was hosted by the Ifakara Health Institute in Dar es Salaam, Tanzania in November 2017 to present the overall results of the project work undertaken to achieve Objective 4. The workshop was attended by more than 40 participants from all WHO regions. The key conclusions were:

- The workshop discussions revealed a lack of agreement around the definition of residual malaria transmission.
- There were many similarities and differences seen in approaches to measure and characterize residual transmission. All studies included a vector and a human component; however, few presented their results in an integrated way. Approaches and methods to link human and vector aspects should be evaluated and standardized.
- There are factors beyond residual transmission, including the quality of implementation of vector control tools (i.e. suboptimal access and/or use of LLINs), which also need to be addressed in some contexts.
- Strong community engagement is essential for successful research and interventions.
- There is a clear and urgent need for context-specific strategies and interventions to address residual malaria transmission.
- The workshop played an important role in laying the groundwork for additional research and interventions. Ongoing coordination, and opportunities for collaboration, across research groups will be essential.

3. RESEARCH UPTAKE

Uptake of research outputs has already started with publications and information briefs for stakeholders. This was undertaken through a contract with a communication partner, Lushomo, who will also develop a website platform for publishing findings and exchanging experience and knowledge within research teams.

Plans for 2020–2021

This project will be closed as it is, following the recommendations of the Scientific Working Group for Implementation Research adopted in September 2018.

Partnerships:

The project was developed and managed in collaboration with WHO/GMP and the technical partners of WHO regions involved. The subject of residual malaria is still very actual and many options of partnering are possible, in the WHO and outside.

Leverage created from this project: Project D (Burkina Faso and Tanzania) received supplementary funding from the Agency for International Development, the United States (USAID) to extend research activities to Zanzibar. Leverage has not yet been determined for the other projects.

Gender balance:

- Overall, 62% of project team members were men (22) and 38% were women (13)
- Project A: four men (100%)
- Project B: two women (100%)
- Project C: three men (100%)
- Project D: six men and four women (60% and 40%)
- Project E: three men (100%)
- Project F: seven men and six women (53% and 47%)

Expected Result 1.3.11: Multisectoral approach for prevention and control of malaria and emerging arboviral diseases

Vector-borne diseases, including malaria and emerging arboviral diseases, account for about one-quarter of all infectious diseases. There has been significant progress for malaria, with a recent decrease in malaria morbidity and mortality rates. Other diseases, however, such as those caused by arboviruses like dengue, chikungunya, yellow fever and Zika, are expanding with increasing number of cases and fatalities. It is evident that the prevention and control of these diseases has to be driven by more than a single orientation, and that a multisectoral approach is required to effectively address the dynamically interacting transmission patterns, vector, host, and pathogen relationships, environmental conditions, and the complexities of human behaviour.

In addition, malaria and emerging arboviral diseases are the result and a cause of a lack of development. The burden of these diseases is highest amongst the most vulnerable populations, who also suffer from the lowest level of development. The Multisectoral Action Framework for Malaria (MAFM) developed by the Roll Back Malaria Partnership and the UNDP, includes this development dimension by making actions outside the health sector essential components of VBD prevention and control. A concept note was issued by the Swiss Tropical and Public Health Institute (STPH) and the Swiss Agency for Development and Cooperation (SDC) in February 2016, entitled: *Leveraging the Sustainable Development Goals to intensify transdisciplinary and multisectoral collaboration in the*

global malaria response.[7] The report presents the conceptual framework of this approach, thematic areas of potential interest, and proposals for the way forward:

> The framework calls for action at several levels and in multiple sectors, globally and across inter- and intra-national boundaries, and by different organizations. It emphasizes complementarity, effectiveness and sustainability. It involves new interventions as well as putting new life into those that already exist, and coordinates and manages these in new and innovative ways.

After being launched early in 2016, the MAFM wants to expand to other VBDs, through building collaboration with development agencies, UN organizations, governments and other stakeholders that are willing to push forward an agenda for the control of VDBs in the context of the SDGs. Preliminary discussions were held in 2016 to define the goals and create the space and opportunity for a multisectoral approach to VBDs.

In this context, the IDRC, Canada, the STPH and SDC, Switzerland and TDR/VES began collaboration on building a multidisciplinary approach, linked to *Expected Result 1.3.11*: *Multisectoral approach for the prevention and control of malaria and emerging arboviral diseases*. A call was launched in January 2017 to support five commissioned reviews on specific topics related to multisectoral approaches for the prevention and control of VBDs. The overall objective of the call was to support a landscape analysis that would identify the knowledge gaps in the understanding of transmission patterns and ecology of the mosquito vectors of VBDs. The commissioned reviews were mandated to investigate current knowledge and experiences on the following topics:

1. Industrial activities and VBD transmission

This review had a special focus on gold mining activities that are disrupting the malaria ecosystems in Africa and the Americas. The review included evidence of the outcomes of this activity, in particular in the Amazon and African regions, how this problem can be approached and improved through improved health programmes, and the necessity for an assessment of the situation in Asia.

2. A global review of the role of integrated vector control strategies

Using dengue virus as a proxy, this review described and assessed the individual and combined impact of vector control strategies. There is an immense diversity of dengue control methods within the current global health toolkit. These interventions can be broadly categorized based on their entomological or epidemiological targets within the transmission cycle of the dengue virus disease. Control methods focus on different aspects: the larval mosquito stage (chemical treatment, larvicides, biological controls, insect growth regulators); the adult mosquito stage (IRS, space spraying, adult insecticides, ovitraps, spatial repellents); the role of environmental transmission drivers through environmental management; community education and mobilization campaigns; and personal protective devices (personal repellents, insecticide-impregnated clothing, insecticide-impregnated netting, etc.). In addition, promising new biomedical interventions are being developed and tested including genetic engineering, sterile irradiation, and vaccines.

3. Displacement of people and consequences on VBD transmission

This review focused on gathering knowledge of the impact of migration (for economic, civil unrest or war reasons), displacement of temporary workers, and other population movements. It included a review on current public, private and civil society responses that address the problem, as well as identifying challenges and missed opportunities.

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[7] Available at: https://www.who.int/tdr/news/2017/Concept_Note_on_Multisectoral_Approaches_to_Malaria_2016.pdf.

4. Impact of environmental changes

This review assessed the impact of environmental changes, including climatic, biological (such as biodiversity loss and consequences on VBD cycles), and social changes (including water management). It also presents examples of how interventions are modifying transmission patterns and how this will impact future intervention implementation challenges.

5. Intersectoral collaboration for prevention and control of VBDs

This review examined how stakeholders are working together to achieve the implementation of a global strategy. This review includes an assessment of conceptual frameworks for multisectoral approaches, and provides examples of initiatives and analysis-related outcomes.

The results of the commissioned reviews are now available through final technical reports. A workshop was held to present other aspects of the multisectoral approaches and to discuss frameworks, case studies and recommendations on potential tools. Findings from the workshop recommended that a comprehensive conceptual framework for multisectoral approaches be drafted. Consequently, an Agreement for the Performance of Work (APW) on the development of a conceptual multisectoral approach framework should provide useful guidance to stakeholders.

Plans for 2020–2021

This project will be expanded, as recommended by the Scientific Working Group for Implementation Research, at their meeting held in September 2018. Discussions have started with the Swiss SDC and STPH to finalize the planning of activities for the next biennium.

Publications:

Herdiana H, Sari JFK, Whittaker M. 2018. Intersectoral collaboration for the prevention and control of vector borne diseases to support the implementation of a global strategy: A systematic review. *PLoS One,* 2018, Oct 10;13(10): e0204659. doi: 10.1371/journal.pone.0204659. eCollection.

Jones RT, Tusting LS, Smith HMP, Segbaya S, Macdonald MB, Bangs MJ, Logan JG. The impact of industrial activities on vector-borne disease transmission.
Acta Trop, Dec;188:142-151. doi: 10.1016/j.actatropica.2018.08.033. Epub, 2018, Aug 27.

- Strategic Development Funds (SDFs)

Special Plenary Session on Neglected Zoonotic Diseases

Progress in 2018

TDR worked with the One Health Congress organizers to plan and implement a special plenary session on *Neglected zoonotic diseases in resource-poor, marginalized and under-served communities – Challenges in Infectious Disease Control* for their 5th annual meeting, June 2018. The Congress was attended by 716 One Health advocates, mainly academics and public health officials.

The main focus of the special plenary session was to discuss the challenges to control neglected infectious diseases in resource-poor, marginalized and under-served communities. Neglected infectious diseases heavily impact human health, and that of livestock, in developing countries. It was thus deemed important to discuss how international partners are dealing with these challenges, and identify the best way to develop preventive and therapeutic tools, introduce interdisciplinary collaboration, and support policy changes. The session was chaired by Prof. Martyn Jeggo from the Geelong Centre for Emerging Infectious Diseases, Australia and Dr Bernadette Ramirez from WHO/TDR. Figure 3 presents topics which were covered at the event.

Figure 3. Final programme of the Special Plenary Session on Neglected Zoonotic Diseases

Neglected Zoonotic Diseases in Resource-Poor, Marginalised and Under-Served Communities: Challenges in Infectious Disease Control

CHAIR:
Martyn Jeggo, *Geelong Centre for Emerging Infectious Diseases, Australia*

CO-CHAIR:
Bernadette Ramirez, *World Health Organization*

PROGRAMME:

1. Where we left off: main conclusions of the 2014 International meeting on the control of Neglected Zoonotic Diseases
   Mike Ryan, *World Health Organization*
2. Combatting Neglected Zoonotic Diseases at the human/animal interface: an overview
   Ab Osterhaus, *RIZ Hannover, Germany*
3. Challenges and opportunities to preventing and responding to outbreaks of helminth/bacterial/viral infections in livestock
   Vivek Kapur, *Pennsylvania State University, USA*
4. Need to acquire community support to implementing effective control programmes
   Helen Scott-Orr, *Department of Agriculture and Water Resources, Australia*

Source: One Health Congress literature, June 2018.

Budget and financial implementation

Table 1: Approved Programme Budget 2018–2019 and 2018 funds utilized (preliminary results)

Expected result	Research for Implementation (VES)	2018 progress									Towards 2019		
		$40m budget scenario			Funds utilized as at 31 December 2018			implementation rate			Revised planned costs at January 2019		
		UD	DF	Total	UD	DF	Total	UD	DF	Total	UD	DF	Total
	Environmental changes impact												
1.3.3	Vector-borne diseases and climate change in Africa	300 000		300 000	533		533	0%		0%	60 000		60 000
1.3.7	Control of vector-borne diseases in SE-Asia through environmental measures	250 000	300 000	550 000	245 107		245 107	98%	0%	45%	490 000		490 000
	Emerging challenges												
1.3.6	Impact of insecticide resistance and residual malaria on malaria control	200 000		200 000	41 439		41 439	21%		21%	200 000		200 000
1.3.11	Multi-sectoral approach on malaria control	100 000	940 000	1040 000	2 873		2 873	3%	0%	0%	255 000		255 000
	Social and community dynamics												
1.3.10	Urban health interventions for control of vector-borne diseases	300 000		300 000	77 183		77 183	26%		26%	375 000		375 000
	Research on gender equity												
1.3.8	Training course for gender data analysis in vector-borne diseases	100 000		100 000	14 912		14 912	15%		15%	100 000		100 000
1.3.12	Gender responsive health interventions	100 000	200 000	300 000	59 651		59 651	60%	0%	20%	180 000		180 000
	Total	**1 350 000**	**1 440 000**	**2 790 000**	**441 698**	**0**	**441 698**	**33%**	**0%**	**16%**	**1 660 000**	**0**	**1 660 000**

Table 2: Proposed programme budget and workplan 2020-2021

In line with the 2018-2023 strategy, financial figures are now shown under the heading of Research for Implementation.

Expected result	Research for Implementation	$40m scenario			$50m scenario		
		UD	DF	Total	UD	DF	Total
	Research for policy						
1.1.1	Country preparedness for disease outbreaks	150 000		150 000	200 000		200 000
1.1.4	Country resilience to the threat of drug-resistant infections		3 500 000	3 500 000	370 000	4 600 000	4 970 000
1.3.3	Vector-borne diseases and increasing resilience under climate change conditions	400 000	300 000	700 000	500 000	400 000	900 000
	Research for implementation						
1.1.7	Maximized utilization of data for public health decision-making	210 000		210 000	400 000		400 000
1.1.8	Maximized utilization of safety information for public health decision-making	220 000	200 000	420 000	400 000	400 000	800 000
1.2.1	Strategies to achieve and sustain disease elimination	760 000		760 000	1 500 000		1 500 000
1.2.6	Optimized approaches for effective delivery and impact assessment of public health interventions	550 000	300 000	850 000	800 000	600 000	1 400 000
1.3.12	Strategies to promote gender-responsive health interventions on prevention and control of infectious diseases of poverty	300 000	300 000	600 000	550 000	300 000	850 000
	Research for innovation						
1.1.5	Directions for development and accelerated access to new tools and strategies	110 000		110 000	130 000		130 000
1.3.10	Urban health interventions for vector-borne and other infectious diseases of poverty	150 000		150 000	300 000		300 000
1.3.14	Testing of innovative strategies for vector control	100 000	800 000	900 000	300 000	1 000 000	1 300 000
	Research for integrated approaches						
1.3.11	Multisectoral approach for malaria and emerging arboviral diseases	400 000		400 000	500 000		500 000
	Total	**3 350 000**	**5 400 000**	**8 750 000**	**5 950 000**	**7 300 000**	**13 250 000**

Funding by project

Project ID	Principal investigator	PI gender	Supplier name (Institution)	Project title	Funding in US$	Disease or research topic	Countries involved
B60010	Caroline Lachance	F	Universite de Montreal	Urban Health: scoping reviews and research gap analysis on urban health interventions for the prevention and control of vector-borne and other infectious diseases of poverty.	14 998	Urban Health	Canada
B70064	Fredros Okumu	M	Ifakara Health Institute	This PR is raised to reimburse extra costs ($4512) occurred during the workshop ref. PO201858979.	4 512	Malaria	Tanzania, United Republic of
B60100	Thomas Scalway	M	Lushomo	Investigation of the magnitude and causes of Residual Malaria Transmission in selected settings and in collaboration with GMP/WHO.	23 400	Malaria	South Africa
B80036	Giuseppina Ortu	F		Situation analysis concerning surveillance and arboviral diseases control in West Africa.	6 200	Arboviruses in Africa	United Kingdom
B80054	Laura Dean	F	Liverpool School of Tropical Medicine	An APW with The Liverpool School of Tropical Medicine, led by Miss Laura Dean, entitled: “Technical editing for the development of a guidance document on gender and intersectionality in research on infectious diseases of poverty”.	7 600	Gender	United Kingdom
B80053	Rosemary Morgan	F		An APW with Dr Rosemary Morgan for “Technical support coordination for the development of a guidance document on gender and intersectionality in research on infectious diseases of poverty”.	12 000	Gender	United States
B80052	Chandani Kharel	F	Herd International Private Limited	An APW with HERD International Pvt Limited led by Dr Chandani Kharel, entitled: “Technical revision of a guidance document on gender and intersectionality in research on infectious diseases of poverty”	7 600	Gender	Nepal
B80062	Vincent Corbel Hu	M	Institut de Recherche pour le Developpement (IRD), Thailand	2nd WIN International Conference on “Integrated approaches and innovative tools for combating insecticide resistance in arbovirus vectors”, Singapore, 1-3 October 2018.	30 000	Insecticide Resistance	Thailand

Project ID	Principal investigator	PI gender	Supplier name (Institution)	Project title	Funding in US$	Disease or research topic	Countries involved
B80041	Thomas Scalway	M	Lushomo	Communication support for two research projects in South-East Asia	5 000	VBDs	South Africa
B70011	Jeffrey Hii	M	Malaria Consortium	Impact of socio-ecological systems and resilience (SESR)-based strategies on dengue vector control in schools and neighbouring household communities in Cambodia	120 000	Arboviruses in SEAR	Thailand
B70012	Pattamaporn Kittayapong	F	Mahidol University, Go Green	Innovative vector birth control and socio-ecological strategies for the prevention of dengue, chikungunya and Zika disease in the ASEAN tourist settings	120 000	Arboviruses in SEAR	Thailand

TDR funding in 2018

CONTRIBUTOR	
Core contributors	**Amount (US$)**
Sweden	5 037 631
United Kingdom of Great Britain and Northern Ireland (UK)	4 246 657
Switzerland	1 654 965
Luxembourg	1 157 407
World Health Organization	1 100 000
Germany	875 798
Belgium	707 547
Norway	357 270
Japan	200 000
Thailand	93 291
China	55 000
India	55 000
Malaysia	25 000
Mexico	20 000
Panama	7 000
Turkey	5 000
Miscellaneous	1 009
Sub-total	15 598 577
Contributors providing specific project funding	**Amount (US$)**
Bill & Melinda Gates Foundation	1 968 153
National Institute for Health Research (NIHR), UK	1 494 204
United Nations Development Programme (UNDP)	1 061 400
U.S. Agency for International Development (USAID)	697 175
Sweden	546 249
Swiss Development Cooperation Agency (SDC/DDC)	508 048
Luxembourg	115 741
Other	65 830
Sub-total	6 456 799
TOTAL CONTRIBUTIONS	**22 055 376**

The contribution from the Government of Sweden reflects the 2018 portion of their 2018-2019 funding agreement.

Publications resulting from the TDR/IDRC Research Initiative on VBDs and Climate Change

Special Issue of the Journal of Infectious Diseases of Poverty:

1. Bardosh, KL, S Ryan, K Ebi, S Welburn, B Singer. 2017. Addressing vulnerability, building resilience: community-based adaptation to vector-borne diseases in the context of global change. *J Infect Dis Pov*, 6, 21.
2. Ceccato P, B Ramirez, T Manyangadze, P Gwakisa, MC Thomson. 2018. Data and tools to integrate climate and environmental information into public health. *J Infect Dis Pov. (forthcoming).*
3. Fouque F and JC Reeder. 2018. Impact of climate change on Vector-Borne Disease Transmission: A look at the evidence. *J Infect Dis Pov, (submitted).*
4. Gbalegba CGN, H Ba, KD Silue, O Ba, E Tia, M Chouaibou, NTY Tian-Bi, GY Yapi, B Kone, J Utzinger, BG Koudou. 2018. Distribution of *Plasmodium spp* infection in asymptomatic carriers in perennial and low seasonal malaria transmission settings in West Africa. *J Infect Dis Pov,* https://doi.org/10.1186/s40249-018-0412-9.
5. Kalinda C, MJ Chimbari, S Mukaratirwa. 2017b. Effect of temperature on the *Bulinus globosus* - *Schistosoma haematobium* system. *J Infect Dis Pov*, 6: 57. DOI 10.1186/s40249-017-0260-z
6. Koffi AMA, M Doumbia, G Fokou, M Keita, B Kone and NN Abe. 2018. Community knowledge, attitudes and practices related to schistosomiasis and associated healthcare-seeking behaviours in northern Côte d'Ivoire and southern Mauritania. *J Infect Dis Pov,* 7:70. https://doi.org/10.1186/s40249-018-0453-0.
7. M'Bra RK, B Kone, YG Yapi, KD Silue, I Sy, D Vienneau, N Soro, G Cisse and J Utzinger. 2018. Risk factors for schistosomiasis in an urban area in northern Côte d'Ivoire. *J Infect Dis Pov,* 7:47. https://doi.org/10.1186/s40249-018-0431-6.
8. Ramirez B, TI Vector. 2017a. Support for research towards understanding the population health vulnerabilities to vector-borne diseases: Increasing resilience under climate change conditions in Africa. *J Infect Dis Pov,* 6, 7.
9. Saigilu M, H Nnko, A Ngonyoka, ON Moses, A Estes, P Gwakisa. 2018. Assessment of knowledge and attitudes of pastoralists towards tsetse flies and trypanosomiasis in the Maasai Steppe, Northern Tanzania. *J Infect Dis Pov, (submitted).*
10. Scalway T, M Otmani-Del Barrio M and B Ramirez. 2018. Research on vector borne diseases in the context of climate change: experiences from multisectoral stakeholder engagement through implementation of a communication strategy. *J Infect Dis Pov, (manuscript in preparation).*
11. Simwango M, ON Moses, S Kimera, P Gwakisa. 2018. Vector-borne co-infections in cattle in a livestock-wildlife interface ecosystem in northern Tanzania. *J Infect Dis Po, (submitted).*
12. Thomson MC, AG Munoz, R Cousin R, J Shumake-Guillemot. 2018. Climate drivers of vector-borne diseases in Africa and their relevance to control programmes. *J Infect Dis Pov,* 7:81. https://doi.org/10.1186/s40249-018-0460-1.
13. Wilcox BA, C Richter, JA Steele, P Echaubard, B Ramirez. 2018. Vector borne disease control and climate change adaptation: resilience and the role of local knowledge and biodiversity. *J Infect Dis Pov, (submitted).*
14. Wilcox BA. M Garine-Wichatitsky, P Echaubard, B Ramirez. 2018. Vector borne disease and climate change adaptation in African dryland social-ecological systems. *J Infect Dis Pov, (submitted).*

Project A: Social, environmental and climate change impact of vector-borne diseases in arid areas of Southern Africa (Principal Investigator: Moses Chimbari, College of Health Sciences, University of KwaZulu-Natal, Durban, South Africa)

15. Bergquist R, NW Brattig, MJ Chimbari, J Zinsstag, J Utzinger. 2017. Ecohealth research in Africa: Where from-where to? *Acta Tropica,* 154:1–8.
16. Chimbari MJ. 2017. Lessons from implementation of ecohealth projects in Southern Africa: A principal investigator's perspective. *Acta Tropica*, 175:9–19.
17. Chimbari M. 2012. Enhancing schistosomiasis control strategy for Zimbabwe: Building on past experiences. *J Parasitol Res,* 353768.
18. Chirebvu E, MJ Chimbari and BN Ngwenya. 2014. Assessment of risk factors associated with malaria transmission in Tubu village, northern Botswana. *Malaria Res Treat,* doi:10.1155/2014/403069.
19. Chirebvu E, MJ Chimbari. 2015. Characteristics of *Anopheles arabiensis* larval habitats in Tubu village, Botswana. *J Vector Ecol,* 40(1);129–38.
20. Chirebvu E, MJ Chimbari, BN Ngwenya, B Sartorius. 2016. Clinical malaria transmission trends and its association with climatic variables in Tubu Village, Botswana: A Retrospective Analysis. *PLoS One,* 11(3).
21. Chirebvu E, MJ Chimbari. 2016. Characterization of an indoor-resting population of *Anopheles arabiensis* (Diptera: Culicidae) and the implications on malaria Transmission in Tubu Village in Okavango Subdistrict, Botswana. *J Med Entom,* 53(3): 569–576.
22. Gunda R, MJ Chimbari, Mukaratirwa S. 2016. Assessment of burden of malaria in Gwanda District, Zimbabwe, using the disability adjusted life years. *Int J Environ Res Pub Health,* 13(2): 244.
23. Gunda, R., MJ Chimbari, S Shamu, B Sartorius, S Mukaratirwa. 2017a. Malaria incidence trends and their association with climatic variables in rural Gwanda, Zimbabwe, 2005–2015. *Malaria Journal*, 16: 13.
24. Gunda, R., S Shamu, MJ Chimbari, S Mukaratirwa. 2017b. Economic burden of malaria on rural households in Gwanda district, Zimbabwe. *African J Primary Health Care & Family Medicine*, 9(1): 6.
25. Gunda R, MJ Chimbari. 2017. Cost-effectiveness analysis of malaria interventions using disability adjusted life years: a systematic review. Cost Effectiveness and Resource Allocation. *Cost Eff Resources Alloc,* 15:10. doi: 10.1186/s12962-017-0072-9.
26. Kabuyaya M, MJ Chimbari, T Manyangadze, S Mukaratirwa. 2017a. Efficacy of praziquantel on *Schistosoma haematobium* and re-infection rates among school-going children in the Ndumo area of uMkhanyakude district, KwaZulu-Natal, South Africa. *Infect Dis Pov,* 6:9.
27. Kabuyaya M, MJ Chimbari, T Manyangadze, S Mukaratirwa. 2017b. Schistosomiasis risk factors based on the infection status among school-going children in the Ndumo area, uMkhanyakude district, South Africa. *Southern African J Infect Dis,* 32(2):67–72.
28. Kabuyaya M, MJ Chimbari, S Mukaratirwa. 2018. Infection status and risk factors associated with urinary schistosomiasis among school-going children in the Ndumo area of uMkhanyakude district in KwaZulu-Natal, South Africa: two years post treatment. *Int J Infect Dis,* doi: 10.1016/j.ijid.2018.04.002.
29. Kalinda C, MJ Chimbari, S Mukaratirwa. 2017. Effect of temperature on the *Bulinus globosus* – *Schistosoma haematobium* system. *Infect Dis Pov,* 6:57.
30. Kalinda C, MJ Chimbari, S Mukaratirwa. 2017a. Implications of changing temperatures on the growth, fecundity and survival of intermediate host snails of schistosomiasis: A systematic review. *Int J Environ Res Public Health*, 14(1):18.
31. Kalinda C, MJ Chimbari, S Mukaratirwa. 2018. Schistosomiasis in Zambia: a systematic review of past and present experiences. *Infect Dis Pov,* 7:41.
32. Kalinda C, MJ Chimbari, WE Grant, HH Wang, JN Odhiambo, S Mukaratirwa. 2018. Simulation of population dynamics of *Bulinus globosus:* Effects of environmental temperature on production of *Schistosoma haematobium* cercariae. *PLoS Negl Trop Dis,*12(8). doi: 10.1371/journal.pntd.0006651.
33. Macherera M, MJ Chimbari. 2016. Developing a community-centred malaria early warning system based on indigenous knowledge: Gwanda District, Zimbabwe. Jàmbá: *J Disaster Risk Studies,* 8(1): a289.
34. Macherera M, MJ Chimbari. 2016. A review of studies on community based early warning systems. Jàmbá: *J Disaster Risk Studies,* 8(1): a206.
35. Macherera M, MJ Chimbari, S Mukaratirwa. 2017. Indigenous environmental indicators for malaria: A district study in Zimbabwe. *Acta Tropica*, 175: 50–59.
36. Manyangadze T, MJ Chimbari, S Mukaratirwa, M Gabriselasie. 2015. Application of geo-spatial technology in schistosomiasis modelling in Africa: A review. *Geospatial Health,* 10(326): 99–110.

37. Manyangadze T, MJ Chimbari, M Gebreslasie, P Ceccato, S Mukaratirwa. 2016. Modelling the spatial and seasonal distribution of suitable habitats of schistosomiasis intermediate host snails using Maxent in Ndumo area, KwaZulu-Natal Province, South Africa. *Parasites and Vectors*, 9:572.
38. Manyangadze T, MJ Chimbari, M Gebreslasie, S Mukaratirwa. 2016. Risk factors and micro-geographical heterogeneity of Schistosoma haematobium in Ndumo area, uMkhanyakude district, KwaZulu-Natal, South Africa. *Acta Tropica*, 159: 176–184.
39. Manyangadze T, MJ Chimbari, M Macherera, S Mukaratirwa. 2017a. Micro-spatial distribution of malaria cases and control strategies at ward level in Gwanda district, Matabeleland South, Zimbabwe. *Malaria Journal*, 16:11.
40. Maphane D, BN Ngwenya, MR Motsholapheko, OD Kolawole, L Magole. 2017. Rural livelihoods and community local knowledge of risk of malaria transmission in the Okavango Delta, Botswana. 49: *Botswana Note and Records*, 49:136.
41. Mbereko A, BB Mukamuri, MJ Chimbari. 2015. Exclusion and contests over wetlands used for farming in Zimbabwe: a case study of broad-ridge and broad-furrow tillage system on Zungwi Vlei**.** *J Political Ecology,* 21: 322–338.
42. Midzi N, T Mduluza, MJ Chimbari, C Tshuma, L Charimari, G Mhlanga, et al. 2014. Distribution of schistosomiasis and soil transmitted helminthiasis in Zimbabwe: towards a national plan of action for control and elimination. *PloS Negl Trop Dis,* 14:8(8).
43. Musesengwa R, MJ Chimbari. 2017a. Community engagement practices in Southern Africa: Review and thematic synthesis of studies done in Botswana, Zimbabwe and South Africa. *Acta Tropica*, 175:20–30.
44. Musesengwa R, MJ Chimbari. 2017b. Experiences of community members and researchers on community engagement in an Ecohealth project in South Africa and Zimbabwe. *BMC Medical Ethics*, 18:15.
45. Musesengwa R, MJ Chimbari, S Mukaratirwa. 2017. Initiating community engagement in an ecohealth research project in Southern Africa. *Infect Dis Pov,* 6:11.
46. Musesengwa R, MJ Chimbari, S Mukaratirwa. 2018. A framework for community and stakeholder engagement experiences from a multicenter study in Southern Africa. *J Empir Res Hum Res Ethics,* doi: 10.1177/1556264618769002.
47. Mutegeki E, MJ Chimbari, S Mukaratirwa. 2017. Assessment of individual and household malaria risk factors among women in a South African village. *Acta Tropica*, 175:71–77.
48. Ngwenya BN, OT Thakadu, MJ Chimbari. 2017. Memories of environmental change and local adaptations among molapo farming communities in the Okavango Delta, Botswana – a gender perspective. *Acta Tropica,* 175:31–41.
49. Nyati-Jokomo Z, MJ Chimbari. 2017. Risk factors for schistosomiasis transmission among school children in Gwanda district, Zimbabwe. *Acta Tropica*, 175:84–90.
50. Ramolefhe GT, BN Ngwenya, NO Ama, MS Nnyepi, MJ Chimbari. 2017. Perceptions of safe water and accessibility by rural farming communities residing along the fringes of the Okavango Delta, Botswana. *Botswana Notes and Records*, 49:117.
51. Rubaba O, MJ Chimbari, S Mukaratirwa. 2016. The role of snail aestivation in transmission of schistosomiasis in changing climatic conditions. *African Journal of Aquatic Science*, pp 143–146, doi.org/10.2989/16085914.2016.1145103.
52. Rubaba O, MJ Chimbari, W Soko, T Mangangadze. S Mukaratirwa. 2018. Validation of a urine circulating cathodic antigen cassette test for detection of Schistosoma haematobium in uMkhanyakude district of South Africa. *Acta Tropica,* 182:161–165.
53. Sacolo J, MJ Chimbari, C Kalinda. 2018. Knowledge, attitudes and practices on schistosomiasis in sub-Saharan Africa: a systematic review. *BMC Infect Dis*, 18(1):46.
54. Soko W, MJ Chimbari, S Mukaratirwa. 2015. Insecticide resistance in malaria-transmitting mosquitoes in Zimbabwe: A review. *J Infect Dis Pov*, 4(46).

Project B: Early warning systems for improved human health and resilience to climate sensitive vector-borne diseases in Kenya (Principal Investigator: Benson Estambale, JOOUST, Kenya)

55. Amadi, JA, DO Olago, GO Ong'-amo, SO Oriaso, IK Nyamongo, BBA Estambale. 2018. "We don't want our clothes to smell smoke": changing malaria control practices and opportunities for integrated community-based management in Baringo, Kenya. *BMC Public Health,* 18:609.
56. Amadi JA, DO Olago, GA Ong'amo, SO Oriaso, M Nanyingi, IK Nyamongo, BBA Estambale. 2018. Sensitivity of vegetation to climate variability and its implications for malaria risk in Baringo, Kenya. *PLOS One*, 13(7).
57. Amadi JA, GO Ong'amo, DO Olago, SO Oriaso, IK Nyamongo, BBA Estambale. 2018. Mapping the potential *Anopheles gambiae* s.l. larval distribution using remotely sensed climatic and environmental variables in Baringo, Kenya. *Med Vet Entom,* doi: 10.1111/mve.12312.
58. Bukachi SA, S Wandibba, IK Nyamongo. 2017. The socio-economic burden of human African trypanosomiasis and the coping strategies of households in the South Western Kenya foci. *Plos Negl Trop Dis,* 11(10):21.
59. Kipruto EK, AO Ochieng, DN Anyona, M Mbalanya, EN Mutua, D Onguru, IK Nyamongo, BBA Estambale. 2017. Effect of climatic variability on malaria trends in Baringo County, Kenya. *Malaria Journal*, 16:11.
60. Mutua EN, SA Bukachi, BK Bett, BA Estambale, IK Nyamongo. 2017a. "We do not bury dead livestock like human beings": Community behaviours and risk of Rift Valley Fever virus infection in Baringo County, Kenya. *Plos Negl Trop Dis,* 11(5):17.
61. Mutua E, S Bukachi, B Bett, B Estambale, I Nyamongo. 2017b. Youth participation in smallholder livestock production and marketing. *IDS Bulletin: Transforming Development Knowledge*, 48(3).
62. Mutua EN, SA Bukachi, BK Bett, BA Estambale, IK Nyamongo. 2016. Lay knowledge and management of malaria in Baringo county, Kenya. *Malaria Journal,* 15**:**486.
63. Ochieng AO, MO Nanyingi, E Kipruto, IM Ondiba, FA Amimo, C Oludhe, DO Olago, IK Nyamongo, BA Estambale. 2016. Ecological niche modelling of Rift Valley fever virus vectors in Baringo, Kenya. *Infect Ecol Epidemiol,* 6: 32322.
64. Omondi CO, LM Kamau, HK Njaanake, D Anyona, D Onguru, B Estambale. 2017. Evaluation of three rapid diagnostic test kits in the diagnosis of *Plasmodium* species infections among primary school children in Baringo County, Kenya. *Open J Clinical Diag,* 7:31–44.
65. Omondi CJ, D Onguru, L Kamau, M Nanyingi, et al. 2017. Perennial transmission of malaria in the low altitude areas of Baringo County, Kenya. *Malaria Journal,* 16:8.
66. Ondiba IM, A Florenca, Oyieke, IK Nyamongo, BBA Estambale. 2017. Diversity, Distribution and abundance of potential Rift Valley Fever vectors in Baringo County, Kenya. *Int J Mosquito Research*, 4(4) 42–48.
67. Ondiba IM, A Florenca, Oyieke, AO Ochieng, DN Anyona, IK Nyamongo, BBA Estambale. 2017. Malaria vector species distribution and seasonal population dynamics across varied ecological zones in Baringo County, Kenya. *Int J Mosquito Research*, 7(21).
68. Owek CJ, E Oluoch, J Wachira, B Estambale and YA Afrane. 2017. Community perceptions and attitudes on malaria case management and the role of community health workers. *Malaria Journal,* 16:9.
69. Ondiba IM, FA Oyieke, GO Ong'amo, MM Olumula, IK Nyamongo, BBA Estambale. 2018. Malaria vector abundance is associated with house structures in Baringo County, Kenya. *PLoS One,* 13(6).

Project C: Predicting vulnerability and improving resilience of the Maasai communities to vector-borne infections: an ecohealth approach in the Maasai Steppe ecosystem (Principal Investigator: Paul Gwakisa, Nelson Mandela African Institute of Science and Technology, Arusha, Tanzania)

70. Ngonyoka A, PS Gwakisa, AB Estes, HJ Nnko, PJ Hudson, IM Cattadori. 2017. Variation of tsetse fly abundance in relation to habitat and host presence in the Maasai Steppe, Tanzania. *J Vector Ecology*, 42(1), 34–43.
71. Ngonyoka A, PS Gwakisa, AB Estes, LP Salekwa, HJ Nnko. PJ Hudson, IM Cattadori. 2017. Patterns of tsetse abundance and trypanosome infection rates among habitats of surveyed villages in Maasai steppe of northern Tanzania. *Infect Dis Pov,* 6(1):126.
72. Nnko HJ, PS Gwakisa, A Ngonyoka, M Saigilu, M Ole-Neselle, W Kisoka, C Sindato, A Estes.2017. Pastoralists' vulnerability to trypanosomiasis in Maasai Steppe. *Ecohealth*, 14(4), 718–731.

73. Nnko HJ, A Ngonyoka, L Salekwa, AB Estes, PJ Hudson, PS Gwakisa, IM Cattadori. 2017. Seasonal variation of tsetse fly species abundance and prevalence of trypanosomes in the Maasai Steppe, Tanzania. *J Vector Ecol*, 42(1), 24–33.
74. Salekwa LP, HJ Nnko, A Ngonyoka, AB Estes, M Agaba, PS Gwakisa. 2014. Relative abundance of tsetse fly species and their infection rates in Simanjiro, Northern Tanzania. *Livestock Research for Rural Development*, Volume 26, Article #213.
75. Saigilu M, H Nnko, A Ngonyoka, ON Moses, A Estes, P Gwakisa. 2018. Assessment of knowledge and attitudes of pastoralists towards tsetse flies and trypanosomiasis in the Maasai Steppe, Northern Tanzania. *Infect Dis Pov, (submitted).*
76. Simwango M, A Ngonyoka, HJ Nnko, LP Salekwa, M Ole-Neselle, SI Kimera, PS Gwakisa, 2017. Molecular prevalence of trypanosome infections in cattle and tsetse flies in the Maasai Steppe, northern Tanzania. *Parasites & Vectors*, 10:11.
77. Simwango M, ON Moses, S Kimera, P Gwakisa. 2018. Vector-borne co-infections in cattle in a livestock-wildlife interface ecosystem in northern Tanzania. *Infect Dis Pov, (submitted).*

Project D: Human African Trypanosomiasis: alleviating the effects of climate change through understanding human-vector-parasite interactions (Principal Investigator: John Hargrove, South African Centre of Excellence in Epidemiological Modelling and Analysis, University of Stellenbosch, Stellenbosch, South Africa)

78. Ackley SF, Hargrove JW. 2017. A dynamic model for estimating adult female mortality from ovarian dissection data for the tsetse fly *Glossina pallidipes* Austen sampled in Zimbabwe. *PLoS Negl Trop Dis*, 11(8):20.
79. Auty HK, K Picozzi, I Malele, SJ Torr, S Cleaveland, S Welburn. 2012. Using molecular data for epidemiological inference: assessing the prevalence of *Trypanosoma brucei* rhodesiense in tsetse in Serengeti, Tanzania. *PLoS Negl Trop Dis,* doi: 10.1371/journal.pntd.0001501.
80. Auty H, SJ Torr, T Michoel, S Jayaraman, MJ Morrison. 2015. Cattle trypanosomiasis: the diversity of trypanosomes and implications for disease epidemiology and control. *Rev Sci Tech,* 34(2).
81. Auty H, L Morrison, SJ Torr, JS Lord. 2016. Transmission dynamics of Rhodesian sleeping sickness at the interface of wildlife and livestock areas. *Trends in Parasitology***,** 32(8): 608–621.
82. Auty H, S Cleaveland, I Malele, J Masoy, T Lembo, P Bessell, S Torr, K Picozzi, SC Welburn. 2016. Quantifying heterogeneity in host-vector contact: tsetse (*Glossina synnertoni* and *G pallidipes*) host choice in Serengeti National Park, Tanzania. *PLoS One,* 11(10).
83. Byamungu M, G Nkwengulila, S Matembo S. 2016. Evaluation of knowledge, attitude and practices of agro-pastoralists on tsetse fly (*Glossina* sp.) in Western Serengeti Tanzania. *J Vet Med Animal Health*, 8:169–175.
84. Byamungu M, J Hargrove, G Nkwegulila, S Matembo. 2017. Evaluation of trapping devices for tsetse flies (*Glossina spp*) in western Serengeti. *Imp J Interdisciplinary Research,* 3:951–955.
85. Courtin F, M Camara, JB Rayaisse, M Kagbadouno, E Dama, O Camara, IS Traore, J Rouamba, M Peylhard, MB Somda. M Leno, MJ Lehane, Sj Torr, P Solano, V Jamonneau, B Bucehton. 2015. Reducing human-tsetse contact significantly enhances the efficacy of sleeping sickness active screening campaigns: a promising result in the context of elimination. *PLoS Negl Trop Dis,* 12:9(8).
86. Cunningham LJ, JK Lingley, LR Haines, JM Ndung'u, SJ Torr, ER Adams. 2016. Illuminating the prevalence of *Trypanosoma brucei s.l***.** in *Glossina* using LAMP as a tool for xenomonitoring. *PLoS Negl Trop Dis,* 10(2): e0004441. doi: 10.1371/journal.pntd.0004441.
87. English S, H Cowen, E Garnett, JW Hargrove. 2016. Maternal effects on offspring in a natural population of the viviparous tsetse fly. *Ecological Entomology*, 41(5).
88. Hargrove JW, R Ouifki, D Kajunguri, GA Vale, SJ Torr. 2012. Modelling the control of trypanosomiasis using trypanosides or insecticide-treated livestock. *PLoS Neg Trop Dis,* 6(5).
89. Hargrove JW, Ackley SF. 2015. Mortality estimates from ovarian age distributions of the tsetse fly *Glossina pallidipes* Austen sampled in Zimbabwe suggest the need for new analytical approaches. *Bull Entom Res,* **105**, 294–304.
90. Hargrove J. 2013. An example from the world of tsetse flies. *Math Bioci Eng.* 10(3):691-704.
91. Hargrove JW, MO Muzari. 2015. Artificial warthog burrows used to sample adult and immature tsetse (*Glossina* spp) in the Zambezi Valley of Zimbabwe *PLoS Neglected Tropical Diseases,* 9(3): e0003565. doi: 10.1371/journal.pntd.0003565.

92. Hargrove JW, MO Muzari. 2015. Nutritional levels of pregnant and postpartum tsetse (*G. pallidipes* Austen) captured in artificial warthog burrows in the Zambezi Valley of Zimbabwe. *Physiological Entomology,* 40, 138–148.
93. Hargrove JW, MO Muzari, S English. 2018. How maternal investment varies with environmental factors and the age and physiological state of wild tsetse *Glossina pallidipes* and *Glossina morsitans. R Soc Open Sci,* 5(2):171739.
94. Kajunguri D, JW Hargrove, R Ouifki, JYT Mugisha, PG Coleman, SC Welburn. 2014. Modelling the use of insecticide-treated cattle to control tsetse and *Trypanosoma brucei rhodesiense* in a multi-host population. *Bull Mathematical Biology,* 76, 673–696. https://doi:10.1007/s11538-014-9938-6.
95. Kovacic V, I Tirados, J Esterhuizen, CTN Mangwiro, MK Lehane, SJ Torr, H Smith. 2016. We remember… Elders' memories and perceptions of sleeping sickness control interventions in West Nile, Uganda. *PLoS Negl Trop Dis,* doi.org/10.1371/journal.pntd.0004745.
96. Lord JS, Z Mthombothi, VK Lagat, F Atuhaire and JW Hargrove. 2017. Host-seeking efficiency can explain population dynamics of the tsetse fly *Glossina morsitans* in response to host density decline. *PLoS Negl Trop Dis,* 11(7)14.
97. Lord JS, SJ Torr, HK Auty, PM Brock, M Byamungu, JW Hargrove, LJ Morrison, F Mramba, GA Vale, MC Stanton. 2018. Geostatistical models using remotely-sensed data predict savanna tsetse decline across the interface between protected and unprotected areas in Serengeti, Tanzania. *J Appl Ecol,* 55(4).
98. Mramba F, F Oloo, M Byamungu, T Krober, A McMulling, S Mihok, PM Guerin. 2013. Standardizing visual control devices for tsetse flies: East African species *Glossina swynnertoni. PLoS Negl Trop Dis,* 7(2).
99. Mwaseba D. 2017. *Reinvesting in dipping facilities is key to controlling African animal trypanosomiasis in local communities near Serengeti National Park in Tanzania.* http://vbd-environment.org/assets/documents/Project_D_Papers_and_Resources/Mwaseba_2017.pdf.
100. Mwaseba DL, KJ Kigoda. 2017. Knowledge, attitude and practices about tsetse control among communities neighbouring Serengeti National Park, Tanzania. *Heliyon 3.*
101. Moore S, S Shrestha, KW Tomlinson, H Vuong. 2011. Predicting the effect of climate change on African trypanosomiasis: integrating epidemiology with parasite and vector biology. *J Royal Society Interface,* doi. 10.1098.
102. Njoroge MM, I Tirados, SW Lindsay, GA Vale, SJ Torr, U Fillinger. 2017. Exploring the potential for using cattle for malaria vector surveillance and control: a pilot study in Kenya. Parasites & Vectors, 10:18. doi: 10.1186/s 13071-016-1957-8.
103. Rock KS, CM Stone, IM Hastings, MJ Keeling, SJ Torr, N Chitnis. 2015. Mathematical models of human African trypanosomiasis epidemiology. *Adv Parasitol,* 87:53–133.
104. Shaw AP, GR Wint, G Cecchi, SJ Torr, RC Mattioli, TP Robinson. 2015. Mapping the benefit-cost ratios of interventions against bovine trypanosomiasis in Eastern Africa. *Prev Vet Med,* 122(4):406–416.
105. Solano P, SJ Torr, MJ Lehane. 2013. Is vector control needed to eliminate gambiense human African trypanosomiasis? *Front Cell Infect Microbiol,* 3:33.
106. Tirados I, J Esterhuizen, V Kovacic, CTN Mangwiro, GA Vale, I Hastings, P Solano, MJ Lehane, SJ Torr. 2015. Tsetse control and Gambian sleeping sickness: implications for control strategy. *PLoS Negl Trop Dis,* **9**(8): e0003822. doi: 10.1371/journal.pntd.0003822.
107. Torr SJ, A Chamisa, TN Mangwiro, GA Vale. 2012. Where, when and why do tsetse contact humans? Answers from studies in a national park of Zimbabwe. *PLoS Negl Trop Dis,* 6(8).
108. Torr SJ, GA Vale. 2015. Know your foe: lessons from the analysis of tsetse fly behaviour. *Trends in Parasitology,* 31, 95–99.
109. Vale GA, DR Hale, A Chamisa, SJ Torr. 2012. Towards an early warning system for Rhodesian sleeping sickness in savannah areas: Man-like traps for tsetse flies. *PLoS Negl Trop Dis,* 6(12).
110. Vale GA, A Chamisa, C Mangwiro, SJ Torr. 2013. A neglected aspect of the epidemiology of sleeping sickness: The propensity of the tsetse fly vector to enter houses. *PLoS Negl Trop Dis.* 7(2).
111. Vale GA, JW Hargrove, A Chamisa, DR Hall, C Mangwiro, SJ Torr. 2013. Factors affecting the propensity of tsetse flies to enter houses and attack humans inside: increased risk of sleeping sickness in warmer climates. *PLoS Neg TropDis,* 7(4).
112. Vale GA, JW Hargrove, P Solano, F Courtin, J-B Rayaisse, MJ Lehane, J Esterhuizen, I Tirados, SJ Torr. 2014. Explaining the host-finding behaviour of blood-sucking insects: computerized simulation of the effects of habitat geometry on tsetse fly movement. *PLoS Negl Trop Dis,* 8(6): e2901. doi: 10.1371/journal.pntd.0002901.
113. Vale G, J Hargrove. 2015. Predicting the effect of climate change on the abundance and distribution of tsetse flies. *SACEMA Quarterly*. Published on November 30, 2015.

114. Vale GA, JW Hargrove, NA Cullis, S Chamisa, SJ Torr. 2015. Efficacy of electrocuting devices to catch tsetse flies (Glossinidae) and other Diptera. *PLoS Negl Trop Dis,* 9(10). doi: e0004169. 10.1271/journal.pntd.0004169.
115. Vale GA, JW Hargrove, MJ Lehane, P Solano, SJ Torr. 2015. Optimal strategies for controlling riverine tsetse flies using targets: a modelling study. *PLoS Negl Trop Dis,* doi: 10.1371/journal. pntd.0003615.
116. Vale GA, SJ Torr. 2015. Surveillance and sampling of disease vectors. *Revue Scientifique et Technique (International Office of Epizootics)* 34, 227–233.
117. Vale GA, JW Hargrove, A Chamisa, IF Grant, SJ Torr. 2015. Pyrethroid treatment of cattle for tsetse control: reducing its impact on dung fauna. *PLoS Negl Trop Dis,* 9(3).
118. Van Aardenne L, P Wolski and C Jack. 2017. *Rekomitjie climate variability and change. Final Scientific Report.* Climate System Analysis Group. Cape Town, South Africa. http://vbd-environment.org/assets/documents/Project_D_Papers_and_Resources/van_Aardenne_et_al_2017_Rekomitjie_Climate_Variability_and_Change.pdf.
119. Van Aardenne L, Wolski P, Jack C. 2017. Serengeti Climate Variability and Change. Final Scientific Report. Climate System Analysis Group, Cape Town, South Africa. http://vbd-environment.org/assets/documents/Project_D_Papers_and_Resources/van_Aardenne_et_al_2017_Serengeti_Climate_Variability_and_Change.pdf.

Project E: Vulnerability and resilience to malaria and schistosomiasis in northern and southern fringes of the Sahelia belt in the context of climate change (Principal Investigator: Brama Kone, Universite de Bouake et Centre Suisse de Recherches Scientifiques en Côte d'Ivoire, Abidjan, Côte d'Ivoire)

120. Boko ANN, G Cissé, B Koné, SF Dedy. 2016. Croyances locales et stratégies d'adaptation aux variations climatiques à Korhogo (Côte d'Ivoire) *Tropicultura*, 34(1): 40–46.
121. Boko ANN, G Cissé, B Koné, D Séri. 2016. Variabilité Climatique Et Changements Dans L'environnement À Korhogo En Côte d'Ivoire: Mythes Ou Réalité? *European Scientific Journal,* 12(5), 1857–7881.
122. Custer B, B Kone, E Kouassi, E Ontiri, P Watts, ZF Yi. 2014. Reflexive Evolution of the Ecohealth Paradigm: A Possible Yin-Yang Design. *Ecohealth,* 11(3); 286–289.
123. Feagan M, B Kone, N Brou, Y Agbo-Houenou, E Kouassi, J Spiegal. 2014. Confrontation avec le context disciplinaire institutionalisé : réflexion critique des approches écosystémiques de la sante sur la base des expériences des jeunes chercheurs au Canada, en Afrique occidentale et centrale et en Amérique centrale, *VetigO – la revue électronique en science de l'environnement* [Online] Hors-série 19 Août 2014, Online since 11 August 2014, connection on 27 August 2014.
124. Gbalegba NGC, H B, KD Silue, O Ba, E Tia, M Chouaibou, NTY Tian-Bi, GY Yapi, B Kone, J Utzinger, B Koudou. 2018. Distribution of *Plasmodium* spp. Infection in asymptomatic carriers in perennial and low seasonal malaria transmission settings in West Africa. *J Infect Dis Pov,* 7:39.
125. Gbalegba NGC, KD Silue, O Ba, H Ba, NTY Tian-Bi, GY Yapi, A Kaba, B Kon, J Utzinger, BG Koudou. 2017. Prevalence and seasonal transmission of *Schistosoma haematobium* infection among school-aged children in Kaedi town, southern Mauritania. *Parasites & Vectors*, 10, 12.
126. Koffi AMA, M Doumbia, G Fokou, M Keita, B Kone and NN Abe. 2018. Community knowledge, attitudes and practices related to schistosomiasis and associated healthcare-seeking behaviours in northern Côte d'Ivoire and southern Mauritania. *Infect Dis Pov,* 7:70. doi.org/10.1186/s40249-018-0453-0.
127. Kone B, M Feagan, YA Houenou, N Brou, PV Houenou, B Fayomi, E Ngnikam, G Cisse, J Spiegel, E Kouassi. 2011. Facilitating the relationship between researchers and policy-makers: experiences from three ecohealth projects in West and Central Africa. *Ecohealth,* 8(4):413–417.
128. Kone B, M Doumbia, I Sy, K Dongo, Y Agbo-Houenou, PV Houenou, B Fayomi, B Bonfoh, M Tanner, G Cisse. 2014. Étude des diarrhées en milieu périurbain à Abidjan par l'approche écossant, *VertigO – la revue électronique en sciences de l'environnement* [Online], Hors-série 19 Août 2015 online since 11 August 2014, connection on 27 August 2015.
129. Kouakou E, B Kone, A N-Go, G Cisse G, C Ifejika-Speranza, I Savane. 2014. Ground water sensitivity to climate variability in the white Bandama basin, Ivory Coast. *SpringerPlus*, 3:226; Online since May 2014. Connection on 3 October 2014.
130. M'Bra RK, B Kone, DP Soro, RTAS N'krumah, N Soro, JA Ndione, I Sy, P Ceccato, KL Ebi, J Utzinger, C Schindler, G Cisse. 2018. Impact of climate variability on the transmission risk of malaria in northern Côte d'Ivoire. *PLoS One,* 13(6).

131. M'bra Kouassi R, B Kone, E Kouakou Yao, B Silue, G Cisse, N Soro. 2015. Approvisionnement en eau potable, qualité de la ressource et risques sanitaires associes à Korhogo (Nord-Côte d'Ivoire). Environ Risque Sante 14 : 230–241. doi: 10.1684/ers.2015.0781
132. M'Bra RK, B Kone, YG Yapi, KD Silue, I Sy, D Vienneau, N Soro, G Cisse and J Utzinger. 2018. Risk factors for schistosomiasis in an urban area in northern Côte d'Ivoire. *J Infect Dis Pov,* 7:47. doi.org/10.1186/s40249-018-0431-6.
133. Tia E, NGC Gbalégba, KR M'Bra, A Kaba, OA Boby, M Koné, M Chouaibou, B Koné, B Koudou. 2016. Étude du niveau de production larvaire d'*Anopheles gambiae* s.l. (Diptera : Culicidae) dans différents types de gîtes à Oussou-yaokro au Centre-Ouest et à Korhogo, au Nord (Côte d'Ivoire). *J Applied Biosciences,* 105: 10170–10182.

Others:

134. Ayana EK, P Ceccato, JR Fisher, R DeFries. 2016. Examining the relationship between environmental factors and conflict in pastoralist areas of East Africa. 2016. *Sci Total Environ,* 557-588:601–611.
135. Brieger WR, JU Sommerfeld, UV Amazigo, CDI Network. 2015. The potential for community-directed interventions: reaching underserved populations in Africa. *Int Q Community Health Educ,* 35(4):295–316.
136. Campbell-Lendrum D, L Manga, M Bagayoko, J Sommerfeld. 2015. Climate change and vector-borne diseases: what are the implications for public health research and policy? *Philos Trans R Soc Lond B Biol Sci,* 370(1665).
137. Ceccato P, C Vancutsem, R Klaver, J Rowland, SJ Connor. 2012. A vectorial capacity product to monitor changing malaria transmission potential in epidemic regions of Africa. *J Trop Med,* 2012:595948.
138. Del Corral J, MB Blumenthal, G Mantilla, P Ceccato, SJ Connor, MC Thomson. 2012. Climate information for public health: the role of the IRI climate data library in an integrated knowledge system. *Geospat Health,* 6(3) S15–24.
139. Hosking J, D Campbell-Lendrum. 2012. How well does climate change and human health research match the demands of policymakers? A scoping review. *Environ Health Perspect,* 120(8):1076–1082.
140. Neira M, D Campbell-Lendrum, M Maiero, C Dora, F Bustreo. 2014. Health and climate change: the end of the beginning. *Lancet,* 384(996):2085–2086.
141. Thomson, MC, I Ukawuba, CL Hershey, A Bennett, P Ceccato, B Lyon, T Dinku. 2017. Using rainfall and temperature data in the evaluation of national malaria control programs in Africa. *Am J Trop Med Hyg,* 97(3_Suppl):32–45.
142. WHO/AFRO, Public Health and Environment. *Report on the work of WHO* (2010–2011). https://www.afro.who.int/sites/default/files/2017-06/PHE-Public-Health-and-Environment-in-AFRO-Report-2010-2011.pdf.
143. WHO. 2013. *Protecting health from climate change: vulnerability and adaptation assessment*. https://www.afro.who.int/sites/default/files/2017-06/9789241564687_eng.pdf.
144. WHO. 2014. *Guidance to protect health from climate change through health adaptation planning*. https://www.afro.who.int/sites/default/files/2017-06/9789241508001_eng.pdf
145. WHO. 2014. *Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s*. https://www.afro.who.int/sites/default/files/2017-06/9789241507691_eng.pdf.
146. WHO. 2014. *Gender, Climate Change and Health* http://apps.who.int/iris/bitstream/handle/10665/144781/9789241508186_eng.pdf;jsessionid=1A9F31CEBFCCA1B08AAC9A410376C0F3?sequence=1.
147. WHO. 2015. Strengthening health resilience to climate change. https://www.afro.who.int/sites/default/files/2017-06/conference_briefing_1_healthresilience_27aug.pdf.
148. WHO. 2015. *Did you know: by taking action on climate change you can strengthen public health.* https://www.afro.who.int/publications/did-you-know-taking-action-climate-change-you-can-strengthen-public-health.
149. WHO. 2015. *Operational framework for building climate resilient health systems*. https://www.afro.who.int/sites/default/files/2017-06/9789241565073_eng.pdf.
150. WHO. 2015. *Lessons learned on health adaptation to climate variability and change: experiences across low- and middle-income countries.* http://apps.who.int/iris/bitstream/handle/10665/176009/9789241564953_eng.pdf?sequence=1.

151. WHO. 2016. *Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks* http://apps.who.int/iris/bitstream/handle/10665/204585/9789241565196_eng.pdf;jsessionid=5152F40857555C2D0F3D45AD7C4E1529?sequence=1.

152. WHO. 2017. *Keeping the vector out: Housing improvements for vector control and sustainable* development. http://apps.who.int/iris/bitstream/handle/10665/259404/9789241513166-eng.pdf?sequence=1.

153. Woodward A, KR Smith, D Campbell-Lendrum, DD Chadee, Y Honda, Q Liu, J Olwoch, B Revich, R Sauerborn, Z Chafe, U Confalonieri, A Haines. 2014. *Climate change and health: on the latest IPCC report.* 383(9924):1185–1189.

Advanced degrees of students supported by the TDR/IDRC Research Initiative on VBDs and Climate Change

Project A: Social, environmental and climate change impact of vector-borne diseases in arid areas of Southern Africa

1	Kellen David	Woman	PhD, UKZN	The effect of temperature on *Schistosoma mansoni* - *Biomphalaria pfeifferi* interaction
2	Resign Gundu	Man	PhD, UKZN	Burden of malaria and the related household economic costs in Gwanda District, Zimbabwe
3	Zibusiso Jokomo	Woman	PhD, UKZN	Social determinants of schistosomiasis in Gwanda District, Zimbabwe
4	Dr Muhubiru Kabuyaya	Man	MSc, UKZN	Schistosomiasis infection rates and related risk factors among school-going children after treatment with Praziquantel in Jozini municipality in uMkhanyakude district, KwaZulu-Natal, South Africa
5	Chester Kalida	Man	PhD, UKZN	Experimental studies on the effect of temperature on the *Bulinus globosus-Schistosoma haematobium* system
6	Margaret Macherera	Woman	PhD, UKZN	Development of a community-based malaria early warning system based on indigenous knowledge: the case of Gwanda District, Zimbabwe
7	Keoleboge Malela	Woman	MSc, UB	Analysis of the sociocultural and institutional determinants of bilharzia: A case study of the Okavango River Panhandle communities in Botswana
8	Tawanda Manyagadze	Man	PhD, UKZN	Modelling schistosomiasis under changing climate conditions: the case of uMkhanyakude District in Kwazulu-Natal, South Africa
9	Dirontsho Maphane	Woman	MSc, UB	Analysis of local knowledge on the prevention of and adaptation to malaria endemicity in the Okavango Delta, Botswana: The case of Shakawe Village
10	Dr Alexio Mbereko	Man	Post-doc, UKZN	Social science
11	Dr Motsolapheko Moseki	Man	Post-doc, UKZN	Malaria and schistosomiasis
12	Prestage Murima	Woman	PhD, UKZN	Institutional determinants of health for malaria and schistosomiasis in Southern Africa
13	Rosemary Zarafet Musesengwa	Woman	PhD, UKZN	Community engagement strategies and experiences in a multicentre study in Botswana and Zimbabwe
14	Chipo Mutambo	Woman	MSc, UKZN	Effectiveness of health education for control and prevention of schistosomiasis among primary school children in Gwanda District, Zimbabwe
15	Ezra Mutegeki	Man	MSc, UKZN	Malaria knowledge, attitudes and practices among women in Mgedula village, Jozini local municipality, uMkhanyakude District, KwaZulu Natal, South Africa

16	Meron Chacha Ndege	Man	PhD, UKZN	Malaria vector dynamics under changing climate conditions in semi-arid areas of uMkhanyakude District, South Africa
17	Ntobeko Ndlovu	Man	MSc, UKZN	Soil-transmitted helminths in the context of climate change in Umkhanyakude
18	Dr Owen Rubaba	Man	Post-doctoral fellow, UKZN	Aestivation studies in South Africa
19	White Soko	Man	PhD, UKZN	Effect of temperature on insecticide sensitivity of *Anopheles gambiae* mosquitoes under laboratory conditions in South Africa
20	Gosaitse Tubatsi	Woman	PhD, UKZN	Effects of environmental factors influencing survival of larvae and adult *Anopheles* mosquito

Project B. Early warning systems for improved human health and resilience to climate sensitive vector-borne diseases in Kenya

21	Lavinca Achieng	Woman	MSc, UN	Analysis of the economic burden of treating malaria in Baringo County
22	Evans Juma	Man	MSc, UN	Virology; assessment of seroprevalence of RVF in humans and livestock and its socioeconomic impacts in Baringo County, Kenya
23	Dancan Kobia	Man	MSc, UN	Entomology; diversity and distribution of malaria and RVF vector larvae in different aquatic habitats along an altitudinal gradient in Baringo County, Kenya
24	C Loye	Man	MSc, UN	Entomology
25	Edna Nduku Mutua	Woman	PhD, UN	Anthropology; community adaptation to malaria and RVF in Baringo County, Kenya
26	Isabella Moraa Ondiba	Woman	PhD, UN	Entomology; impact of seasonal variability of Malaria and RVF vector bionomics and infection status in Baringo County, Kenya
27	Alfred Ochieng	Man	PhD, JOOUST	Spatial modelling; modelling and analysis of vector and environmental data to predict the risk of RVF in Baringo County, Kenya
28	Collins Omondi	Man	MSc, KU	Parasitology; assessing the seasonal trends of *Plasmodium falciparum* infections among primary school children in Baringo County, Kenya

Project C. Predicting vulnerability and improving resilience of Maasai communities to vector-borne infections: an ecohealth approach in the Maasai Steppe ecosystem

29	Meshack Saigilu Meshshilieki	Man	MSc, NMAIST	Social science surveys
30	Happiness J Nnko	Woman	PhD, NMAIST	Climate impact on tsetse and trypanosome distribution in the Tanzania Maasai Steppe
31	Anibariki Ngonyoka	Man	PhD, NMAIST	Correlates of land cover characteristics on abundance and distribution of tsetse flies and trypanosomiasis prevalence in the Maasai Steppe
32	Linda P Salekwa	Woman	PhD, NMAIST	Trypanosome genetic identification
33	Maria Simwango	Woman	MSc, SU	Molecular prevalence of trypanosome species in cattle and tsetse fly hosts

Project D. Human African trypanosomiasis: alleviating the effects of climate change through understanding the human-vector-parasite interactions

34	Sara Ackley	Woman	PhD, UCSF	Analysis of tsetse fly ovarian dissection data
35	Nada Abdelatif	Woman	MSc, SACEMA; PhD, SACEMA	Modelling of African animal trypanosomiasis; assessment of future risk of trypanosomiasis infection in KwaZulu-Natal, South Africa and ways of alleviating that risk
36	Dr Mechtilda Byanmungu	Woman	Postdoctoral fellow, UDS	Climate, tsetse/trypanosomiasis dynamics in Serengeti ecosystem
37	Andrew Chamisa	Man	PhD, US	Contact between tsetse flies and humans under various meteorological conditions (temperature and rainfall); comparing samples of two species (*G m morsitans* and *G pallidipes*) differing in microclimate, measuring tsetse infection status
38	Annitta Chihota	Woman	MPhil, UZ	Modelling tsetse fly population dynamics
39	Dr Sinead English	Woman	Post-doctoral fellow, UC	Analysis of existing data from warthog burrows
40	Roux-Cil Ferreira	Woman	MSc, US	Individual-based model of tsetse fly population dynamics: modelling an extensive mark-release-recapture experiment
41	Tokpa Jamah	Man	MSc, SACEMA	Modelling the economics of trypanocides and insecticide-treated cattle interventions on trypanosomiasis disease within a multi-host population using delay differential equations
42	Kinyemi Kigoda	Woman	MA, SU	Rural development; development studies; climate change, gender and perceived biting risk from tsetse flies in Tanzania: a case of communities neighbouring Ikorongo-Grumeti game reserves, Serengeti District, Tanzania
43	Clement Mangwiro	Man	PhD, BUSE	Conducting experiments on various sampling devices in different habitats and varying levels of tsetse-host interactions; collecting samples for analysis
44	Learnmore Nyakupinda	Man	MPhil, UZ	*T. brucei* infection rates in Zimbabwe mammals
45	Rory Pilosoff	Man	Research Fellow, UFS	Economic and social impact of tsetse fly control in Zimbabwe
46	William Shereni	Man	PhD, SACEMA	Aspects of climate change and tsetse fly biology in Zimbabwe
47	David Tsikire	Man	MSc, UZ	Age-specific infection rates in female tsetse as a function of season and climate

Project E. Vulnerability and resilience to malaria and schistosomiasis in northern and southern fringes of the Sahelian belt in the context of climate change Vulnerability and resilience to malaria and schistosomiasis in northern and southern fringes of the Sahelian belt in the context of climate change

48	Ando Honorate Larissa Ballet	Woman	MSc, UFHB	Socioéconomique; Fardeau économique du paludisme et des bilharzioses dans un context de changement climatique: Analyse à partir des ménages de Korhogo
49	Med Mahmoud Cheikh	Man	MSc, USTM	Biology and the environment; climate variability, ecosystem characterization and dynamics of malaria and schistosomiasis in Kaedi, Mauritania
50	N'guessan Guy Constant Gbalegba	Man	PhD, UNA	Environmental epidemiology; Changement climatique et maladies vectorielles: Cas du paludisme et des bilharzioses aux franges nord et sud de la bande Sahelienne
51	Aboudramane Kaba	Man	PhD, UFHB	Biostatistics; Modelisation de la vulnérabilité au paludisme et aux bilharzioses et résilience des populations de Korhogo et Kaedi: Analyse des déterminants et différences dans un context de changement climatique
52	Amoin Jeanne d'Arc Koffi Koukaou	Woman	PhD, UAO	Sociology and anthropology; Déterminants de la résilience des populations des zones semi-arides de Korhogo (Côte d'Ivoire) et de Kaedi (Mauritania) au paludisme et aux bilharzioses dans un context de changement climatique
53	Koussi Richard M'Bra	Man	PhD, UFHB	Eau, hygiène et assainissement: Analyse intégrée de facteurs de risque au paludisme et aux bilharzioses à Korhogo (Nord Côte d'Ivoire) et à Kaedi (Sud Mauritanie)
54	Honorine Moro	Woman	PhD, UFHB	Environmental health
55	Sidibe Moussokoro	Woman	PhD, UAME	Biology and the environment; impact of rice cultivation on the epidemiology of malaria and schistosomiasis in Kaedi, Mauritania
56	Tanoh Serges N'Krumah	Man	PhD, UFHB	Environmental health
57	Ibrahima Semega	Man	MSc, USt	Geography; Vulnerability and resilience against malaria and schistosomiasis in Kaedi, Mauritania in the context of climate change
58	Pewonheta Dramane Soro	Man	MSc, UFHB	Climate and health; climate variability, ecosystem characterization and dynamics of malaria and schistosomiasis in Korhogo, Côte d'Ivoire
59	Richard Yappi	Man	PhD, UFHB	Environmental health