**Indigenous health, livestock, and climate change adaptation in Kanungu District, Uganda**

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# Abstract

Indigenous populations are considered among the most susceptible to the impacts of climate change due to social, economic, and political marginalization, and dependence on the environment for resources and spiritual well-being. Uganda's Batwa are an Indigenous group with traditional hunter-gatherer livelihoods who, as conservation refugees since the early 1990s, are attempting to transition to an agrarian lifestyle. Livestock keeping may represent an appropriate adaptation option contributing to health and socio-economic development through food security and income generation. Currently, our understanding of planned adaptation remains limited, particularly as it pertains to livestock.

This dissertation assessed livestock keeping as a climate change adaptation option for Batwa with the overarching hypothesis that livestock have the potential to improve health and well-being. The first objective was to systematically synthesize the evidence on the impacts of livestock on human malaria risk. Malaria was selected as a globally significant, climate-sensitive health outcome reported by Batwa as a health priority. This objective was motivated by the potential of livestock to protect or exacerbate human risk to a climate-sensitive disease. Findings from the systematic review suggested that livestock may reduce malaria risk where local mosquito vectors do not prefer human to animal hosts, where livestock are kept away from human sleeping quarters during peak mosquito feeding times, and where mosquito bed nets are used. This objective thus validated and characterized the role of livestock in affecting malaria outcomes.

The second objective was to compare malaria prevalence between Batwa and non-Batwa of Kanungu District and identify risk factors for infection. This objective aimed to understand and characterize the differential health burden – focusing on malaria – between the Batwa and their non-Indigenous neighbours as a baseline for investigating the role that livestock might play in affecting health outcomes in the two populations. The Batwa had twice the odds of malaria parasitemia as non-Batwa (OR 2.2, 95% CI 1.2-4.0). Results of multivariate models showed that relative poverty (OR 2.0, 95% CI 1.0-3.9) and house construction (OR 2.5, 95% CI 1.0-6.7) were additional risk factors to the influence of ethnicity for malaria in this region. Livestock reduced the odds of infection among a sub-sample of livestock owners (OR 0.3, 95% CI 0.1-0.9). These results point to substantial

differences in malaria burden between Batwa and non-Batwa, highlight socio-economic gradients between the two populations, and indicate a potential role for livestock in affecting health outcomes.

The third objective was to characterize the potential of livestock to reduce the climate change vulnerability of Batwa, using non-Batwa as a comparative temporal analogue. A concurrent mixed methods analysis identified current benefits and drawbacks of livestock keeping, in addition to barriers and facilitators of engaging in this livelihood strategy. A set of criteria for assessing appropriate adaptations was modified from the vulnerability and sustainable livelihoods literatures, and applied to qualitative data on livestock livelihoods in the Kanungu context. The analysis suggested that livestock represent an adaptation option that offers a range of health and monetary benefits with the potential to decrease dependence on climate-sensitive livelihoods in the long-term. However, extreme poverty, limited access to land and technical support exclude Batwa from taking advantage of livestock livelihood-related opportunities. Interventions that simultaneously address immediate needs and medium-to-long-term development goals would be required for Batwa adaptation.

This thesis contributes to the climate change adaptation, Indigenous health, and malaria literatures, combining a set of disparate but overlapping methodological lenses to provide an evidence-base to support livestock keeping as an adaptation intervention to reduce Batwa vulnerability to climate change.

# Résumé

Les populations autochtones sont considérées comme des plus susceptibles aux impacts des changements climatiques à cause de leur marginalisation sociale, économique et politique ainsi que de leur dépendance envers l'environnement pour des ressources et leur bien-être spirituel. Les Batwa d'Ouganda forment un groupe autochtone traditionnellement chasseur-cueilleur qui, étant réfugiés de la conservation depuis les années 1990, tentent d'adopter un mode de vie agraire. Les moyens de subsistance d'élevage peuvent représenter une option d'adaptation adéquate contribuant au développement socio-économique et à la santé via la sécurité alimentaire et la génération des revenus. Actuellement, notre compréhension de l'adaptation planifiée est limitée notamment en ce qui concerne les moyens de subsistance d'élevage.

Cette thèse a évalué les moyens de subsistance d'élevage comme une option d'adaptation face aux changements climatiques pour les Batwa en suivant l'hypothèse globale que le bétail a le potentiel d'améliorer la santé et le bien-être. Le premier objectif était de synthétiser systématiquement les éléments de preuve sur les impacts de l'élevage sur le risque du paludisme humain. Le paludisme a été choisi en tant que maladie mondialement importante, sensible au climat et identifiée par les Batwa comme une priorité cruciale dans le domaine de la santé. Cet objectif a été motivé par le potentiel du bétail pour protéger ou exacerber les risques auxquels les humains font face en rapport à une maladie sensible au climat. Les résultats de l'étude systématique de la littérature ont suggéré que le bétail peut réduire le risque de paludisme lorsque les insectes-vecteurs locaux ne préfèrent pas les humains comparativement aux animaux, lorsque le bétail est tenu éloigné des residences humains pendant les périodes de pointe d'alimentation des moustiques et lorsque les moustiquaires sont utilisées. Cet objectif validait et caractérisait le rôle du bétail impactant le taux de paludisme chez l'humain.

Le deuxième objectif était de comparer la prévalence du paludisme entre les Batwa et les non-Batwa du district de Kanungu et d'identifier les facteurs de risque d'infection. Cet objectif visait à comprendre et caractériser le fardeau différent de la maladie - en se concentrant sur le paludisme - entre les Batwa et leurs voisins non-autochtones comme une base de référence pour étudier le rôle que le bétail pourrait jouer sur les états de santé de ces deux populations. Les Batwa avaient deux fois plus de chances de parasitémie du paludisme que les non-Batwa (OR 2.2, 95%, CI 1.2-4.0). Les résultats des modèles à variables multiples ont montré que la pauvreté relative (OR 2.0, 95%, CI 1.0-3.9) et la construction domiciliaire (OR 2.5, 95%, CI 1.0-6.7) étaient des facteurs de risque additionnels à l'influence de l'ethnicité sur le paludisme dans cette région. Le bétail a réduit les chances d'infection au sein d'un sous-échantillon de propriétaires de bétail (OR 0.3, 95%, CI 0.1-0.9). Ces résultats démontrent des différences importantes du fardeau du paludisme entre les Batwa et non Batwa, mettant en évidence les gradients socio-économiques entre ces deux populations et indiquent un rôle potentiel du bétail qui consiste à affecter les états de santé.

Le troisième objectif était de caractériser le potentiel des moyens de subsistance d'élevage pour réduire la vulnérabilité des Batwa face aux changements climatiques en utilisant les non-Batwa comme un analogue temporel. Une analyse simultanée avec méthodes mixtes a identifié les avantages et désavantages des moyens de subsistance d'élevage ainsi que les obstacles et appuis à adopter cette stratégie d'élevage. Un ensemble de critères pour évaluer les adaptations appropriées a été modifié à partir de la littérature sur la vulnérabilité et des moyens de subsistance durables et appliqué à des données qualitatives sur les moyens de subsistance d'élevage dans le contexte de Kanungu. Cette analyse suggère que l'élevage représente une option d'adaptation offrant une gamme d'avantages monétaires et dans le domaine de la santé, avec le potentiel de réduire la dépendance aux moyens de subsistance vulnérables aux changements climatiques à long terme. Cependant, l'extrême pauvreté et l'accès limité aux terres et à l'assistance technique nécessaire empêchent les Batwa de profiter des opportunités liées aux moyens de subsistance d'élevage. Des interventions qui répondent simultanément aux besoins immédiats et aux objectifs de développement à moyen et long termes sont requises pour l'adaptation des Batwa.

Cette thèse contribue à l'adaptation aux changements climatiques, la santé autochtone et à la littérature sur le paludisme en combinant des méthodes distinctes, mais reliées afin de fournir une base de preuves pour soutenir l'élevage de bétail comme intervention d'adaptation réduisant la vulnérabilité des Batwa aux changements climatiques.

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# Acronyms

**AGI:** Acute gastrointestinal infection

**BCH:** Bwindi Community Hospital

**BDP:** Batwa Development Program

**CM:** community member

**HIV/AIDS:** Human Autoimmune Virus/Acquired Immunodeficiency Syndrome

**IPCC:** Intergovernmental Panel on Climate Change

**IVM:** Integrated Vector Management

**KI:** Key informant

**RDT:** Rapid Diagnostic Test

**SES:** Socioeconomic status

**SLA:** Sustainable Livelihoods Approaches

**SSA:** Sub-Saharan Africa

**SSI:** semi-structured interview

**UNFCCC:** United Nations Framework Convention on Climate Change

**WHO:** World Health Organization

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# Chapter One: Introduction

## 1.1 Overview

Climate change has been described as one of the biggest global health threats - and opportunities - of the 21st century (Costello et al., 2009; Watts et al., 2015). Populations globally will have to cope with, and adapt to, these changes. The purpose of this dissertation is to understand the potential health benefits of livestock to improve resilience to climate change in a population of Indigenous peoples in southwestern Uganda. As a significant global health problem and climate-sensitive vector-borne disease, malaria is a focus of this research. The role of livestock in mediating malaria risk among rural farmers broadly, and Indigenous and non-Indigenous Kanungu District community members specifically, is examined. This research adds to the climate change adaptation and health literature by providing place-based evidence to inform intervention in a vulnerable population. In addition, it contributes to the health knowledge of this under-researched Indigenous group.

## 1.2 Research rationale

Climate change is having, and will continue to have, wide ranging and significant impacts on human health (Costello et al., 2009; Hess, Eidson, Tlumak, Raab, & Luber, 2014; Watts et al., 2015). Increased temperatures will change pathogen and vector reproduction rates, ranges and distributions, resulting in changing patterns of disease (McMichael, Montgomery, & Costello, 2012). Changes in seasonality and weather variability are predicted to result in decreased net crop yields, with implications for food security and malnutrition (McMichael et al., 2012). Climate change will also affect water security and sanitation, air pollution, population displacement, and heat stress, with the net impacts expected to increase morbidity and premature mortality globally (McMichael et al., 2012; Watts et al., 2015).

Malaria is a significant global health burden that is highly climate sensitive (Caminade et al., 2014; WHO, 2015). Half of the world's population is at risk of malaria, with predicted increases in population-at-risk due to climate change (Caminade et al., 2014). While this mosquito-borne parasitic disease is both preventable and curable, the majority of cases occur in sub-Saharan Africa where those at risk have limited financial and physical access to prophylaxis and treatment (Sachs & Malaney, 2002; WHO, 2015; Worrall, Basu, & Hanson, 2005).

Certain regions are expected to fare worse in the face of a changing climate (IPCC, 2014b; McMichael, 2013). Economic dependence on rain-fed agriculture, limited governance structures, weak infrastructure, and poor public health service capacities make sub-Saharan African nations among the most vulnerable to predicted impacts (Rockstrom, 2000; Stern, 2008). Uganda, located in East Africa, is particularly vulnerable due to a high dependence on rain-fed agriculture, extreme poverty, and limited health care system capacity (Berrang-Ford et al., 2012; Hussein, 2011; Magrath, 2008; Namanya, 2009). Climate related disasters and drought have been responsible for financial losses in excess of 65 million USD annually in Uganda (NWDR, 2005). Predicted climate changes in Uganda include increasing temperatures, higher frequency and severity of extreme weather events and decreasing predictability of precipitation (Hepworth, 2010; Namanya, 2009). These changes are projected to have predominantly negative impacts on health. Food security is expected to decrease due to crop failures and soil degradation (Hepworth, 2010). Increasing prevalence of vector-borne and diarrheal diseases are predicted as a result of temperature, precipitation, and extreme weather event changes (Berrang-Ford et al., 2012; Namanya, 2009). Increased poverty due to asset loss, migration and increased health care costs is also expected (Hussein, 2011; Kansiime, 2012; Magrath, 2008; Namanya, 2009).

Within country disparities also exist. Some populations will be disproportionately affected by the adverse effects of climate change. Women, children, the poor, those with pre-existing health conditions, and Indigenous peoples have been highlighted as highly vulnerable sub-populations (Haines, Kovats, Campbell-Lendrum, & Corvalan, 2006a; Harper et al., 2015; Watts et al., 2015). Despite this, there is a notable gap regarding our understanding of Indigenous health and how it will be affected by climate change (Durkalec, Furgal, Skinner, & Sheldon, 2015; Ford, 2012; Salick & Ross, 2009). This research gap is particularly acute for non-Arctic Indigenous populations, with the least being known about low-income regions such as sub- Saharan Africa (Berrang-Ford, Ford, & Paterson, 2011; Ford, 2012).

The Batwa of Uganda are one such group. Loss of their traditional hunter-gatherer livelihood and traditional lands has resulted in significant socioeconomic and health inequalities compared to their non-Indigenous neighbours (Berrang-Ford et al., 2012). While gaps remain in our understanding of the Batwa's current health situation, climate sensitive health outcomes for Batwa include malaria, malnutrition, gastrointestinal disorders, and respiratory disease. Climate change may exacerbate existing challenges.

Adaptations to climate change, particularly "no-regrets" (mainstreaming) adaptations that ameliorate other global health issues such as poverty, have been highlighted as critical to timely and effective adaptation to climate change impacts (Campbell-Lendrum, Manga, Bagayoko, & Sommerfeld, 2015; Watts et al., 2015). The climate change adaptation literature provides vulnerability assessments, and methods for identifying climate sensitive health outcomes (Kristie L Ebi & Burton, 2008; Hess et al., 2014). However, a significant gap in knowledge exists with regards to the evidence-base to guide selection, evaluation, and consideration of adaptation options and interventions. More broadly, and critically, there is a lack of evidence to guide climate change adaptation, with a particular need for evidence on the design of adaptation interventions (Hess et al., 2014; Hosking & Campbell-Lendrum, 2012).

Livestock have been proposed as an adaptation option to reduce climate change vulnerability for the rural poor in some regions (Jones & Thornton, 2009; Thornton, Jones, Alagarswamy, Andresen, & Herrero, 2010). Livestock livelihoods, and livestock sales, have been used by rural populations to cope with climate variability and other shocks (Alary et al., 2014; Berman, Quinn, & Paavola, 2015; Kansiime, 2012; Mertz et al., 2011) and have been used in development projects as a method to improve health and reduce vulnerability in low-income countries (Alary, Corniaux, & Gautier, 2011; Jones & Thornton, 2009; Randolph et al., 2007). While it is understood that livestock can contribute social, economic, and physical well-being — with the potential to increase climate change resilience — there is limited evidence to assess the potential contribution of livestock as a climate change adaptation option (Thornton & Herrero, 2015).

## 1.3 Aims and objectives

The aim of this research is to assess the appropriateness of livestock keeping as an adaptation option to reduce climate change vulnerability of the Batwa of Kanungu District, Uganda. Malaria has been selected as a focus of this research for two reasons. First, malaria was identified as a priority health concern by Batwa (Berrang-Ford et al., 2012). Second, malaria is a highly climate-sensitive vector-borne disease for which increased incidence has been predicted under climate change in the East African highlands (Hay, Noor, et al., 2002; Lindsay & Martens, 1998; Paaijmans et al., 2010). This dissertation has three objectives driven by the hypothesis that livestock have the potential to benefit Batwa health and well-being:

1. to systematically synthesize the evidence on the impacts of livestock on human malaria risk;

2. to determine the prevalence of, and identify modifiable risk factors for, malaria infection among the Batwa and non-Batwa of Kanungu District, with particular focus on livestock ownership; and,

3. to characterize the potential of livestock keeping to reduce the vulnerability of Batwa to climate change.

## 1.4 Dissertation organization

This dissertation has six chapters including this introductory chapter. This is a manuscript-style thesis where the three objectives of the research are addressed in three independent empirical chapters (Chapters Three, Four, and Five). Each manuscript contains a background literature review section and as such, this thesis takes on the repetitive nature of manuscript-style dissertations.

Chapter Two frames the research by reviewing academic literature in three domains: 1) health geography research that has focused on place-based health disparities, 2) the body of work that takes a “vulnerability approach” to understanding the human dimensions of climate change and, 3) sustainable livelihood approaches and their complementarity and differing views on the determinants of vulnerability and resilience. It then provides an overview of the relationship between climate change and health, and presents a snapshot of the literature specific to climate change in Uganda. It reviews the effects of climate change on Indigenous populations, and introduces the study population - the Batwa of Kanungu District, Uganda.

Chapter Three, the first empirical research chapter, presents a systematic literature review of the effect of livestock on human malaria risk (Objective One). This systematic review asked the question: what is the evidence that livestock ameliorate or exacerbate a climate-sensitive health outcome like malaria? The review was informed by a realist approach that attempted to identify contextual factors that determine whether livestock increase (zoopotentiation) or decrease (zooprophylaxis) malaria risk in humans.

Chapter Four, the second manuscript, provides an estimate of the prevalence of malaria as measured by rapid diagnostic test for *Plasmodium falciparum* antigen for Indigenous Batwa and their non-Indigenous neighbours in Kanungu District, Uganda (Objective Two). In addition, this chapter reports results from multivariable analyses of hypothesized determinants of malaria risk including an exploration of the zooprophylaxis hypothesis (subject of the systematic review presented in Chapter Three).

Chapter Five, the final manuscript, is a mixed-methods analysis of the potential of livestock as a climate change adaptation option for Batwa (Objective Three). It employs a temporal analogue comparative approach, with non-Batwa — as relative livestock owners — representing a possible future proxy for Batwa. Using a set of criteria adapted from the climate change adaptation literature, this work examines the benefits, drawbacks, barriers, and facilitators to Batwa uptake of livestock to understand the potential of livestock to reduce climate change vulnerability. It examines the ability of livestock to accrue health and socioeconomic benefits for Batwa.

Chapter Six concludes this dissertation, and is organized around the substantive contributions to knowledge this thesis provides, as well as methodological contributions and policy implications of the research. Limitations and future research questions are also considered.

### 1.5 Author contributions

In this section, I outline my own contributions and the contributions of others to the empirical research chapters. Under the supervision of my committee, I designed the studies, collected, analyzed and interpreted data, and wrote each of the manuscripts. My supervisors provided advice and edited each of the manuscripts.

Chapter Three: I conceptualized the research question with guidance from LBF and PM. I carried out data collection and analysis. LBF contributed to interpretation of results and structure of the argument. NR provided guidance on the discussion. I wrote the manuscript which LBF, PM and NR edited.

Chapter Four: I conceptualized the research question with guidance from LBF. This research builds upon the Indigenous Health Adaptation to Climate Change (IHACC) burden of disease study of Ugandan Batwa. Between December 2011 and April 2014, IHACC conducted a quarterly survey on household and individual prevalence and risk factors for three climate-sensitive health outcomes: malaria, food security and nutrition, and acute gastrointestinal infection. The survey included a collection of a rapid diagnostic blood test (RDT) for *Plasmodium falciparum* antigen. In July 2013, I helped with coordination of the Batwa survey and oversaw quality control of the competed surveys.

I visited the ten Local Councils (LCs) containing Batwa settlements in Kanungu District and sought permission to carry out the IHACC survey among a sample of non-Batwa in these LCs with the help of a Ugandan team member, Sebastian Twesigomwe. I coordinated the administration of the survey and RDTs with assistance from ST and Jolene Labbé. Sherilee Harper and Victoria Edge provided guidance on sampling strategies prior to data collection. Margot Charette assisted with data entry and Kaitlin Patterson provided troubleshooting advice regarding data management and statistical analysis. I wrote the manuscript and NR, LBF, and PM provided feedback and edits. Finally, Sherilee Harper, Manisha Kulkarni, Didas Namanya, Sebastian Twesigomwe, and Jolene Labbé provided further manuscript edits.

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# Chapter Two: Literature Review

## 2.1 Overview

This chapter outlines the research approaches used to frame and address the relationship between livestock, livelihoods, and human health, in the context of climate change and the literatures that have informed the research question (Figure 2.1). First, the disciplinary underpinnings of health geography with a focus on health inequities and their social determinants will be discussed. This is followed by a review of Vulnerability and Sustainable Livelihood approaches. It then provides a synthesis of the literature pertaining to livestock as an adaptation option to improve health resilience to climate change. I begin with an overview of climate change impacts on human health, which provides the backdrop for this work. I focus on malaria, a highly climate-sensitive disease with significant health burden in sub-Saharan Africa in general and Uganda in particular, and among the top climate-sensitive health outcomes prioritized by the Batwa. An introduction to Integrated Vector Management, an approach to malaria prevention, provides background for Chapter Three. The regional climate change context of Uganda is then reviewed. I synthesize the literature on Indigenous health and climate change, highlighting the differential vulnerability of these populations globally, providing background for Chapters Four and Five. I then narrow to the study population, the Batwa of Southwest Uganda, and current knowledge on their experiences of health and climate change. Finally, I summarize the literature regarding the three pathways through which I propose livestock may reduce climate change vulnerability.

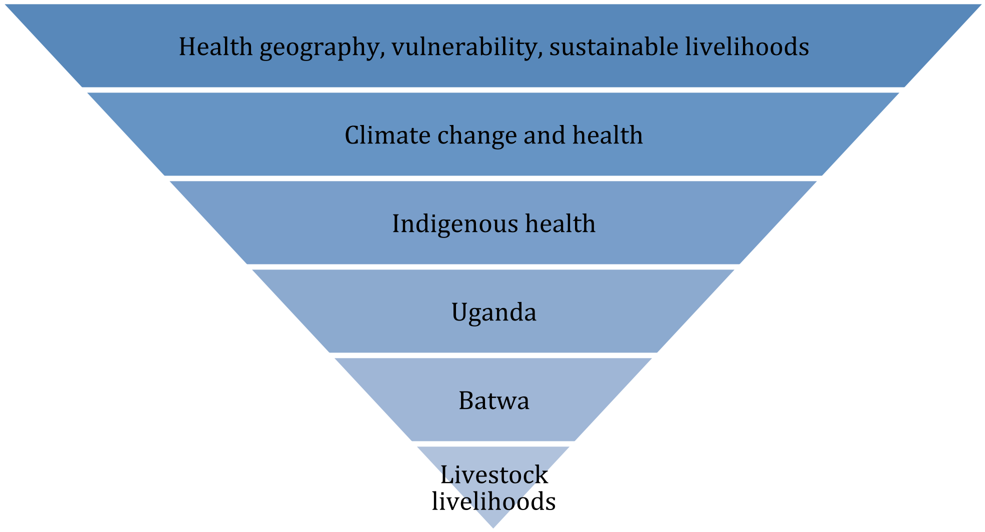


Figure 2.1 Literature review structure

## 2.2 Health geography

This research is situated within the health geography sub-discipline of human geography, which examines the effect of space and place on health and health care (Andrews & Moon, 2005). Disease ecology (the interaction between populations, places, and disease causing agents to produce health or disease), with its roots in epidemiology, and the geographies of health care provision, are the twin traditions of medical geography (Dummer, 2008). Now referred to as health or post-medical geography, following the cultural turn in geography, this sub-discipline has broadened its focus to include social, and cultural aspects of health, going beyond disease distribution to conceptualize well-being and experience of health (T. Brown, McLafferty, & Moon, 2010; Kearns, 1993; Kearns & Moon, 2002). This has involved a shift from quantitative and spatial methods to include qualitative methods. A critical view of the power relations that govern how people interact with their environments and how that affects their health is also apparent (Kearns & Collins, 2010). Health geography continues to emphasize the importance of the environment on health, where environment refers to the social and physical contexts in which people carry out their lives (Andrews & Moon, 2005; Cutchin, 2007; Dummer, 2008). Health geographers use a wide variety of theoretical frameworks to explore relationships between health and place (Cutchin, 2007; Dummer, 2008), but share an interest in the structures within society at various scales that cause health to be inequitably distributed within and between populations (Andrews & Moon, 2005; Carmalt & Faubion, 2010; Grady & Wadhwa, 2015).

Health geographers have a long-standing tradition of examining health inequalities within and among places (Curtis, 2004; Kearns & Collins, 2010; Luginaah, Bezner Kerr, & Dixon, 2015). Health and disease are socially patterned. Variations in depression, coronary heart disease, obesity, and negative health behaviours like smoking, vary by neighbourhood socioeconomic status (SES) as measured by education, income, and occupation (Adler et al., 1994; Kulkarni & Subramanian, 2010). Although the greatest health inequalities are apparent between those in the lowest and highest SES groups, there is a step-wise gradient whereby every step up the SES ladder leads to an improvement in health outcomes. The psychosocial effect describes how individuals in lower SES groups have limited resources to cope with stressful life events such as job loss, divorce or death of a loved one (Marmot et al., 1998). Stress has been physiologically linked to illnesses such as coronary heart disease and stroke, and impairs immune function making individuals more susceptible to disease. Not only are individuals in higher SES groups less likely to experience stressful life events, when they do happen, they are better able to cope with and adapt to changing circumstances (Adler et al., 1994; Evans & Kim, 2010). One's perception of relative social position may also result in differences in health outcomes (Wilkinson, 1992). The perception of being less well-off than others may result in stress that is associated with physiologic manifestations such as susceptibility to infectious disease (Adler et al., 1994).

The social determinants of health as the cause of health inequalities was proposed by Marc Lalonde in 1974 (Lalonde, 1974). Lalonde proposed twelve key determinants of health: income and social status, social support networks, education and literacy, employment and working conditions, social environments, physical environments, personal health practices and coping skills, healthy child development, biology and genetic endowment, health services, gender, and culture (Lalonde, 1974). These are the social factors that dictate access to power, income, goods, and services and are responsible for the differences in health between and within populations (Marmot, 2005). The social determinants of health approach is used by health geographers to understand how, and to what degree, social and physical environments that are a result of explicit policies and public choice affect health (Kawachi & Kennedy, 1997). They are systemic, structural, unethical, avoidable, and act at multiple scales. International forces such as trade agreements, the global market, and international policies trickle down to national and local scales to determine policies that affect peoples' lives regarding social assistance, employment and health care (Marmot, Friel, Bell, Houweling, & Taylor, 2008).

### 2.3 Vulnerability to climate change

Global environmental change has become an expanding area of interest to health geographers (Dummer, 2008; Gatrell & Elliott, 2009; Moser, 2010). The social determinants of health inequalities are also the mediating factors through which climate will affect health (Haines et al., 2006a). They are the political, economic and social conditions that make exposure unsafe or challenging (Ford & Smit, 2004). The Vulnerability Approach has been consistently applied to the study of human dimensions of climate change. Vulnerability, or susceptibility to harm (Cutter, 1996; Smit, Burton, Klein, & Street, 1999), is described as a function of exposure-sensitivity, and adaptive capacity where exposure-sensitivity is the interaction between climate stimulus characteristics and the characteristics of the exposure unit (community, household, individual, nation, or region) (Smit, Burton, Klein, & Wandel, 2000). Adaptive capacity is negatively associated with vulnerability; it is the ability of the unit to cope with, and respond to change (Smit et al., 1999). The stimulus or stressor, could be a climate event such as flooding or drought, or climate variability (O'Brien, Eriksen, Nygaard, & Schjolden, 2007). Adaptations are a result of adaptive capacity, and are the strategies or actions taken to respond to actual or expected stimuli (Adger, 2006; Smit et al., 2000).

The two main conceptualizations of vulnerability are biophysical (also called "outcome", or "end-point") vulnerability, and contextual (or "social", "human-security", or "starting-point") vulnerability (O'Brien et al., 2007). Biophysical vulnerability focuses on geographical aspects, where the location of livelihood activities and settlements make communities more susceptible to damage as a result of a climate hazard (Eakin & Luers, 2006; Fussel, 2007; O'Brien et al., 2007). In this framing, vulnerability is often quantified by mortality rates or financial losses. Societal factors such as culture, values, SES, are not considered and yet these factors play a significant role in how climate change is experienced (Kelly & Adger, 2000; O'Brien et al., 2007). Contextual vulnerability describes how climate change will exacerbate existing inequalities by interacting with non-climatic factors (Adger, 2006; O'Brien et al., 2007). The drivers of vulnerability are the social, political, and economic factors that set people up to be harmed by a changing climate (Adger, 2006; Kelly & Adger, 2000; O'Brien et al., 2007; Smit et al., 2000). In this framing, climate change is only one possible stressor. As such, vulnerability can be reduced by addressing the contextual factors that determine susceptibility, such as poverty, and governance (Brooks, Adger, & Kelly, 2005). In this approach, vulnerability, like health, is socially structured. The social determinants of health, upstream factors, or the "causes of causes" undermine or bolster resilience.

### *2.3.1. Reducing vulnerability: Resilience and Adaptation*

Resilience is often viewed as the inverse of vulnerability (O'Brien et al., 2007). While many definitions of resilience exist from various disciplines (Joakim, Mortsch, & Oulahen, 2015), the IPCC Fifth Assessment Report employs the following definition: "the capacity of a social-ecological system to cope with a hazardous event or disturbance, responding or reorganizing in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning and transformation" (Arctic Council, 2013 p. viii). Adaptations are actions employed in the face of real or anticipated stressors to reduce damage and take advantage of potential benefits. As such, adaptations increase resilience (Ford, Cunsolo Willox, et al., 2014; Joakim et al., 2015). A critique of the conceptualizations of vulnerability, resilience, and adaptation is that they tend to under-emphasize the power-relations that create vulnerability making the individual, household, or community responsible for resilience or adaptation rather than the sociopolitical structures that unfairly expose them to climate change hazards and variability (Cannon & Mueller-Mahn, 2010). Therefore, it is important to underscore the social construction of vulnerability and resilience, and seek to contextualize vulnerability, within the cultural, social, economic, ecological, and political environments in which people carry out their lives and livelihoods (Ford, Cunsolo Willox, et al., 2014). The failure or success of adaptations will depend upon the perspectives of various stakeholders and whose values are prioritized with respect to outcomes (De Souza et al., 2015; O'Brien & Wolf, 2010).

Adaptations will be highly place- and population-dependent (McMichael, 2013). The selection of appropriate adaptation policies involves adaptation assessments that evaluate and rank potential strategies to reduce vulnerability to climate change (Kristie L Ebi, Lindgren, Suk, & Semenza, 2013). Literature on what adaptations *should* and *should not do* abounds: adaptations should complement development goals; should not contribute to greenhouse gas emissions; should build upon current policies; should be culturally acceptable; should not exacerbate current vulnerabilities; should involve multisectoral approaches and multidisciplinary teams; should build on existing knowledge to avoid research fatigue; and so on (Conway & Mustelin, 2014; Kristie L Ebi et al., 2013; Khan & Roberts, 2013; McMichael, 2013; Preston, Mustelin, & Maloney, 2015). However, due to the uncertainties of future climate change risks, complexities of social-ecological systems, and potential for unintended negative consequences, significant gaps still exist with regards to how communities, and governments prioritize adaptation options, and their demonstrable effectiveness to reduce vulnerability to climate variability and change. Examples of practical adaptations are lacking and a need remains for evidence to inform adaptation decision-making (Conway & Mustelin, 2014; De Souza et al., 2015; Ford, Cunsolo Willox, et al., 2014).

### 2.4 Sustainable livelihoods

Climate change is altering the ways in which people provide for themselves and their families (Cannon & Mueller-Mahn, 2010; Uy, Takeuchi, & Shaw, 2011). Climate change impacts are already affecting the health and well-being of impoverished populations in developing countries. The rural poor who rely on natural resources and rain-fed agriculture for their livelihoods are particularly sensitive to climate change (Siddiqi, 2011). The ways in which these populations cope with and respond to climate stressors have often been described in the literature using a combination of the Sustainable Livelihoods Approaches (SLA) with the Vulnerability Approach (Uy et al., 2011).

The SLA has been widely applied to the study and practice of rural development particularly by development agencies and non-governmental organizations (Allison & Ellis, 2001; Brocklesby & Fisher, 2003; Carney, 1999). Livelihoods, according to the framework, go beyond the ways in which people earn a living, incorporating access to resources and services (Ashley & Carney, 1999; Chambers & Conway, 1991; Ellis, 1998). Sustainable livelihoods depend on people's access to assets or capitals; human capital (e.g., education, skills, health), financial capital (e.g., income, investments, insurance), social capital (e.g., family, social networks, interpersonal relationships), natural capital (e.g., land), and physical capital (e.g., access to roads, infrastructure) (Carney, 1999) - a notion based on Amartya Sen's idea of capabilities (Amekawa, 2011; Bebbington, 1999; Chambers & Conway, 1991). These capitals are mobilized to build livelihood portfolios which represent the combinations of activities that people or households rely on to improve their quality of life (Ellis, 1998). Further, they engage in livelihood strategies, including intensification, extensification, diversification, and migration to cope with external stresses and shocks (Amekawa, 2011; Scoones, 1998). Stresses and shocks, seasonality, and changing trends over time constitute the vulnerability context (Brocklesby & Fisher, 2003). In the sustainable livelihoods approach, livelihood diversification is an important strategy for coping and responding to the vulnerability context (Carney, 1999; Chambers, 1989; Ellis, 1998). Concurrent diversification describes carrying out multiple activities at the same time, spatial diversification reflects spreading activities across locations – perhaps including migration of household members – and temporal diversification indicates changing from one activity to another over time (Goulden, Adger, Allison, & Conway, 2013). While livelihood diversification can be concurrent, spatial, and temporal in nature, for the purposes of this dissertation, the discussion will be limited to concurrent livelihood diversification. Examples of concurrent livelihood diversification include, but are not limited to, incorporating new crop varieties or livestock species into current crop and livestock agriculture activities, or the uptake of new on- and off-farm sources of income.

Livelihoods are viewed within broader structures, and are subject to exogenous forces such as market, governance, and cultural norms, reflected in policies, institutions and processes (Allison & Ellis, 2001; Allison & Horemans, 2006; Ashley & Carney, 1999). People make trade-offs, often prioritizing one type of capital over another to create their livelihoods constrained by the broader forces acting upon them (Bebbington, 1999; Brocklesby & Fisher, 2003). As a people-centered approach, focusing on strengthening capabilities and capitals, it therefore takes a positive view to reducing vulnerability and poverty (Allison & Ellis, 2001; Allison & Horemans, 2006; Ferrol-Schulte, Wolff, Ferse, &

Glaser, 2013). This framework also includes consideration of multiple scales, how individuals interact within a household, households within a community, towns within a county, and broader institutions that constrain or facilitate their abilities and access to resources (Ashley & Carney, 1999). The overarching goal of sustainable livelihoods is to reduce poverty through expanding the asset base and improving the well-being of rural communities (Bebbington, 1999; Brocklesby & Fisher, 2003; Carney, 1999). In this approach, sustainability can be compared to resilience in that it represents the ability of the system to cope with and adapt to social and environmental shocks (Allison & Horemans, 2006; Chambers & Conway, 1991; Scoones, 1998).

### 2.5 Climate change impacts on health

Climate change effects, commonly characterized as direct and indirect, are already being seen in the health of global populations, and are expected to worsen over time (McMichael et al., 2012; Watts et al., 2015). Direct effects include morbidity and mortality due to heat and cold stress, and extreme weather events (Haines, Kovats, Campbell-Lendrum, & Corvalan, 2006b; McMichael et al., 2012; McMichael, Woodruff, & Hales, 2006). Heat waves cause the highest fatalities in the elderly, and those with cardiovascular and respiratory conditions (De Blois et al., 2015), while the role of cold weather beyond seasonal infections like the common cold and influenza are not well understood (Franchini & Mannucci, 2015; McMichael et al., 2006).

Indirect effects include altered food security, migration, infectious disease rates and distribution, and mental health. While knowledge gaps persist (Thornton, Ericksen, Herrero, & Challinor, 2014), there is consensus that climate change will have serious consequences for food security (Franchini & Mannucci, 2015; St Louis & Hess, 2008). Increased variability and unpredictability of rainfall will result in drought and crop failures in some regions. Resource scarcity and limited agricultural opportunities (so-called social responses to climate change) will continue to result in migration of rural populations to urban centres resulting in overcrowding, overwhelming of sanitation and health services, and increased disease transmission (Costello et al., 2009). Infectious and parasitic diseases are also climate-sensitive and may increase under future climate scenarios (Confalonieri, Menezes, & Souza, 2015). Changes in ambient and water temperature, humidity, and precipitation events will affect the transmission of vector-, water-, food-, air-borne and zoonotic diseases (Confalonieri et al., 2015). Diarrhea-causing bacteria reproduce more rapidly at higher temperatures (Myers & Patz, 2009). Run-off caused by intense periods of rainfall can contaminate water sources and result in higher rates of diarrheal diseases (Kovats & Akhtar, 2008; Thomas et al., 2006). These events are expected to increase with future climate change (Harper, Edge, Schuster-Wallace, Berke, & McEwen, 2011). Climate change can affect mental health by altering people's cultural and livelihood interactions with their environments. Experiencing first-hand, or witnessing the effects of climate disasters on others through the media, is also associated with psychological stress, and high rates of suicide (Berry, Bowen, & Kjellstrom, 2010; Cunsolo Willox et al., 2015; Doherty & Clayton, 2011; Harper et al., 2015).

*2.5.1 Climate change impacts on malaria*

Malaria is a vector-borne protozoan disease. Five *Plasmodium* parasite species are infective to humans although *P. falciparum* and *P. vivax* are the most significant in terms of health burden (Cotter et al., 2013; Ouattara & Laurens, 2015). The malaria parasite is transmitted by female mosquito vectors of the *Anopheles* genus (WHO, 2015). Malaria incidence has decreased by approximately 37% since 2000, and eradication of the disease has reappeared on the global agenda with 34 countries aiming for eradication by 2020 (Snow, 2015; WHO, 2015; Zelman, Kiszewski, Cotter, & Liu, 2014). Nonetheless, malaria remains one of the largest global health challenges, with 214 million cases and 450,000 fatalities estimated to have occurred in 2015 (Murray et al., 2014; Ouattara & Laurens, 2015; WHO, 2015).

The range and distribution of vector-borne diseases will be altered by a changing climate. The current and future effects of climate change on malaria are a subject of ongoing debate (Campbell-Lendrum et al., 2015). Temperature has a U-shaped relationship with vector survival whereby increasing temperature can increase viability and reproductive activity of mosquito vectors (although ideal temperature range varies by vector species), until an upper temperature threshold is reached above which vectors no longer reproduce (Niang et al., 2014). In some regions, particularly the East African highlands, increasing temperatures have been associated with increased malaria incidence due to vector habitat suitability and immunologically naive populations (Hay, Noor, et al., 2002; Lindsay & Martens, 1998; Paaijmans et al., 2010). In other regions, however, temperatures may increase beyond ideal vector ranges, with concomitant predicted decreases in malaria incidence (Lunde, Bayoh, & Lindtjorn, 2013). Attribution of malaria rate increases to anthropogenic climate change is particularly challenging and some of these changes have been associated with increased antimalarial drug resistance, El Niño Southern Oscillation effects, migration, and breakdowns in malaria control programs (Hay, Cox, et al., 2002). A similar relationship is seen with rainfall (Paaijmans, Wandago, Githeko, & Takken, 2007). These relationships are complex and are dependent on the lifecycles and replication requirements of specific parasite and vector species (Blanford et al., 2013). These occur in the context of social and economic changes that can inhibit or exacerbate disease transmission (Gething et al., 2010). For example, economic growth may increase the likelihood of screening doors and windows, and high quality building materials that exclude vectors. In rapidly developing urban areas, construction sites and household water storage containers may make ideal breeding grounds for certain vectors.

### *2.5.2 Integrated Vector Management*

Integrated Vector Management (IVM), is an approach to vector-borne disease control that is promoted by the World Health Organization (Lizzi, Qualls, Brown, & Beier, 2014; Mutero, Schlodder, Kabatereine, & Kramer, 2012). The approach involves context specific combination of chemical and non-chemical vector control strategies (WHO, 2008). The strategies should be synergistic in nature and selected based on available evidence. IVM is intended to be cost-effective and sustainable avoiding overreliance on any single form of vector control strategy, particularly chemical control measures with harmful environmental and human health effects, and combatting insecticidal resistance (Mutero et al., 2012; WHO, 2001, 2004). Further, IVM is intended as an intersectoral approach since agriculture and environment-related activities can alter ecosystems in ways that increase vector populations (WHO, 2008). Incorporating IVM into infrastructure and development project design may have significant impacts on vector-borne disease (WHO, 2008).

### 2.6 Indigenous health and climate change

It is widely accepted that some populations are at greater risk of harm from climate change than others (De Souza et al., 2015; Ford, 2012; Haines, Ebi, Smith, & Woodward, 2014; McMichael et al., 2012; Walpole, Rasanathan, & Campbell-Lendrum, 2009; Woodward et al., 2014). Women, children, the elderly, the poor, rural, homeless, and migrant populations, are considered particularly susceptible due to their exposure-sensitivities, e.g., immune status, lack of political voice and mobility, and geographic locations (Haines et al., 2014; Seidel & Bell, 2014; Walpole et al., 2009).

Indigenous populations, despite resilient histories and traditional knowledge, are considered vulnerable to climate change health impacts due to their reliance on the land (for livelihoods, spirituality, cultural activities), socioeconomic and political marginalization, limited access to health care, and geographic remoteness (Ford, 2012; Garnelo, Brandao, & Levino, 2005; Nettleton et al., 2007; Pearce, Ford, Willox, & Smit, 2015). There is considerable variation in the scholarship on Indigenous health vulnerability globally (Ford, 2012). Much of the literature focuses on Arctic and Australian Indigenous groups with a relative paucity of information regarding Indigenous populations in developing countries (Ford, 2012; Hofmeijer et al., 2013). Across the literature, a trend appears showing that Indigenous populations face a higher burden of ill health relative to their non-Indigenous compatriots in both developing and developed nations (Gracey & King, 2009; Ohenjo et al., 2006).

Food security and safety, for example, currently pose climate-sensitive health risks to Indigenous populations. Increased temperatures and extreme weather events (flooding, hail) were associated with lower crop yields which had negative implications for food security of Indigenous communities dependent on rain-fed crop agriculture in Uganda and Peru (Hofmeijer et al., 2013; Patterson, Berrang-Ford, Lwasa, Namanya, Ford, Twebaze, et al., In review; Sherman et al., 2015). In Indigenous Canadian populations (Inuit, First Nations, and Métis), the high cost of store bought foods and traditional food gathering, coupled with the decreasing safety of traditional food gathering processes and species distribution due to climate change, has also resulted in higher rates of food insecurity (Ford & Beaumier, 2011; Ford, Lardeau, & Vanderbilt, 2012; Lynn et al., 2013; Skinner, Hanning, Desjardins, & Tsuji, 2013).

## 2.7 Climate change in Uganda

Africa is already experiencing climate change, and projections indicate that temperatures will increase faster relative to global averages (Niang et al., 2014). Uganda is also experiencing climate change (GoU, 2014). Since 1951, annual total rainfall has shown no significant change, however the onset and duration of rainy seasons have shown significant variation (USAID, 2013). Average annual temperatures have changed during this time period, with both minimum and maximum temperatures seeing increases (GoU, 2014; USAID, 2013). Rainfall projections are currently conflicting (USAID, 2013) but the sub-Saharan highlands are expected to see increases in precipitation and extreme rainfall by the end of the century (Niang et al., 2014). Elevated surface temperatures of Lake Victoria (Marshall et al., 2013), and projected reductions in surface water discharge (or streamflow) in the Ugandan Nile (Beyene, Lettenmaier, & Kabat, 2010; Kingston & Taylor, 2010) will have negative consequences for water and food security via altered freshwater ecosystems and limits to irrigation. Climatic drivers of water quality and quantity, however, are likely to be less important relative to population growth, irrigation, and land use change (Niang et al., 2014). Distribution and intensity of rainfall may be more important to crop yields than annual precipitation, particularly to farmers, as downpours or dry-spells wash away seeds or kill seedlings (Osbahr, Dorward, Stern, & Cooper, 2011). Increased temperature in highland areas of Eastern Africa may allow for increased maize, cassava, and banana production with potential decreases in bean yields (Jarvis, Ramirez-Villegas, Campo, & Navarro-Racines, 2012; Thornton, Jones, Ericksen, & Challinor, 2011). Perennial cash crops may also be affected by warming in East Africa; Ugandan tea yields are projected to decrease by mid-century and coffee pests may decrease coffee yields (Niang et al., 2014).

Southwestern Uganda's bimodal seasonality and dependence on rain-fed agriculture both facilitate its agricultural potential and vulnerability to climate variability and change (Apuuli, Wright, Elias, & Burton, 2000). Based on climate data from Kabale District, in southwestern Uganda, a slight decrease in precipitation between the period of 1951-1981 and 1981-2010 has been shown (USAID, 2013). The onset and duration of seasons has varied significantly over the 60 year period but shows no overall trends (GoU, 2014; USAID, 2013). Reports have also shown significant increases in annual temperature in the southwestern region from the early 1990s and increases in the minimum and maximum annual temperatures from 1970-2000 (GoU, 2014). Within country climate predictions for southwestern Uganda, and East Africa more broadly, are currently limited by the availability of climate data (Bagamba, Bashaasha, Claessens, & Antle, 2012; Hartter et al., 2012; Thornton et al., 2010); however, minimum and maximum temperature increases are predicted across Uganda for the middle to end of the century (GoU, 2014). Rainfall predictions across Uganda are geographically heterogeneous, with projected decreases in rainfall for the southwestern region and increases in the central region for the middle and end of the century (GoU, 2014).

### *2.7.1 Climate change and health in Uganda*

The Ugandan health system is overburdened (GoU, 2007), suffering from a lack of resources and skilled labour (GoU, 2014). Many of Uganda's endemic diseases are climate-sensitive: malaria, lymphatic filariasis, schistosomiasis, trachoma, and gastrointestinal illnesses caused by a range of bacteria and protozoa (USAID, 2014). The rates of these infections are expected to increase overall due to climate change (GoU, 2007; USAID, 2014). Increased frequency and intensity of extreme weather events in recent years has resulted in higher rates of diarrheal diseases and hospitalization, population displacement, loss of infrastructure, and crop damage demonstrating both direct and indirect effects on human health (GoU, 2007, 2014).

In Uganda, where over 70% of the 34.9 million total population relies on agriculture for their livelihoods, sensitivity to variations in precipitation and seasonality is high (GoU, 2015; Hartter et al., 2012). Populations dependent on rain-fed agriculture for food and livelihoods will be most severely affected by these changes with projected increases in food insecurity and malnutrition (Franchini & Mannucci, 2015; St Louis & Hess, 2008; Thornton et al., 2014). Matooke (East African cooking banana), maize, and other grain crop yields are projected to decrease under climate projections (GoU, 2007). Coffee, one of Uganda's main exports, is expected to experience decreased crop yields as a result of altered temperature and precipitation patterns as well as disease and pest infestations (GoU, 2014). These effects are likely to exacerbate pre-existing food insecurity in Uganda (GoU, 2007).

Although reports note an increase in floods, droughts, and extreme weather events in Uganda, and outbreaks of water- and vector-borne diseases and other climate sensitive health outcomes (GoU, 2014), there has been limited evidence-based research linking these health outcomes to climate variability and change (Hosking & Campbell-Lendrum, 2012).

### 2.8 The Batwa of southwest Uganda

The Batwa (Abayanda, Twa) are a Central African population of Pygmy traditional hunter-gatherer forest-dwellers (MRG, 2010). Population estimates are lacking but in the Great Lakes region, the Batwa populations of Burundi, Democratic Republic of Congo, Rwanda, and Uganda estimated at between 65,000-120,000 people (MRG, 2010; Warrilow, 2008) with the Ugandan Batwa estimated to number approximately 6,700 (UBOS, 2002). The Batwa share a common history of land dispossession, discrimination and social exclusion, lack of political representation, violence, and extreme poverty (Kidd, 2008; Lewis, 2000; Warrilow, 2008). There is negligible peer-reviewed literature on the Batwa of Kanungu District (Uganda) in particular, and for the Central African Batwa population in general. A keyword search using the terms "Batwa" and "Uganda" in Web of Science returns 12 results. Two of the articles refer to bee colonies in the Bwindi Impenetrable National Park (Bwindi) (Kajobe, 2007; Kajobe & Roubik, 2006). One refers to Rwandan and Burundian migrants, some of whom settled in Uganda (Ngendakumana, 1991). Another two pertain to forest encroachment and use of forest products by communities surrounding Bwindi (Bitariho, McNeilage, Babaasa, & Barigyira, 2006; Kayanja & Byarugaba, 2001). Bitariho et al. (2006) encourage controlled use of Bwindi for traditional medicine purposes by Batwa and non-Batwa (Bitariho et al., 2006). Kayanja and Byarugaba (2001), focusing broadly on Ugandan forests, mention Batwa as historical inhabitants of the southwestern forests of Uganda. Perry et al. (2014) provide an analysis of the pygmy phenotype in Batwa and show that it has a genotypic basis while Nasidze and colleagues (2011) describe the microbial composition of Batwa saliva (Nasidze et al., 2011). Martin et al. (2015) discuss the cultural and economic impacts of Bwindi park management on Batwa and provide a social justice framework for conservation. Banbury et al. (2015) describe Batwa market interaction. The IHACC research group published the three remaining articles. Prior to 2012, there were no peer-reviewed articles focused on the health, social experiences, or livelihoods of the Batwa, however, a doctoral thesis provides an anthropological analysis of the history of marginalization and current context of Batwa in the neighbouring Kisoro District (Kidd, 2008). Beyond this, the literature remains negligible.

The Batwa are generally accepted as the sole inhabitants of the Central African Region until the mid-1500s, however the Ugandan government does not officially recognize Batwa as Indigenous (Lewis, 2000; Warrilow, 2008; Zaninka, 2001), instead describing all 65 ethnic groups in Uganda as Indigenous (ILO & ACHPR, 2009). The working definition of Indigenous includes self-identification, as well as culture, language, and occupation of ancestral lands (UN, 2004). Recognition of Indigeneity in the African context is a point of contention stemming from the argument that relative to European colonialists, all Africans are Indigenous, a position comparable to other Indigenous populations who have also experienced colonization (ACHPR, 2005; Ohenjo et al., 2006)

Over the past forty years, Batwa have experienced displacement from their traditional lands in Bwindi, Echuya, and Mgahinga parks for conservation purposes, and populations were settled in Kanungu, Kisoro, and Kabale Districts (Warrilow, 2008), where the majority of Batwa live today (Kabananukye & Kwagala, 2007). In Kanungu District, Uganda, Batwa became conservation refugees after Bwindi was gazetted in 1991 (Lewis, 2000). Denied rights to access the forest for food and livelihoods, Batwa squatted on the lands of Bantu people surrounding the park, and were not given compensation or land rights (Lewis, 2000). The creation of Bwindi Park was motivated by conservation and tourism goals, specifically related to the mountain gorilla. Income from gorilla trekking in the park is estimated to generate 700,000 USD annually for the Ugandan Government (Kayanja & Byarugaba, 2001). While 20% of this is mandated for local community projects (Baker, Milner-Gulland, & Leader-Williams, 2012), there is evidence suggesting that park benefits have not been distributed equitably to or among Batwa (Lewis, 2000; Martin et al., 2015).

In response to the dispossession of the Batwa in Uganda, a number of non-governmental organizations (NGOs) began purchasing land for Batwa over the decade following eviction, and this practice continues to date. The Mgahinga and Bwindi Impenetrable Forest Conservation Trust (the *Trust*), which was established in 1995 under a 4.3 million USD World Bank grant through the Global Environment Facility (Belanger, Coppenger, Fried, & Kanchev, 2005; Zaninka, 2001), first purchased land for Batwa in trust.

Later, the African International Christian Ministry and the Batwa Development Program (BDP) also purchased lands for Batwa. The BDP, which remains active in supporting Batwa in Kanungu Disctrict, is funded by Kellermann Foundation, a charitable organization founded by a missionary doctor and his wife. The Kellerman Foundation also established and continues to support the operation of a local hospital, the Bwindi Community Hospital (BCH) (Belanger et al., 2005). The *Trust* reportedly purchased a total of 326 hectares of land of varying quality up to 2002, while the Kellerman Foundation has purchased approximately an additional 100 acres (Belanger et al., 2005); however the current land area settled by Batwa is unknown. Today in Kanungu, Batwa reside in ten settlements located at varying distances from the Bwindi Park border, comprising approximately 100-200 households (Patterson, Berrang-Ford, Lwasa, Namanya, Ford, & Harper, In review), although significant migration between settlements for food, work, and social purposes occurs.

Many Batwa children now attend primary school through the support of NGOs, and some have completed secondary or higher education (Banbury et al., 2015; Patterson, Berrang-Ford, Lwasa, Namanya, Ford, & Harper, In review). The United Organization for Batwa Development in Uganda (UOBDU), established in 2000 by the Forest Peoples Program and Minority Rights Group International (Belanger et al., 2005), advocates for rights of Batwa in Uganda. Currently, this organization works primarily with the Batwa of Kisoro District (Freeman, 2007). The BDP and CARE Uganda have also supported livelihood initiatives for Batwa, including provision of seeds and animals, however these projects are not well documented (Belanger et al., 2005). Despite these external support programs and assistance, Batwa continue to face discrimination, and are commonly characterized by non-Batwa as "dirty", "lazy", and "backward" (Warrilow, 2008; Lewis, 2000). These stereotypes are attributed, in part, to the difficulty in applying traditional hunter-gatherer ways to a sedentary agricultural lifestyle that has been imposed upon Batwa (Lewis, 2000). In particular, an 'immediate return' economy carried over from hunter gatherer traditions has been suggested as a barrier to adapting to the agricultural requirements of investing time and resources in planting and harvesting food (Lewis, 2000). However, research with Batwa by Belanger et al. (2005), for example, has shown that when Batwa immediate needs for food, and shelter were met they invested in, and planned for, long-term futures (Belanger et al., 2005).

### *2.8.1 Batwa health*

The rural poor of Uganda face considerable health challenges due to widespread poverty, lack of infrastructure, limited access to health care, and a reliance on subsistence agriculture for food and livelihoods. Southwestern Uganda has been described as one of the poorest and most densely populated regions in Africa (Baker et al., 2012). The added burdens of a history of forced migration from Bwindi, and loss of livelihoods, have caused Batwa to be described as "the most vulnerable of the vulnerable" (Berrang-Ford et al., 2012). This is illustrated by poor health and socioeconomic status relative to their non-Indigenous neighbours and national averages (Table 3.1). As of 2003, Batwa had a life expectancy at birth of 28 years, compared to 53 years for the average Ugandan. Similarly, under 5-year child mortality rates for Batwa (41%) were twice as high as the southwest Ugandan rate of 18% in 2000, although improvements in recent years are presumed (Belanger et al., 2005; Berrang-Ford et al., 2012). Research in two Batwa settlements in Kanungu reported Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome (HIV/AIDS), malaria, malnutrition, gastrointestinal disease, and respiratory illness as major community-identified health concerns (Berrang-Ford et al., 2012). HIV prevalence among Batwa is 2.2%, which is 40% lower than the non-Batwa population (Birungi, 2010); however, due to sexual exploitation, rates are thought to be on the rise (Belanger et al., 2005).

Climate-sensitive health outcomes are also higher among Batwa than their non-Indigenous neighbours. Ninety-seven percent of Kanungu Batwa were identified as food insecure, the highest reported level of food insecurity in the global literature (Patterson, Berrang-Ford, Lwasa, Namanya, Ford, & Harper, In review). Similarly, annual incidence rates of acute gastrointestinal illness (AGI) among Batwa were among the highest rates reported internationally (S. Clark et al., 2015). Malaria prevalence among Batwa following an insecticide-treated net campaign was estimated at 4.1%, a rate similar to other studies conducted in the area (Lewnard et al., 2014). Health disparities for Batwa are socially mediated, and associated drivers of poor health include land tenure security, employment, wealth, access to health care and education (Berrang-Ford et al., 2012; S. Clark et al., In press; Patterson, Berrang-Ford, Lwasa, Namanya, Ford, Twebaze, et al., In review; Patterson, Berrang-Ford, Lwasa, Namanya, Ford, & Harper, In review).

Table 2.1: Comparison of socioeconomic and health indicators for Ugandan Batwa relative to regional and national averages, adapted from (Berrang-Ford et al., 2012)*.

| **Indicator** | | **Batwa** | **Southwest Uganda**[a] | **Uganda** |
|---|---|---|---|---|
| Health | Life expectancy at birth (years) | 28[b] | n/a | 59[c] |
| | Child mortality (% under 5 years) | 38[b] | 12.8[d] | 9 [d] |
| | HIV/AIDS (%) | 2.3[e] | 3.8[e] | 7.4[f] |
| Education | Adult literacy (% 15-49 years) | <10[g] | Women: 75.5<br>Men: 77.7[d] | Women: 64.2<br>Men: 77.5[d] |
| Income | GDP per capita (constant 2000 USD) | 160[h] | n/a | 696[i] |

*Information in the table is based on the most recent available data. Notably, Batwa data presented in this table are older than regional data due to negligible research in Batwa communities, [a] Kiruhura, Isingiro, Mbarara, Ibanda, Bushenyi, Ntungamo, Rukungiri, Kabale, Kisoro, and Kanungu Districts. [b] as of 2000 (BDP, 2003), [c] As of 2013 (World Bank, 2015), [d] As of 2011 (UBOS, 2011), [e] As of 2009 for Mpungu and Kayonza subcounties in Kanungu District (Birungi, 2010), [f] As of 2014 (UNAIDS, 2015), [g] As of 2012 (Berrang-Ford et al., 2012), [h] (Patterson, Berrang-Ford, Lwasa, Namanya, Ford, Twebaze, et al., In review), [i] As of 2014 (World Bank, 2015).

## 2.9 Livestock keeping for climate change adaptation

Livestock have potential to reduce climate change vulnerability through their contributions to: 1) rural development, income generation, and poverty reduction; 2) human health; and, 3) their current use as a coping strategy for climatic and non-climatic shocks. The following is an overview of the literature pertaining to these relationships.

### *2.9.1 Livestock and rural development*

Livestock have been identified as one of the few livelihood options for the world's most impoverished (Alary et al., 2011; Delgado, Rosegrant, Steinfeld, Ehui, & Courbois, 2001; Hawkes & Ruel, 2006; Herrero et al., 2013; Upton, 2004). Approximately 70% of the world's rural poor, and over 80% of impoverished Africans depend on livestock to support their households (FAO, 2011; Herrero et al., 2013; Hoffmann, 2013). The majority of poor rural livestock keepers are smallholders, keeping small numbers of animals to supplement other forms of income (Herrero et al., 2013; Randolph et al., 2007). Livestock are often integrated with food crops resulting in mixed crop-livestock systems, with crop residues being fed to livestock and livestock providing manure and traction for crop production (Randolph et al., 2007; Upton, 2004). In some cases, livestock are kept for income generation through the sale of offspring and or animal products (D. D. Miller & Welch, 2013). They are kept to diversify the livelihood base (Upton, 2004), provide animal source foods (milk, meat, eggs) (Berti, Krasevec, & FitzGerald, 2004; Kawarazuka & Bene, 2010; Murphy & Allen, 2003), act as insurance (Alary et al., 2011; Delgado et al., 2001; Hoddinott, 2006; Randolph et al., 2007; Scoones, 1992; Upton, 2004), serve cultural or spiritual purposes, and to reflect social standing (Blackwell, 2010; Doran, Low, & Kemp, 1979; Moll, 2005). Urbanization and rapidly growing size and wealth of the global population is expected to increase demand for animal source products (Delgado et al., 2001). This argument is frequently used to promote the intensification of livestock systems in developing countries, enabling the poor to benefit from new market opportunities. Yet most growth in the the livestock sector has occured in developing countries in the form of monogastric (poultry, swine) commercial production in peri-urban zones (Delgado et al., 2001; Herrero et al., 2013).

### *2.9.2 Livestock and human health*

Livestock have myriad effects on human health (Table 2.2) although the causal pathways are not well understood (Randolph et al., 2007). The importance of livestock for nutrition and food security has been highlighted in the grey literature, however systematic reviews find a modest positive impact (Girard, Self, McAuliffe, & Olude, 2012). Animal source foods are good sources of micronutrients and contain factors that improve the bioavailability of other nutrients (D. D. Miller & Welch, 2013). Livestock-related interventions have been shown to increase weight- and height-for-age among Nepalese children relative to non-intervention children (L. C. Miller et al., 2014). However, improvements in food production may not result in improved household diets or nutrition outcomes, in particular since food distribution within households is not always equitable (Girard et al., 2012). Research on nutrition and livestock livelihoods remains conflicting, with the evidence base depending on studies with small sample sizes and of poor quality (Azzarri, Zezza, Haile, & Cross, 2015; Girard et al., 2012; Leroy & Frongillo, 2007; L. C. Miller et al., 2014; Ruel, Alderman, & Maternal Child Nutr Study, 2013). In addition to the potential benefits of animal source food for nutrition, increased household income may benefit health through improved access to non-animal source foods (Alary et al., 2011; Girard et al., 2012) and health care (Alary et al., 2011; Delgado et al., 2001; Randolph et al., 2007; Scoones, 1992).

Livestock also have negative impacts on human health. Livestock-related acute gastrointestinal infections (AGI) may occur as a result of incorrect storage and handing of animal source food, inappropriate hygiene after animal handling, or environmental contamination with animal waste (Grace, 2015; Grace, Gilbert, Randolph, & Kang'ethe, 2012; Randolph et al., 2007; Schlundt, Toyofuku, Jansen, & Herbst, 2004). Important zoonotic enteric pathogens include *E. coli, Salmonella spp, Campylobacter, Cryptosporidium* and *Giardia* (Bigras-Poulin, Ravel, Belanger, & Michel, 2004; Schlundt et al., 2004). Many enteric diseases have both human and animal reservoirs, making attribution to animal sources difficult, particularly in a developing country setting where sanitation, water quality and hygiene are poor (Ashbolt, 2004). While handling and consumption of livestock and their products are known risk factors for enteric disease, contextual factors such as access to clean water, play an important role in disease severity, incidence and prevalence (Vu Dinh et al., 2012). In addition, tending to livestock may divert womens' time away from childcare (L. C. Miller et al., 2014) and household income may be diverted from health and welfare expenses towards veterinary care and other costly inputs (Randolph et al., 2007).

Table 2.2: Summary of documented impacts of smallholder livestock keeping on human health.

| Health-related outcome | Theorized direction of impact | Causal Pathway |
|---|---|---|
| Nutrition | + | Increased consumption of animal protein (Berti et al., 2004; Delgado et al., 2001; Kawarazuka & Bene, 2010; Murphy & Allen, 2003).<br>Animal traction increases crop yields (Delgado et al., 2001; Powell, Pearson, & Hopkins, 1998; Randolph et al., 2007; Scoones, 1992)<br>Ability to buy more/more nutritious food through sale of animal products (Alary et al., 2011; Delgado et al., 2001; Girard et al., 2012)<br>Animal waste as fertilizer increases crop yields (Delgado et al., 2001; Powell et al., 1998; Randolph et al., 2007; Scoones, 1992). |
| Access to healthcare | +/- | Increased income from sale of animal products (Alary et al., 2011; Delgado et al., 2001; Randolph et al., 2007; Scoones, 1992).<br>Animal traction increases crop yields (Delgado et al., 2001; Powell et al., 1998; Randolph et al., 2007).<br>Diversion of resources for animal husbandry/veterinary care (Randolph et al., 2007)<br>Insurance (Bosman, Moll, & Udo, 1997; Doran et al., 1979; Hoddinott, 2006; Moll, 2005) |
| Social status | + | Socio-cultural symbolism, bride-price (Blackwell, 2010; Doran et al., 1979; Moll, 2005) |
| Vector borne disease | +/- | Zoopotentiation (Bogh, Clarke, Pinder, Sanyang, & Lindsay, 2001; Bogh, Clarke, Walraven, & Lindsay, 2002; Bouma & Rowland, 1995; Sota & Mogi, 1989)/zooprophylaxis (Maia et al., 2012; Tirados, Gibson, Young, & Torr, 2011)<br>Watering ponds/fish ponds as breeding grounds for insect vectors (van der Hoek, 2004) |
| Zoonotic infections | - | Close contact (Grace et al., 2012; Pathela et al., 2006; Taylor, Latham, & Woolhouse, 2001) |
| Foodborne disease | - | Consumption of improperly prepared animal proteins (Bigras-Poulin et al., 2004; Schlundt et al., 2004) |
| Child health | - | Diversion of female labour for animal care (Randolph et al., 2007) |
| Environmental contamination | - | Animal waste contaminates water sources, crops (Bigras-Poulin et al., 2004; Delgado et al., 2001; Payment et al., 1997) |
| Occupational hazards | - | Crushing/trampling during animal handling (Douphrate, Rosecrance, Stallones, Reynolds, & Gilkey, 2009; Langley & Morrow, 2010) |

### *2.9.3 Livestock keeping as a coping strategy*

The adaptation capacity of a household is dependent on the flexibility of livelihood options available (Thornton et al., 2007; USAID, 2013). A diverse set of livelihood options allows households to spread risk; failure of one livelihood option is compensated for by relying on other options (Goulden et al., 2013). Households with more diverse livelihood portfolios tend to cope better with climate variability and change (Berman et al., 2015; USAID, 2013).

Wealthier, more resilient households, tend to rely on a higher number of livelihood options, which may include on- and off-farm activities (Berman et al., 2015; Goulden et al., 2013; Pouliotte, Smit, & Westerhoff, 2009). However, if the livelihoods are all similarly climate-sensitive, a diverse livelihood portfolio will not be protective from climate-related shocks (Goulden et al., 2013).

Livelihood diversification to include livestock has been used by rural farmers to adapt to climate change (Kansiime, 2012). Thornton et al (2010) showed that as likelihood of crop failure increased as a result of climate variability, households tended to take up, or become more dependent on livestock keeping (Thornton et al., 2010). Successful agricultural livelihood adaptation options tend to require minimal land and investment, be relatively climate resilient, and be self-sustaining; of which small ruminants and poultry have been shown as examples (Anik & Khan, 2012; Pouliotte et al., 2009). Livestock then consitute a portion of the asset base that can be sold to cope with shocks (Berman et al., 2015; Goulden et al., 2013). Livestock livelhoods can also be used as a short-term stepping stone to off-farm, climate-insensitive forms of income (IDRC, 2012).

### 2.10 Summary

In this chapter I have presented the conceptual underpinnings of and the literatures that inform the research. This research is situated within the discipline of health geography; the social determinants of health - income and social status, social support networks, education and literacy, employment and working conditions, social environments, physical environments, personal health practices and coping skills, healthy child development, biology and genetic endowment, health services, gender, and culture - mediate the health inequities experienced by Batwa. These factors also dictate Batwa health vulnerability to climate change. It is also through these factors that we propose livestock livelihoods as an adaptation option which may increase Batwa resilience. I proposed three pathways through which livestock may reduce vulnerability to climate change: income generation and poverty reduction, health, and as a coping strategy. As highlighted by this review chapter, the literature on Indigenous health and climate change is growing, yet considerable gaps remain regarding African Indigenous populations, their current vulnerability, and potential adaptation options. Further, little is known about the health of Batwa. This dissertation aims to contribute to these research gaps.

# Chapter Three: A systematic, realist review of zooprophylaxis for malaria control

## 3.1 Overview

In this chapter, I address the first objective of the dissertation, to systematically synthesize the evidence on the impacts of livestock on human malaria risk. By assessing the evidence of livestock's influence on human malaria risk, a climate-sensitive and globally important health outcome, I will generate hypotheses regarding the effect of livestock on Batwa malaria risk. These hypotheses will inform analyses of risk factors for malaria infection within the study population of this dissertation. The potential of livestock to affect malaria risk for Batwa will impact the overall potential of livestock to contribute to Batwa health, and therefore, the appropriateness of livestock livelihoods as a climate change adaptation option. In this way, the chapter also contributes to the overarching goal of this thesis to assess the appropriateness of livestock livelihoods to reduce Batwa climate change vulnerability. The following work draws upon and contributes to parasitology, infectious disease, entomology, and veterinary science literatures broadly, and the malaria and zooprophylaxis literatures in particular. This manuscript has been published in *Malaria Journal*:

Donnelly, B., Berrang-Ford, L., Ross, N.A., Michel, P. (2015). A systematic, realist review of zooprophylaxis for malaria control, *Malaria Journal, 14:313.*

## 3.2 Abstract

Background: Integrated vector management (IVM) is recommended as a sustainable approach to malaria control. IVM consists of combining vector control methods based on scientific evidence to maximize efficacy and cost-effectiveness while minimizing negative impacts, such as insecticide resistance and environmental damage. Zooprophylaxis has been identified as a possible component of IVM as livestock may draw mosquitoes away from humans, decreasing human-vector contact and malaria transmission. It is possible, however, that livestock may actually draw mosquitoes to humans, increasing malaria transmission (zoopotentiation). The goal of this paper is to take a realist approach to a systematic review of peer-reviewed literature to understand the contexts under which zooprophylaxis or zoopotentiation occur.

Methods: Three electronic databases were searched using the keywords ‘zooprophylaxis’ and ‘zoopotentiation’, and forward and backward citation tracking employed, to identify relevant articles. Only empirical, peer-reviewed articles were included. Critical appraisal was applied to articles retained for full review.

Results: Twenty empirical studies met inclusion criteria after critical appraisal. A range of experimental and observational study designs were reported. Outcome measures included human malaria infection and mosquito feeding behaviour. Two key factors were consistently associated with zooprophylaxis and zoopotentiation: the characteristics of the local mosquito vector, and the location of livestock relative to human sleeping quarters. These associations were modified by the use of bed nets and socioeconomic factors.

Discussion: This review suggests that malaria risk is reduced (zooprophylaxis) in areas where predominant mosquito species do not prefer human hosts, where livestock are kept at a distance from human sleeping quarters at night, and where mosquito nets or other protective measures are used. Zoopotentiation occurs where livestock are housed within or near human sleeping quarters at night and where mosquito species prefer human hosts.

Conclusion: The evidence suggests that zooprophylaxis could be part of an effective strategy to reduce malaria transmission under specific ecological and geographical conditions. The current scientific evidence base is inconclusive on understanding the role of socioeconomic factors, optimal distance between livestock and human sleeping quarters, and the effect of animal species and number on zooprophylaxis.

### 3.3 Background

Despite renewed commitments and control efforts in recent years (Cox, Hay, Abeku, Checchi, & Snow, 2007; Eisele et al., 2012; Siri, 2014) malaria continues to be a major contributor to global health burden, with approximately 165 million cases in 2013 (Murray et al., 2014). Integrated vector management (IVM) has been promoted as a sustainable approach to combat malaria (Mutero et al., 2012; WHO, 2004) in the face of increasing insecticide resistance of malaria vectors, and environmental and health concerns (WHO, 2001, 2004). This strategy involves combining chemical and non-chemical interventions targeted to specific ecological settings in a way that maximizes efficacy while minimizing cost and negative environmental impacts (WHO, 2004). IVM makes use of environmental modification, environmental manipulation, chemical control methods, and biological methods (WHO, 2004) (Table 3.1).

Strategic placement of livestock sheds or pens has also been proposed as a component of IVM to reduce contact between vectors and human hosts (Mutero et al., 2004; Walker, 2002). The World Health Organization (WHO) began recommending this type of intervention in 1982 as a method to divert mosquitoes from human populations (Bogh et al., 2002). This purposeful use of livestock (i.e., as dead-end hosts) to divert mosquitoes away from humans is described as active zooprophylaxis. Passive zooprophylaxis occurs where normal presence of livestock draws mosquitoes away from humans (Bogh et al., 2001). Insecticide zooprophylaxis, more commonly described in tsetse fly control, involves the use of insecticide-treated cattle and has also been investigated for the control of malaria vectors (Habtewold, Prior, Torr, & Gibson, 2004; Habtewold, Walker, Curtis, Osir, & Thapa, 2001; A. M. Mahande, F. W. Mosha, J. M. Mahande, & E. J. Kweka, 2007; Rowland et al., 2001).

There remains considerable debate regarding the efficacy of zooprophylaxis (Bhutta et al., 2008; Bogh et al., 2001; Bogh et al., 2002; Bouma & Rowland, 1995; Charlwood, 2001; Saul, 2003; 1982). In addition to the literature supporting zooprophylaxis (Maia et al., 2012; Tirados et al., 2011), there is evidence that supports zoopotentiation; livestock presence may actually *increase* malaria transmission by creating additional blood meal sources, which, in turn, can increase vector lifespan and population density (Bogh et al., 2001; Bogh et al., 2002; Bouma & Rowland, 1995). Due to the divergent nature of the literature and the complexity of the relationship between livestock and malaria prevalence, there has been a reluctance to employ zooprophylaxis in control programmes (Ghebreyesus et al., 2000; Hewitt, Kamal, Muhammad, & Rowland, 1994; Mutero et al., 2004).

The goal of this paper was to characterize and critically assess the potential for zooprophylaxis to reduce malaria transmission, with specific attention paid to the contexts under which it may be an effective component of IVM. The strategic framework for IVM calls for evidence-based decision-making in the selection of appropriate interventions that acknowledge the local context, including vector ecology, epidemiology and socioeconomic factors (WHO, 2004).

Table 3.1 Summary of integrated vector management (IVM) approach (Walker, 2002; WHO, 1980, 1982)

| **Method** | **Chemical** | **Biological** | **Environmental management** | | |
|---|---|---|---|---|---|
| Definition | Reduce the vector population by killing larvae or adult vectors with insecticides (e.g., DDT) | Using natural predators or pathogens of vector species | Disrupting vectoral habitat to reduce human-vector interaction and/or vector reproduction and survival | | |
| Sub-type | - | - | Modification of human habitats and behaviours | Environmantal manipulation | Environmental modification |
| Sub-type definition | - | - | Locating human habitats and changing behaviour to reduce vector-host contact | Long term change to physical environment to prevent vector habitats | Temporary change to physical environment to prevent larval development |
| Examples | • Indoor residual spraying<br>• Space spraying | • Larvivorous fish<br>• Nematodes<br>• Bacteria | • Sleeping under bed nets<br>• Placing human settlements away from vector breeding sites<br>• Screening doors and windows<br>• Zooprophylaxis | • Wetland and marsh drainage<br>• Ditch filling | Tree planting |

### 3.4 Methods

A modified systematic review methodology, employing realist approaches (Pawson, Greenhalgh, Harvey, & Walshe, 2004, 2005) was applied to the self-identifying zooprophylaxis literature. This approach recognizes *a priori* that the scientific literature in this area is conflicting and in this case focuses on *when, why,* and *in what contexts* zooprophylaxis or zoopotentiation may occur. A meta-analysis, furthermore, was not feasible due to the variety of study designs (including both observational and experimental designs) and to the variety of outcome measures employed in this research area. ISI Web of knowledge, CAB Direct and PubMed databases were searched in December 2014 using the keywords 'zooprophylaxis' and 'zoopotentiation'. While this invariably excluded studies of malaria risk factors that consider the presence of animals, but did not self-identify using the terms 'zoopotentiation' or 'zooprophylaxis', the search was limited to these explicit terms for two reasons: 1) to select a proxy sample of the key literature explicitly emphasizing and investigating zooprophylaxis, more likely to provide direct discussion, consideration of causal pathways of association and depth regarding the role of animals in malaria transmission; and, 2) to limit the number of results to a feasible and directly relevant sample for in-depth realist analysis. This search retrieved 75 documents after removal of duplicates. Only empirical, peer-reviewed articles that focused on either malaria infection in humans or mosquito behaviour associated with livestock presence were reviewed. Mathematical models of mosquito behaviour and review articles were excluded from the synthesis but their content was assessed to provide context for interpretation of results (Table 3.2). A total of 20 articles met final inclusion criteria and were retained for critical appraisal after full article review (Figure 3.1). Forward and backward citation tracking were applied to the articles selected for critical appraisal with one additional relevant article identified.

Data extraction from each article included author, date of publication, study location, livestock exposure, malaria risk outcome measures, study design, and study limitations. Published results reporting significant associations at the 95% confidence level were classified as supporting a significant zooprophylaxis or zoopotentiation effect. Critical appraisal (Heller et al., 2008) resulted in the exclusion of 14 articles. Reasons for exclusion (Appendix 1) were related to data analysis such as a lack of evidence of statistical significance (Kirnowordoyo & Supalin, 1986; A. M. Mahande, F. Mosha, J. Mahande, & E. Kweka, 2007), and pooling of data preventing conclusions from being made on the effect of livestock on malaria risk (Kaburi et al., 2009). Others were excluded based on study design issues, such as the absence of a comparison group (Bhatt, Srivastava, Rajnikant, & Yadav, 2008) and small sample sizes (McCall, Mosha, Njunwa, & Sherlock, 2001). The pertinent results and conclusions of each study were analysed with regard to the associations between livestock and malaria risk.

Table 3.2 Inclusion and exclusion criteria for document selection

| Inclusion | Exclusion |
|---|---|
| Empirical peer-reviewed articles | Reviews, editorials, frameworks, mathematical models, grey literature, non-empirical studies |
| Livestock as a predictor variable | No livestock variable or comparison |
| Malaria risk outcome such as human biting index or diagnosed malaria infection | Malaria outcome based only on febrile illness (no confirmed diagnosis) |

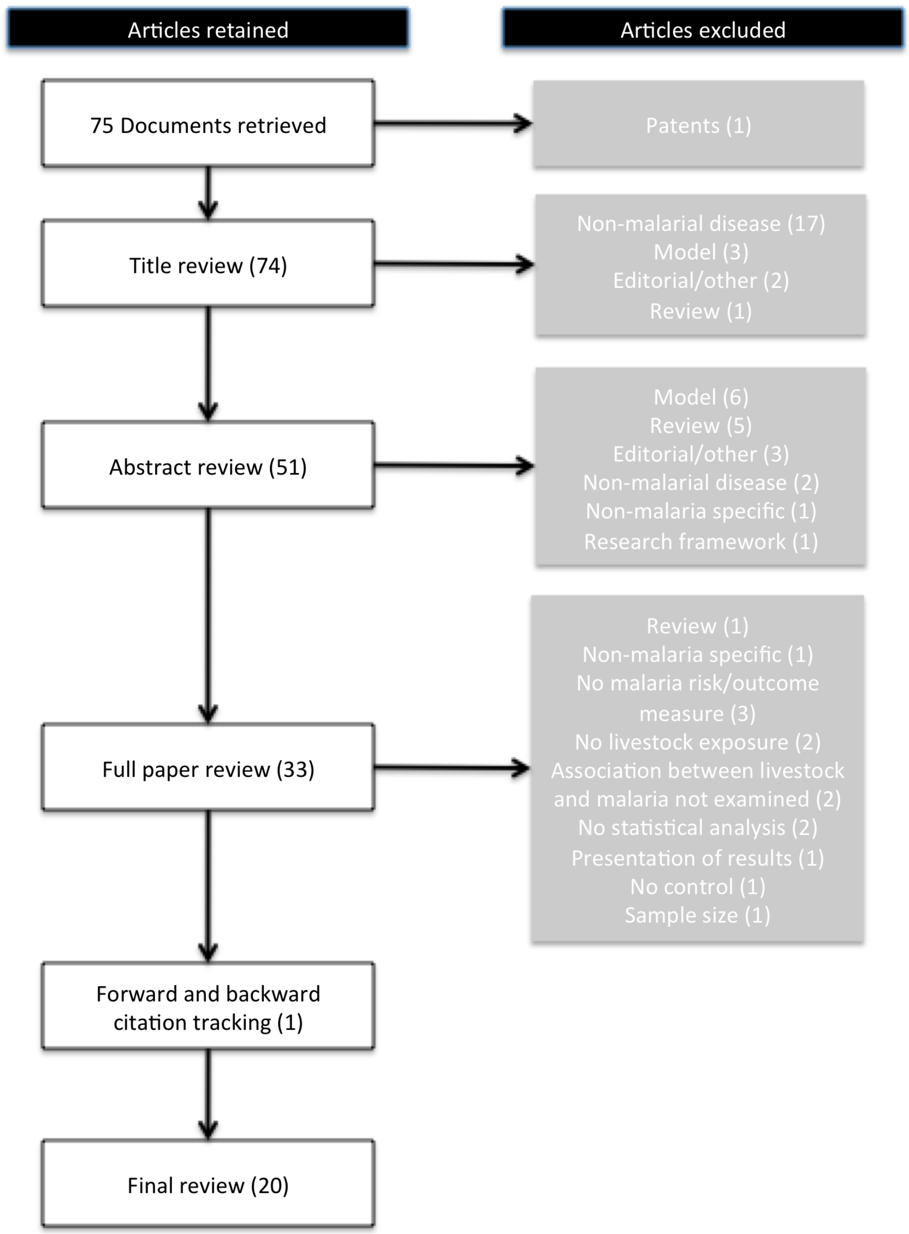


Figure 3.1 Systematic article selection process.

## 3.5 Results

*35.1 Study characteristics*

Twenty articles met inclusion criteria; 15 were observational studies and five were experimental (Table 3.3). Of the observational designs, there were 12 cross-sectional, two case-control, and one cohort design. The majority (16) of studies were conducted in sub-Saharan Africa (SSA), nine from East Africa, five from West Africa and two from southern Africa. The remaining four studies were carried out in Pakistan (2), Bolivia (1) and Lao PDR (1). Two articles reported on a single study conducted in The Gambia, although each article reports analysis of a different outcome (malaria infection *versus* mosquito feeding behaviour).

*3.5.2 Outcome measures*

Four studies measured parasitaemia as an outcome. Three articles defined parasitaemia by positive identification of the parasite by thick and thin blood smears and one used a positive result on a malaria rapid diagnostic test (RDT). One study used recurrent household-level malaria infection defined as two or more infections for two or more household members over nine screening events but did not report the screening method used. Four studies reported mosquito feeding behaviour as measured by human blood index, which is the proportion of blood meals taken on a human out of the total number of blood meals taken. Five studies used mosquito abundance or mosquito presence as their outcome measure and four studies measured host attraction either by human landing catches or human-baited traps. One study reported both human blood index and mosquito abundance as outcome measures and another used both human blood index and host attractiveness by human landing catch.

*3.5.3 Key determinants of zooprophylaxis and zoopotentiation*

Two main factors were consistently associated with zooprophylaxis and zoopotentiation: the predominant vector species present, and the location of livestock relative to humans, particularly during peak feeding times. Zooprophylaxis was considered to be dependent on the relative preference of mosquitoes for animal hosts (zoophily) in seven studies. Where the predominant mosquito species prefers human to animal hosts (anthropophily), and human hosts are available, keeping livestock nearby is unlikely to result in zooprophylaxis. Relative zoophily was reported as an important predictor of zooprophylaxis in five studies where multiple mosquito species were present. For example, *Anopheles gambiae* sensu stricto and *Anopheles funestus* were generally found to be anthropophilic compared to other species such as *Anopheles pharoensis* and *Anopheles arabiensis*, which were readily deferred from humans to feeding on livestock species (Bogh et al., 2001; Habtewold et al., 2004; Iwashita et al., 2014; Tirados et al., 2011).

In some cases, *An. arabiensis* were found to be opportunistic in their host choices, or were anthropophilic but exophagic (prefer to feed outdoors) and therefore would feed on animals if no humans were found outdoors (Tirados, Costantini, Gibson, & Torr, 2006). Many of the entomological studies (Bogh et al., 2001; Habtewold et al., 2001; Iwashita et al., 2014; Tirados et al., 2006) collected only indoor resting mosquitoes for the assessment of blood meals, which may bias samples towards endophilic (indoor resting) and endophagic (indoor feeding) species, which often tend to be anthropophilic (Hewitt et al., 1994). Mosquito species were not identified in the five studies that measured human malaria infection as the outcome.

Fourteen studies found that proximity or location of livestock relative to humans influenced malaria risk. When animals were housed inside at night, or in close proximity to sleeping rooms, malaria risk increased (Bogh et al., 2001; Bouma & Rowland, 1995; Ghebreyesus et al., 2000; Hadis, Lulu, Makonnen, & Asfaw, 1997; Hewitt et al., 1994; Iwashita et al., 2014; Palsson, Jaenson, Dias, Laugen, & Bjorkman, 2004). In contrast, when livestock were housed in separate shelters some distance away, malaria risk decreased (Mala et al., 2011; Tirados et al., 2006; Tirados et al., 2011). However, some studies failed to find an association between location of livestock and zooprophylaxis or zoopotentiation. For example, in Lao PDR, owning a cow doubled the risk of mosquito house entry but keeping livestock near or underneath the house at night had no effect (Hiscox et al., 2013). Similarly, a cohort study in The Gambia examined parasite prevalence in children sleeping within 20 m of the nearest cow compared to children sleeping at least 50 m from the nearest cow. No difference could be found in parasite prevalence between the groups when socioeconomic factors were taken into account. It should be noted, however, that other livestock, such as goats, donkeys and horses, were commonly found in participating households but were not included in the analysis (Bogh et al., 2002). While no study specifically tested the impact of keeping livestock at varying distances on malaria risk, Maia and colleagues were unable to detect an effect of cattle at a distance of 20 m on human landing catches of mosquitoes (Maia et al., 2012).

Relative abundance of livestock to humans, or high cattle: human ratio may influence the success of zooprophylaxis (Bogh et al., 2001; Sota & Mogi, 1989). Three studies carried out in the Rift Valley of southern Ethiopia, where *An. arabiensis* is the main malaria vector, examined the relationship between cattle: human ratio and malaria risk. Two of these studies found no association (Tirados et al., 2006; Tirados et al., 2011). The third study did not account for the effect of humans sleeping on raised platforms in trees above cattle to avoid mosquito bites (with high cattle: human ratio) compared to the other two sites where humans slept in traditional dwellings (with lower cattle: human ratio) (Habtewold et al., 2001).

*3.5.4 Influence of modifying variables*

Two contextual factors were shown to modify the association between malaria risk and livestock: the use of bed nets and socioeconomic status. The use of bed nets seems to be an effect modifying factor, preventing even highly anthropophilic species from feeding on humans, forcing them to feed on livestock as an alternative (Iwashita et al., 2014). While two studies found that bed nets had no impact on malaria infection (Bulterys, Mharakurwa, & Thuma, 2009; Hiscox et al., 2013), or mosquito house entry (Hiscox et al., 2013) and another reported that pig ownership remained a significant risk factor for positive RDT when bed nets were accounted for (Temu, Coleman, Abilio, & Kleinschmidt, 2012), six studies reported a relationship between bed nets and zooprophylaxis (Bogh et al., 2001; Bogh et al., 2002; Iwashita et al., 2014; Muriu et al., 2008; Mutero et al., 2004; Yamamoto, Louis, Sie, & Sauerborn, 2009). In two of these studies, the effect of zooprophylaxis was diminished or became non-significant when bed net use was controlled (Bogh et al., 2002; Yamamoto et al., 2009). Iwashita *et al*. (2014) reported that bed nets dramatically reduced human blood feeding in the presence of livestock. A study conducted within a rice irrigation scheme in Kenya suggested that the cause of lower prevalence of malaria in villages where irrigation took place (and where prevalence was expected to be high) was a result of preferential feeding on livestock (Muriu et al., 2008; Mutero et al., 2004). Bed net use was not measured in this study. Other work in the same location has suggested that bed net usage is promoted heavily in irrigated areas where malaria risk is known to be high (Muriu et al., 2008).

Socioeconomic status, measured as wealth or asset ownership was considered in four studies (Bogh et al., 2002; Ghebreyesus et al., 2000; Hiscox et al., 2013; Temu et al., 2012). One study identified a decrease in malaria prevalence with animal ownership, but controlling for wealth removed the effect of zooprophylaxis (Bogh et al., 2002). This study used a financial index based on livestock value to measure wealth and therefore collinearity might be expected between the presence of livestock and wealth. A second study noted that, in univariable analysis, sheep keeping was associated with decreased odds of infection with malaria while pig keeping was associated with increased odds of infection. When wealth was accounted for, the association with sheep ownership was no longer statistically significant while the relationship with pig ownership persisted (Temu et al., 2012). Ghebreyesus *et al*. (2000) included household radio ownership in multivariable analysis and found that livestock sleeping inside the house increased risk of incidence of infection in children. Hiscox *et al*. (2013) did not find that household television ownership was significantly associated with mosquito house entry in univariable analysis, and it was therefore not included in the multivariable analysis. Yamamoto *et al.* (2009) controlled for maternal education level, a robust and commonly used measure of socioeconomic status (Bollen, Glanville, & Stecklov, 2001), and found that the protective effect of donkeys, rabbits and pigs was removed when level of education and bed net use were controlled for. These studies and others (Mutero et al., 2004) emphasized the strong association between measures of socioeconomic status and malaria risk. This important association can confound the relationship between animal ownership and malaria prevalence given that animal ownership is a reflection of social standing. Socioeconomic status is likely an important unmeasured confounder affecting zooprophylaxis in the scientific evidence base.

## 3.6 Discussion

This systematic realist review points to three key findings regarding the context under which zooprophylaxis may be utilized as a component of IVM. First, zooprophylaxis is most likely to be effective when the mosquito species present do not have a strong preference for human hosts. Second, in order to take advantage of mosquito preference for animals, animals must be kept out of human sleeping quarters at night. There is evidence that even in the context of mosquito species with preference for animal hosts, close proximity to humans at night may result in zoopotentiation. Third, where bed nets are used, mosquitoes are more likely to feed on animal hosts as an alternative.

Proximity of livestock to humans at night has been identified as an important factor in zooprophylaxis (Hassanali, Nedorezov, & Sadykou, 2008). What remains unclear is the appropriate distance at which livestock should be kept in order to promote zooprophylaxis or prevent zoopotentiation. It is also unknown whether this distance differs between regions, species and contexts. Incidence rates of *Plasmodium vivax* were reduced in Sri Lankan households where cattle sheds were located within 70 m of the home when wealth, bed nets and other protective measures were considered; however, this effect was weak (RR = 0.70, 95% CI = 0.47-1.03) (van der Hoek, Konradsen, Dijkstra, Amerasinghe, & Amerasinghe, 1998). Current evidence supports the exclusion of animals from human dwellings at night, particularly where mosquito species are zoophilic. Improved estimation and precision around appropriate livestock proximities would benefit from the inclusion of livestock species, their number and location, and use of bed nets or other malaria prophylaxis in future studies.

Mosquito species characteristics were also identified as a key predictor of zooprophylaxis and zoopotentiation. Highly anthropophilic species were generally unaffected by the presence or absence of livestock whereas zoophilic and opportunistic species may be deterred from humans in the presence of alternative hosts. This is consistent with a model by Saul predicting that for vectors with a low human biting index, an increase in animal host density can significantly decrease disease transmission, while the same did not hold for weakly zoophilic species (Saul, 2003). Similarly, Franco *et al*. predict that in the presence of moderately zoophilic vectors, such as *An. arabiensis*, the introduction of livestock would increase malaria transmission except in two cases: 1) where vector carrying capacity has already been reached in the system and the addition of livestock hosts does not increase vector density; and, 2) where livestock density and availability are so great as to counteract the effect of increased vector density associated with the introduction of livestock (Franco, Gomes, Rowland, Coleman, & Davies, 2014).

With regard to the impact of bed nets, since the rate of disease transmission is dependent upon host species interaction, any intervention that decreases contact between host and vector will decrease the risk of infection (WHO, 2004). This has been corroborated by mathematical transmission models which find that while increased cattle density can decrease malaria transmission when sufficient animals are present and are housed separately, the most successful reduction transmission occurs when personal protective measures are also employed (Saul, 2003; Sota & Mogi, 1989). Where accessibility of humans relative to animals is decreased, it is predicted that malaria prevalence and number of bites will decrease (Franco et al., 2014; Saul, 2003). Time of biting and human behaviour may also have an impact on the effectiveness of bed nets. If people are outdoors during peak biting times, bed nets will not be protective against malaria for that portion of the evening (Maia et al., 2012).

Socioeconomic factors may be important unmeasured confounders in studies of zooprophylaxis. Risk factors for malaria are related to poverty through limited access to preventative measures such as bed nets, screened windows, closed roofing, and adequate health care (Worrall et al., 2005). Livestock ownership is also associated with increased socioeconomic status, especially among the rural poor (Kitalyi et al., 2005; Randolph et al., 2007; Upton, 2004). It has been suggested that in addition to zooprophylactic effects, livestock may be a confounder for reduced malaria risk as those who own livestock may also be able to afford preventative and treatment measures (Bogh et al., 2002) or have better overall health and nutritional status (Girard et al., 2012; Randolph et al., 2007). Households keeping animals indoors at night may represent those who are financially restricted from providing alternative livestock shelters, further complicating the inter-relationships between wealth and animal ownership in malaria transmission.

## 3.7 Conclusions

There is scientific evidence to support zooprophylaxis where the dominant vector is highly zoophilic and livestock are kept away from human sleeping quarters during peak vector activity. The use of protection such as bed nets may be complementary, and would be expected to reduce the measured effect of zooprophylaxis in empirical studies. Where vector preference is mixed, varied or unknown, or where the appropriate distance of livestock from sleeping quarters is in debate, there is insufficient evidence to support the use of zooprophylaxis, and some evidence to suggest the possibility of zoopotentiation. Research in three priority areas is required for clearer evidence of contexts to maximize the likelihood of zooprophylaxis occurring and minimize the likelihood of zoopotentiation: 1) estimation of the distance threshold and conditions whereby processes of zoopotentiation transition to zooprophylaxis for specific livestock host and mosquito vector species combinations; 2) consideration of the preference of species to feed indoors *versus* outdoors in entomologic studies in order to accurately assess mosquito host preferences; and, 3) inclusion of socioeconomic factors and the use of other prophylactic measures as key covariates in empirical research assessing zooprophylaxis and zoopotentiation. These research priorities may aid in the development of guidelines for the use of zooprophylaxis as a malaria control intervention for agricultural extension agencies who may wish to make livestock management recommendations, such as the optimal placement of livestock shelters with respect to human sleeping quarters. Zooprophylaxis has the potential to contribute to IVM strategies due to its non-chemical nature, optimal combination with bed nets, potential social desirability, and minimal financial requirements. It will require interdisciplinary collaboration between agricultural extension officers, veterinarians and health care professionals with ongoing monitoring of efficacy.

Table 3.3 Summary of reviewed articles.

| **Author, date** | **Geographic location** | **Sample** | **Findings** | **Accounted for bed net?** | **Accounted for socioeconomic factors?** | **Predominant mosquito species and characteristics (as reported by authors)** | **Animal-related variable** | **Effect** |
|---|---|---|---|---|---|---|---|---|
| Bogh *et al.* (Bogh et al., 2001) | The Gambia | 102 pairs of children | *An. gambiae* s.s. and *An. melas*: no difference in HBI between cattle and non-cattle group. *An. arabiensis* reduction of HBI by 30% in presence of cattle. There was no significant difference in sporozoite rate of all mosquito species in cattle compounds (0.97%) compared to non-cattle compounds (1.28%). | Yes | No | *An. gambiae* s.s. (72%), *An. arabiensis* (10%) - relatively zoophilic, *An. melas* (18%) - relatively zoophilic | Cattle present: children sleeping <20 m from at least one cow *vs* cattle absent: children sleeping >50 m from nearest cow (other livestock present but not considered) | Zooprophylaxis (*An. arabiensis*), none (*An. gambiae* s.s. and *An. melas*) |
| Bogh *et al.* (Bogh et al., 2002) | The Gambia | 102 pairs of children | No difference in parasite prevalence odds ratio between cattle and non-cattle group after adjusting for wealth. Adjusted OR=1.69 (CI=0.67-4.24), p=0.26. | Yes | Yes | As above | As above | None |
| Bouma and Rowland (Bouma & Rowland, 1995) | Pakistan | 2042 slides examined over two years | Higher parasite prevalence in children from households owning cattle (15.2%) than children without (9.5%) Mantel-Haenszel $\chi^2 = 9.6$, $p < 0.005$. The mean parasite rates and prevalence of cattle keeping were positively correlated for seven villages (r=0.79, p=0.036). | No | No | *Anopheles culicifaces* - zoophilic, *Anopheles stephensi* - zoophilic, *Anopheles subpictus* - zoophilic | Cattle or water buffalo kept within the household compound | Zoopotentiation |

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| Bulterys *et al*. (Bulterys et al., 2009) | Zambia | 34 case households, 27 control households | Cattle ownership was associated with reduced odds of recurrent malaria infection (adjusted OR=0.19, CI=0.05-0.69). Households with the most cattle, goats, dogs, or cats had reduced odds of recurrent infection (Adjusted OR=0.13, CI=0.03-0.56). | Yes | No | *An. arabiensis* - anthropophilic/opportunistic, *An. funestus* | Animal ownership (location not measured) | Zooprophylaxis |
| Ghebreyesus *et al*. (Ghebreyesus et al., 2000) | Ethiopia | 2114 children (<10 years) | Animals sleeping indoors increased the incidence rate ratio for malaria infection (adjusted RR=1.92, CI=1.29-2.85). Cattle ownership was not associated with malaria infection (1-2 cows: aRR=0.75, CI=0.39-1.45; 3-4 cows: aRR=1.18, CI=0.65-2.14; ≥5 cows: aRR=1.18, CI=0.64-2.17) nor was sheep and goat ownership (1-4 sheep/goats: aRR=0.93, CI=0.58-1.50; ≥5 sheep goats: aRR + 0.81, CI=0.54-1.22). | No | Yes | *An. arabiensis* | Cattle ownership, sheep and goat ownership, animals sleep inside house | Zoopotentiation for animals sleeping indoors. No effect for sheep/goat or cattle ownership. |
| Habtewold *et al*. (Habtewold et al., 2001) | Ethiopia | 278 mosquitoes | No significant difference in proportion of mosquitoes feeding on humans and livestock for people sleeping with livestock indoors (site B) *vs* livestock housed separately (site A). Higher proportion of mosquitoes feeding on cattle (93.7%) compared to humans (3.1%) for people sleeping on elevated platforms (site C) above livestock ($p < 0.05$). | No | No | *An. arabiensis* - moderately zoophilic | Humans sleep in traditional houses with cattle in separate enclosures (site A), humans sleep in houses with livestock sharing dwelling at night (site B), | Zooprophylaxis |

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| | | | Higher proportion of cattle feeding in site C (93.7%) *vs* sites A (42.7%) and B (54.7%) ($p < 0.001$). | | | | humans sleep in tree platforms above cattle (site C) | |
| Habtewold *et al.* (Habtewold et al., 2004) | Ethiopia | 18 study replications, total mosquito catch not reported | No effect of untreated ox on HBC for *An. arabiensis* but ox odour increased HBC (mean catch/person/night=22 without cattle odour, 32 with, $p < 0.05$). For *An. pharoensis* HBC was significantly reduced in the presence of untreated ox (catch/person/night=50 without and 26 with, $p < 0.01$) but increased in presence of cattle odour (catch/person/night=6 without and 18 with, $p < 0.001$). CIs included but graph printing obscures visualization for most values. | NA | NA | *An. arabiensis* - zoophilic, exophagic. Secondary vector: *An. pharoensis* | "Nearby" specific distance not reported | None (*An. arabiensis*), zooprophylaxis (*An. pharoensis*) |
| Hadis *et al.* (Hadis et al., 1997) | Ethiopia | 611 *An. arabiensis* mosquitoes | Mosquitoes collected from mixed human-livestock dwellings had significantly lower HBI (20.2%) than mosquitoes collected from human-only dwellings (91.5%) $p < 0.001$. | No | No | *An. arabiensis* | Human dwellings *vs* mixed human-cattle dwellings *vs* cattle sheds | Zooprophylaxis |
| Hewitt et al.[E] (Hewitt et al., 1994) | Pakistan | 643 anopheline mosquitoes | HLC increased in presence of a cow (38%, CI=8-68%), and two goats (50%, CI=16-84%). | NA | NA | *An. stephensi* - zoophilic | A cow or two goats tethered 6 m from male mosquito collectors. | Zoopotentiation |

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| Hiscox et al. (Hiscox et al., 2013) | Lao PDR | 879 anopheline mosquitoes | Cow ownership doubled the risk of anopheline house entry (IRR=2.32, CI=1.29-4.17, p =0.005). | Yes | Yes | *Anopheles philippinensis* | Ownership of chickens, ducks, pigs, cows, or buffaloes, and keeping large animals (pigs, cows, buffaloes below the house). | Zoopotentiation for cow ownership but no effect of owning any other animals or keeping large animals below the house. |
| Iwashita *et al*. (Iwashita et al., 2014) | Kenya | 104 houses, 1,664 anopheline mosquitoes | *An. arabiensis* abundance increased by 10% with each additional goat/sheep tethered around the house. (Exp (β)=1.10, β=0.10, p =0.02). The odds of human blood feeding were decreased 0.99 times by each goat or sheep tethered within 500 m of the household (Exp (β)=0.99, β=-0.01, p <0.01). | Yes | No | *An. arabiensis* - zoophilic, exophagic, *An. funestus* s.s. - anthropophilic, endophagic, *An. gambiae* s.s. anthropophagic, endophagic | Cattle or goats/sheep kept within 20 m of house | None (*An gambiae s.s., An funestus s.s*), zoopotentiation (*An arabiensis*) |
| Lardeux et al.[E] (Lardeux, Loayza, Bouchite, & Chavez, 2007) | Bolivia | 384 blood fed mosquitoes | *Anopheles pseudopunctipennis* preferred small ruminants (forage ratio=1.99, CI=1.80-2.19) to equids (1.95, CI=1.38-2.52) to humans (1.47, CI=1.25-1.69) to cows (1.15, CI=0.65-1.66) and avoided pigs (0.34, CI=0.20-0.48) and chickens (0.03, CI=0-0.75). | No | No | *An. pseudopunctipennis* - opportunistic | Various collection locations including outdoor traps and indoor resting collections | Zooprophylaxis |
| Maia *et al*. [E] (Maia et al., 2012) | Ghana | 1,017 anopheline mosquitoes | Presence of cattle reduced the number of *An. gambiae* s.s. for HLC by 66% (p <0.0001) but increased the density of *Anopheles ziemanni* (not statistically | NA | NA | *An. gambiae* s.s. - NA, *An. ziemanni* - zoophilic | Cattle inside 6x7 m experimental pen | Zooprophylaxis (*An gambiae* s.s) |

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| | | | significant). Cattle presence did not influence the HLC number from 20 m away. | | | | | |
| Mala *et al*. (Mala et al., 2011) | Kenya | 20 households, 417 mosquitoes | Odds of *An. arabiensis* occurrence decreased in presence of animals (OR=0.4, p =0.03) and odds decreased with increasing distance to animal shelters (OR=0.88, p <0.001). | No | No | *An. arabiensis* (66%), *An. funestus* (18%), *An. pharoensis* (15%) | Presence of animals, relative distance to animal sheds | Unclear |
| Mutero *et al.* (Mutero et al., 2004) | Kenya | 420 households | Low malaria prevalence in irrigated villages compared to irrigated villages (p <0.05) seems to be associated with preference for cattle feeding by *An. arabiensis* in the irrigated villages. | No | No | *An. arabiensis*- zoophilic | Mean tropical livestock units per village | Zooprophylaxis |
| Palsson *et al.* (Palsson et al., 2004) | Guinea Bissau | 30 households | Presence of pigs indoors associated with increased mosquito abundance ($\chi^2$=17.63, p <0.001) but the presence of goats was not (abundance ($\chi^2$=1.08, p <0.30). Goats were relatively uncommon compared to pigs (relative prevalence of livestock not reported). | No | No | *An. gambiae* s.l. (*An. gambiae* s.s. most abundant) | Presence of pigs or goats inside the house | Zoopotentiation |
| Temu *et al.* (Temu et al., 2012) | Mozambique | 8,338 children from 2748 households | Pig keeping associated with increased odds of malaria infection (OR=3.2, CI=2.1-4.9). | Yes | Yes | *An. gambiae* s.s. - anthropophilic, *An. funestus* - anthropophilic | Children living in households with chickens, goats, sheep, cows, pigs. | Zoopotentiation |
| Tirados *et al.* (Tirados et al., 2006) | Ethiopia | 63, 194 mosquitoes | HLC caught significantly more mosquitoes (163 mosquitoes/trap/night) than CBT (26 mosquitoes/trap/night, | NA | NA | *An. arabiensis* - anthropophilic, exophagic | Cattle: human ratio 0.6:1 *vs* 17:1. | Zoopotentiation |

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|---|---|---|---|---|---|---|---|---|
| | | | F=35.9, p <0.001) outdoors in areas of high cattle: human ratio compared to areas of low cattle: human ratio (HLC=3.1, CBT=2.1, no significant difference reported). | | | | | |
| Tirados *et al.* [E] (Tirados et al., 2011) | Ethiopia | Not reported | Outdoor HLC of *An. arabiensis* was not affected by the presence of a surrounding cattle ring, while the presence of a surrounding cattle ring reduced the outdoor HLC for *An. pharoensis* by 44% (p <0.05). The indoor HLC did not differ from outdoors, for either vector species. The indoor HLC decreased by 49% (p <0.01) in presence of cattle ring for *An. arabiensis.* The catch of *An. arabiensis* in HBT was 25 times greater than in CBT (p <0.001) whereas, for *An. pharoens*is there was no significant difference. HBT and CBT catches were unaffected by a ring of cattle for either vector species. | NA | NA | *An. arabiensis* - opportunistic, exophagic | Presence of a ring of 20 cattle surrounding the place where a person was (either outside or inside hut) | Zooprophylaxis |
| Yamamoto *et al.* (Yamamoto et al., 2009) | Burkina Faso | 117 cases, 221 controls (women and children <9 years) | In univariable analyses, keeping donkeys (OR=0.59, CI=0.34-1.01), rabbits (OR=0.52, CI=0.25-1.09), and pigs (0.26, CI=0.07-0.89) within the compound had a significantly protective effect at the p <0.20 level. While no effect was found | Yes | Yes[#] | *An. gambiae, An. funestus, An. arabiensis* | Animals kept in compound | None |

for cows (OR=0.84, CI=0.45-1.54), sheep (OR=0.84, CI=0.51-1.37), goats (OR=0.08, CI=0.60-1.93), or poultry (OR=1.14, CI=0.68-1.90). No difference between malaria cases and controls associated with animal ownership after adjusting for bed net use and level of education (odds ratio of multivariate analysis not reported).

NA – not applicable due to nature of study design, HBI - human blood index, OBET - odor baited entry trap, PSC - pyrethrum spray catch, HLC human landing catch, HBT/CBT - human/cattle baited trap, [E] – experimental design, observational design if not otherwise stated, [#] - controlled for education level, OR = odds ratio, aRR = adjusted rate ratio, CI = 95% confidence interval.

# Chapter Four: *Plasmodium falciparum* malaria parasitemia among Indigenous Batwa and non-Indigenous communities of Kanungu District, Uganda

## 4.1 Overview

In this chapter, I address the second objective of this dissertation, to determine the prevalence of malaria in the Batwa and non-Batwa of Kanungu and identify modifiable risk factors for infection including livestock ownership. This objective was achieved using a cross-sectional analysis of health survey data that included malaria infection status and household and individual risk factors. As such, this study contributes to the Indigenous health and malaria literatures. Chapter three identified that livestock have the potential to reduce human malaria risk under a specific set of conditions, namely where mosquito species are not strongly anthropophilic, and where livestock are kept away from human sleeping quarters at night. It also identified the use of bed nets and socioeconomic status as risk modifying and counfounding factors, respectively. This manuscript builds upon those findings, incorporating a test for zooprophylaxis among livestock keeping Batwa and non-Batwa, contributing to the literature on zooprophylaxis. This manuscript has been published in *Malaria Journal*:

Donnelly, B., Berrang-Ford, L., Labbé, J., Twesigomwe, S., Lwasa, S., Namanya, D.B., Harper, S., Kulkarni, M., Ross, N.A., IHACC Research Group, Michel, P. (2016). *Plasmodium falciparum* malaria parasitemia among Indigenous Batwa and non-Indigenous communities of Kanungu District, Uganda. *Malaria Journal*, *15:254.*

## 4.2 Abstract

Background: The Indigenous Batwa of southwestern Uganda are among the most highly impoverished populations in Uganda, yet there is negligible research on the prevalence of malaria in this population. *Plasmodium falciparum* malaria parasitemia prevalence was estimated in an Indigenous Batwa and a non-Indigenous neighbouring population, and an exploration of modifiable risk factors was carried out to identify potential entry points for intervention. Additionally, evidence of zooprophylaxis was assessed; hypothesizing that livestock ownership may play a role in malaria risk.

Methods: Two cross-sectional surveys of Batwa and non-Batwa communities were carried out in Kanungu District, Uganda in July 2013 and April 2014 based on a census of adult Batwa and a two-stage systematic random sample of adult non-Batwa in ten Local Councils where Batwa settlements are located. A community-based questionnaire and antigen rapid diagnostic tests for *Plasmodium falciparum* were carried out in the cross-sectional health surveys. A multivariable logistic regression model was built to identify risk factors associated with positive malaria diagnostic test. A subset analysis of livestock owners tested for zooprophylaxis.

Results: Batwa experienced higher prevalence of malaria parasitemia than non-Batwa (9.35% versus 4.45%, respectively) with over twice the odds of infection (OR 2.21, 95% CI 1.23-3.98). Extreme poverty (OR 1.96, 95% CI 0.98-3.94) and having an iron sheet roof (OR 2.54, 95% CI 0.96-6.72) increased the odds of infection. Controlling for ethnicity, wealth, and bed net ownership, keeping animals inside the home at night decreased the odds of parasitemia among livestock owners (OR 0.29, 95% CI 0.09-0.94).

Conclusion: A health disparity exists between Indigenous Batwa and non-Indigenous community members with Batwa having higher prevalence of malaria relative to non-Batwa. Poverty was associated with increased odds of malaria infection for both groups. Findings suggest that open eaves and gaps in housing materials associated with iron sheet roofing represent a modifiable risk factor for malaria, and may facilitate mosquito house entry; although, larger sample sizes will be required to confirm this finding. Evidence for possible zooprophylaxis was observed in this population for those who sheltered animals inside the home at night.

## 4.3 Background

There are renewed calls for malaria eradication with a focus on Africa (Norheim et al., 2015; Snow, 2015). Malaria mortality rates are decreasing in many populations, with global incidence having fallen by approximately 30% since 2003 to 165 million new cases in 2013 (Murray et al., 2014). Despite these gains, malaria remains a major global disease burden, with over 850,000 deaths annually (Murray et al., 2014; Stratton, O'Neill, Kruk, & Bell, 2008).

The elimination of malaria from many western nations has been attributed primarily to social and economic development allowing for screening of windows and doors, destruction of vector breeding sites, and rapid diagnosis and treatment (Breman, 2001). The feasibility of *Plasmodium falciparum* malaria elimination in most of sub-Saharan Africa is low, with Uganda being among the countries with lowest feasibility (Tatem et al., 2010). Sub-Saharan African countries are disproportionately affected by malaria (Murray et al., 2014) due to the presence of highly competent mosquito vectors, widespread poverty, limited infrastructure, and overburdened health systems (Wielgosz, Kato, & Ringler, 2014; Yeka et al., 2012). Those living in extreme poverty are most vulnerable to infectious diseases (Bates et al., 2004), yet within-country disparities are often ignored (Bates et al., 2004; Lawson et al., 2014). African Indigenous populations in particular have consistently poorer health outcomes than their non-Indigenous counterparts (Ohenjo et al., 2006). Social determinants of Indigenous health include, but are not limited to, poverty, discrimination, limited access to health care, and loss of traditional lands (Nettleton et al., 2007). Indigenous and ethnic minority populations elsewhere experience higher rates of malaria, which have been attributed to relative impoverishment, marginalization, and geographic remoteness (Abe et al., 2009; Achidi et al., 2012; Garnelo et al., 2005; Haque et al., 2011; Hotez, Woc-Colburn, & Bottazzi, 2014). In some cases, genetic variations have been identified as drivers of ethnic differences in malaria parasitemia and immunological response (Bolad et al., 2005).

Risk factors for malaria can be conceptualized as non-modifiable and modifiable. Non-modifiable factors such as age and sex have been inconsistently associated with higher malaria risk. In endemic areas, children under 5 years of age have high risk of malaria due to their immunological naïveté (Bates et al., 2004; Kleinschmidt & Sharp, 2001; Pullan, Bukirwa, Staedke, Snow, & Brooker, 2010). Beyond this, the relationship between age and malaria in adults is less clear (T. Smith, Genton, Betuela, Rare, & Alpers, 2002). It is known that regular exposure to malaria results in a functional immunity to the disease which quickly wanes in the absence of exposure. Excluding immunologically-suppressed pregnant women, sex-related variations in malaria risk are generally linked to gender-role and occupational exposures (Bradley et al., 2013; Lewnard et al., 2014). Women in roles as household water-collectors may spend more time near mosquito breeding sites. Men with forest-related jobs may spend their time in mosquito-dense areas (Bates et al., 2004; Lewnard et al., 2014).

Modifiable risk factors include environmental conditions and human behaviour. Local vector ecology, including the locations of swamps, forests, rice paddies where vectors breed, and the proximity of these sites to human habitations may bring humans into frequent contact with mosquitoes (T. D. Clark et al., 2008; Ghebreyesus et al., 2000; Mutero et al., 2004). Housing conditions may also affect transmission. Open eaves and windows, for example, may permit mosquito entry into sleeping quarters (Ghebreyesus et al., 2000; Hiscox et al., 2013; Temu et al., 2012). Education and wealth are known to be protective against malaria. Understanding malaria transmission and prevention may result in behaviours such as staying indoors during peak vector activity, and having access to preventive strategies that may reduce exposure of humans to vectors (T. D. Clark et al., 2008; Rickard et al., 2011). Many of these risk factors are mediated by poverty whereby access to building materials and bed nets may be dependent upon income (Bogh et al., 2002; Muriu et al., 2008; Worrall et al., 2005). Poverty has been described as a key modifiable determinant of malaria burden (Breman, 2001).

Livestock are routinely included in analyses of risk factors for malaria infection, yet their role in malaria transmission is not well understood. Livestock are dead-end hosts for human-infectious *Plasmodium* parasites and may reduce human malaria risk by drawing vectors away from humans (zooprophylaxis) (WHO, 1980, 1982, 2001). In some cases, however, livestock act as additional blood meal sources, and they may alter vector longevity and population density to increase human malaria risk (zoopotentiation) (Bouma & Rowland, 1995; Saul, 2003). Empirical research exploring the association between livestock and malaria risk has been complicated by the confounding role of wealth (Donnelly, Berrang-Ford, Ross, & Michel, 2015). Livestock symbolize social standing, provide food and services, and act as an asset to be sold in times of financial need (Alary et al., 2011; Kitalyi et al., 2005; McDermott, Randolph, & Staal, 1999; Randolph et al., 2007; Upton, 2004). Both livestock and wealth are generally associated with lower malaria prevalence. Given efforts to include zooprophylaxis in integrated vector control programs, there have been calls for further research to understand the impact of livestock on malaria transmission (Donnelly et al., 2015).

The Ugandan Batwa are an Indigenous population with life expectancy and child mortality rates significantly worse than national averages (Berrang-Ford et al., 2012). There remain considerable gaps regarding our understanding of Batwa health; to our knowledge only two peer-reviewed studies currently report the prevalence and risk factors of health outcomes for Batwa in Uganda (S. Clark et al., 2015; Lewnard et al., 2014). While literature on Batwa livelihoods is currently limited, it is thought that Batwa engage in livestock livelihoods at a much lower rate than non-Batwa due to financial restrictions, in addition to their historical hunter-gatherer culture. Further, Namanya (2013) identified consistent differences across risk factors for malaria, including housing and education between Batwa and non-Batwa.

The aims of this paper were: 1) to estimate malaria prevalence in Indigenous Batwa of Kanungu District and compare this with their non-Indigenous neighbours; 2) explore modifiable risk factors for malaria parasitemia in order to identify potential entry points for intervention to reduce malaria prevalence in this study population; and, 3) to test the hypothesis of zooprophylaxis in a sub-set of livestock owners.

## 4.4 Methods

### *4.4.1 Study population*

Kanungu District is located in southwestern Uganda bordering the Democratic Republic of Congo to the west. It contains part of the Bwindi Impenetrable National Park (Bwindi) (Barasa, Egeru, Okello, & Mutuzo, 2010) and has a population of approximately 250,000, 80% of whom live in rural settlements (UBOS, 2014). The majority of the population are of Bakiga ethnicity (Berrang-Ford et al., 2012; Tabuti, Kukunda, Kaweesi, & Kasilo, 2012). The non-Batwa (non-Indigenous populations, including Bakiga) rely mainly on subsistence farming consisting of cash- and food-cropping, and small-scale livestock holdings (Barasa et al., 2010; Tabuti et al., 2012), but tourism centred around gorilla trekking in Bwindi also provides local employment (Berrang-Ford et al., 2012). The Indigenous Batwa population of Kanungu District is approximately 900 (BCH, 2010). The Batwa were evicted from their lands in Bwindi in 1991 and have since had to replace their traditional hunter-gather livelihoods with settled agriculture (Berrang-Ford et al., 2012). Kanungu District is remote and has limited infrastructure and service delivery (Tabuti et al., 2012). It receives rainfall throughout the year, with two dryer seasons from December to February and from June to July. Malaria in Kanungu is characterized by low transmission intensity and low endemicity (Bukirwa et al., 2009; Lewnard et al., 2014; Okiro et al., 2011; Yeka et al., 2012).

#### *4.4.2 Study design and sample*

Two cross-sectional, in-person surveys were administered in July 2013 and April 2014 in the 10 Local Councils (LCs, the smallest government administration unit in Uganda) within the subcounties of Kayantorogo, Kayonza, Kirima, Mpungu and Butogota Town Council containing 10 Batwa settlements (Figure 4.1). Considering the small total population size of the Kanungu Batwa population, a census of all adult Batwa present (> 18 years) was attempted. A two-step proportional systematic random-sample of adult non-Batwa was conducted, whereby one adult was sampled from each selected household. This represented approximately 40% of non-Batwa households in each LC. Sampling frames were provided by Batwa settlement and non-Batwa Local Council 1 (LC1) chairpersons. Our sampling strategy consisted of the following: The LC1 chairperson randomly selected a number between 1 and 10 as the first household to be selected from the sampling frame. We then selected every $n^{th}$ household based on the interval required to obtain a 40% sample. For the second stage, the LC1 chairperson conducted a census of all adults living in the selected households from stage 1. The LC1 chairperson selected the adult to be sampled out of a hat based on the census of adults in those households. The same individuals were interviewed in July and April.

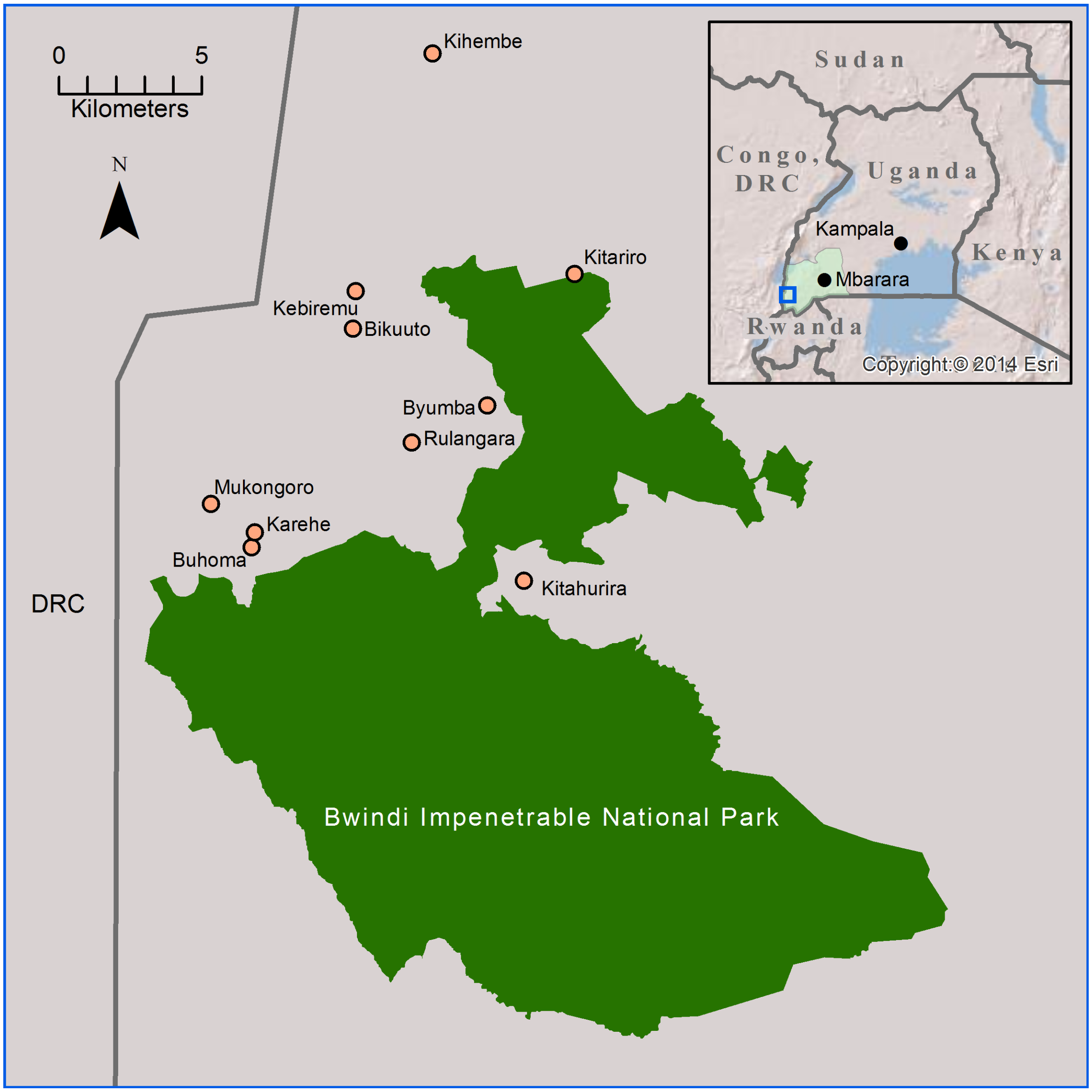


Figure 4.1. Kanungu District Batwa settlements surrounding Bwindi Impenetrable National Park, Uganda. Map created and edited by Adam Bonnycastle and Lea Berrang Ford.

### *4.4.3 Data collection*

*P. falciparum* is the primary cause of malaria in this region (Yeka et al., 2012). Parasitemia (our outcome variable) was classified as a positive result on *CareStart*™ malaria rapid diagnostic test (RDT) detecting histidine-rich protein 2 (HRP2) of *P. falciparum* (Access Bio, Inc. New Jersey, USA) at either the July or April data collections (Abba et al., 2011). The RDT has a sensitivity of 98% and specificity of 97.5% (Three Disease Fund, n.d.). Having a positive test result at either collection period was defined as "RDT ever" while a negative outcome at both collection periods was defined as "RDT never".

At each survey (July and April), participants were interviewed in Rukiga (the local language for both Batwa and non-Batwa) by trained local survey administrators. The survey consisted of three parts: 1) an individual-level health questionnaire, 2) a household questionnaire and 3) a malaria RDT administered by a community health nurse. Part one (individual questionnaire) collected information pertaining to demographics and personal information, health and risk behaviour, and livelihoods. Part two (household questionnaire) collected information on household structure, housing materials, assets, water, and sanitation (Appendix 2). For Batwa, each individual completed parts one and three, with the household head completing part two. The individual questionnaires were later matched to the household questionnaires. For non-Batwa, each individual completed all components. Data were collected in hard copy and entered into Microsoft Excel (Microsoft Corp, USA).

### *4.4.4 Ethics*

This study was designed using a community-based participatory research approach and was approved by the Research Ethics Boards at McGill University and the University of Guelph. The study design is consistent with the Canadian Tri-Council's Policies and requirements of the Ethical Conduct of Research Involving Human Subjects. Informed consent was obtained verbally from all participants. This study is a part of the Indigenous Health Adaptation to Climate Change (IHACC) project, an international initiative with parallel field sites in the Canadian Arctic and Peruvian Amazon (www.ihacc.ca).

*4.4.5 Statistical analysis*

Malaria parasitemia prevalence and risk factors

A total of 649 questionnaires were carried out in July 2013 and 546 surveys were completed in April 2014. All questionnaires from July and April were pooled to create a single study population. This was done to: a) increase the sample size; b) achieve a prevalence reflective across seasons; and, c) account for the potential sporadic nature of infection and risk factors using only one point estimate in time. For individuals who were present for both the July and April surveys, and who were RDT negative at both times (n=709), the risk factor data from the July surveys were used as baseline. If an individual was present in July and April and was RDT positive at one time (n=49), we used data from the time at which they tested positive. If they were present at both July and April and positive at both times (n=1), the July data were used. The period prevalence was calculated by dividing the total number of positive cases by the total number of participants tested.

To identify risk factors associated with parasitemia, a series of univariable logistic regression models were constructed. Risk factors of interest were selected based on theorized relevance in the literature and data availability. Covariates included: age, sex, knowledge of malaria transmission (as reflected by knowing that one should avoid mosquito bites to prevent malaria), roofing material, bed net ownership, and wealth (Table 4.1). To measure wealth, a household-level asset-based wealth index was created using principal component analysis (Booysen, van der Berg, Burger, von Maltitz, & du Rand, 2008; S. Clark et al., 2015; Filmer & Pritchett, 2001). The variables included in the index were cell phone ownership, radio ownership, bicycle ownership, having a source of electricity, land ownership, receiving remittances, toilet type, and having access to hand washing facilities. The resultant component was categorized as a dichotomous variable representing the 50% least poor relative to the 50% poorest individuals. Livestock were not included in the wealth index as we were explicitly interested in evaluating their specific role in malaria transmission. Collinearity between risk factor variables was assessed using a Spearman's rank correlation coefficient with a cut-off of 60%. Where collinearity was identified, the variable with the strongest association with the outcome variable was retained. A multivariable logistic regression model was built, and a final, reduced multivariable model based on variables significant in either the univariable or multivariable model. A mixed-effects logistic regression model with random intercept was tested, but there was no evidence of clustering at the LC-level. Data were analysed using Stata v.11 (Stata Corp., USA).

Table 4.1. Variables relating to malaria risk factors for Batwa and non-Batwa communities in Kanungu District, Uganda.

| Construct | Description | Variable | Justification |
|---|---|---|---|
| *Dependent variable* | | | |
| Malaria parasitemia *(P. falciparum)* | Positive RDT July 2013<br>Positive RDT April 2014 | Dichotomous (Ever positive/Never positive) | RDTs are a widely accepted method of malaria detection and may outperform microscopy in some settings (Abeku et al., 2008; Hopkins et al., 2008; Murray et al., 2014; WHO, 2010) |
| *Independent variables* | | | |
| Ethnicity | Survey date | Dichotomous dummy variable (Batwa/Non-Batwa) | Indigenous populations and ethnic minorities have been identified in the literature as being more vulnerable to malaria (Abe et al., 2009; Achidi et al., 2012; Garnelo et al., 2005; Haque et al., 2011; Hotez et al., 2014) |
| Livestock ownership | Household ownership of animals (any) | Dichotomous (Yes/No) | Livestock have been associated with increases in malaria prevalence through zoopotentiation (Bouma & Rowland, 1995; Ghebreyesus et al., 2000), and decreases in prevalence through zooprophylaxis (Maia et al., 2012; Tirados et al., 2006; Tirados et al., 2011) and wealth (Muriu et al., 2008; Mutero et al., 2004) |
| *Control variables* | | | |
| <u>Individual-level</u> | | | |
| Sex | Observed sex of participant | Dichotomous (Male/Female) | Sex is associated with increased risk due to variations in exposure through livelihood or household activities (Bradley et al., 2013; Lewnard et al., 2014) |
| Age | Self-reported age of participant | Continuous (years) | Children, in areas of high transmission, are more vulnerable to infection than adults due to a lack of acquired immunity (Bates et al., 2004; Kleinschmidt & Sharp, 2001; Pullan et al., 2010) |
| Malaria-related knowledge | Question: What is the best way to prevent malaria? | Dichotomous dummy variable based on correct identification of avoiding mosquito bites. | Understanding malaria transmission is associated with preventive behaviours (Bates et al., 2004; De Beaudrap et al., 2011; Siri, 2014) |
| Bed net use | Question: Does | Dichotomous (Yes/No) | Insecticide treated and untreated |

| | | | |
|---|---|---|---|
| | your household own a mosquito net? | | bed nets are associated with significant reductions in malaria prevalence (De Beaudrap et al., 2011; Pullan et al., 2010; Siri, 2014) |
| <u>Household-level</u> | | | |
| Wealth | Question: Does your household have any of the following items? | Dichotomous dummy variable based on categorization of PCA of variables: cell phone, radio, bicycle, electricity, private latrine, hand washing facilities, remittance, land (lowest 50% of scores/highest 50% of scores) | Wealth is associated with access to malaria prevention and health care (Bates et al., 2004; De Beaudrap et al., 2011; Siri, 2014; Worrall et al., 2005) |
| House construction | Question: What is your roof made of? | Categorical (iron sheets/wood, thatch, banana fibre) | Wall materials, open eaves, and window coverings can facilitate vector entry into the home (Bradley et al., 2013; Hiscox et al., 2013; Temu et al., 2012) |
| Animals kept inside at night | Question: If you own animals, do your animals come into the house during the night? | Dichotomous dummy variable (Yes/No) | Zooprophylaxis/zoopotentiation may be determined by relative proximity of animals to human sleeping quarters (Hadis et al., 1997; Hewitt et al., 1994; Hiscox et al., 2013; Iwashita et al., 2014) |

<u>Zooprophylaxis</u>

A subset analysis of livestock owners assessed the impact of relative location of livestock to humans. The risk factor of interest was whether livestock were housed inside or outside of the home at night. This analysis controlled for bed net use and non-livestock wealth which have been proposed as potential confounding and effect modifying variables, respectively (Donnelly et al., 2015). Sensitivity analyses were used to assess the effect of housing specific livestock species (goats and chickens) inside the house on parasitemia. Although age and sex were not significant in the reduced multivariable model, sensitivity analysis also tested their potential effect on the final model.

## 4.5 Results

### *4.5.1 Batwa and non-Batwa demographics*

A total of 759 questionnaires were completed in July 2013 and April 2014, of which 59.10% (449) of participants were non-Batwa and 40.90% (310) Batwa (Table 4.2). Females were overrepresented in the study population compared to males, slightly more so among non-Batwa than among Batwa. Men were more likely than women to be employed or away finding work and therefore unavailable to participate. The population had an average age of 36.6 years with the Batwa being slightly younger on average than non-Batwa (34.9 years and 37.6 years, respectively, z 2.88, $p<0.01$). Educational attainment differed significantly between Indigenous and non-Indigenous with 73.21% of non-Batwa having any education compared to 41.78% of Batwa ($\chi^2$ 77.23, $p<0.01$). About 40% of adults were employed with no significant difference between groups ($\chi^2$ 0.39, $p=0.53$). 70.55% of Batwa were in the low wealth category compared to 38.07% of non-Batwa ($\chi^2$ 73.81, $p<0.01$). While there was no difference in the average number of household members between the two ethnic groups (non-Batwa 5.0 people/household, Batwa 5.16 people/household, p 0.73), Batwa experienced a greater level of crowding than non-Batwa (2.81 individuals/sleeping room and 2.54 individuals/sleeping room, respectively, z -2.75, $p<0.01$). Bed net ownership (60.09% non-Batwa *versus* 50.49% Batwa, $\chi^2$ 6.84 $p<0.01$) and use were greater among non-Batwa than Batwa (58.07% slept under a bed net the previous night and to 38.61% respectively, $\chi^2$ 27.32, $p<0.01$). Livestock ownership was consistently higher among non-Batwa than Batwa with over half of non-Batwa owning any livestock compared to 32.04% of Batwa ($\chi^2$ 35.68, $p<0.01$). Goats were the most frequently owned livestock among non-Batwa (41.22% and 16.13% owned goats respectively, $\chi^2$ 53.81, $p<0.01$) while Batwa most frequently owned chickens compared to other animals but still, at a lower frequency than non-Batwa (31.53% non-Batwa owned chickens compared to 18.71% Batwa, $\chi^2$ 15.49, $p<0.01$). Both Batwa and non-Batwa brought animals indoors at night, to protect against predation and theft (22.90% non-Batwa, 21.50% Batwa, $\chi^2$ 0.19, p 0.66).

#### *4.5.2 Malaria parasitemia prevalence and risk factors*

Of the 759 questionnaires completed in July 2013 and April 2014, 50 participants tested positive for *P. falciparum* antigen on RDT. One participant tested positive at both data collection events. Only the July data were considered for this participant, resulting in a total of 49 positive cases. Of the positive cases, 20 (40.82%) were non-Batwa and 29 (59.18%)

were Batwa. The parasite period prevalence was 4.45% and 9.35% for non-Batwa and Batwa respectively, thus the odds of a positive RDT result were 2.21 times higher for Batwa than for non-Batwa (95% CI 1.23-3.98).

Table 4.2. Demographics and parasitemia status of Batwa and non-Batwa of Kanungu District, Uganda, July 2013 and April 2014.

| Characteristic | Total surveyed participants | RDT never | RDT ever |
|---|---|---|---|
| | **n (%)** | **n (%)** | **n (%)** |
| *Individual characteristics* | | | |
| Sex | n=749 | n=701 | n=48 |
| Female | 452 (60.35) | 423 (60.34) | 29 (60.42) |
| Male | 297 (39.65) | 278 (39.66) | 19 (39.58) |
| Age | n=688 | n=654 | n=43 |
| Mean | 36.60 [95% CI 35.44-37.8] | 36.40 [95% CI 35.21-37.50] | 39.90 [95% CI 33.50-46.20] |
| Ethnic group | n=758 | n=709 | n=49 |
| Non-Batwa | 448 (59.10) | 428 (60.37) | 20 (40.82) |
| Batwa | 310 (40.90) | 281 (39.63) | 29 (59.18) |
| Malaria prevention knowledge (avoid bites) | n=755 | n=706 | n=49 |
| No | 588 (77.88) | 545 (77.20) | 43 (87.76) |
| Yes | 167 (22.12) | 161 (22.80) | 6 (12.24) |
| *Household characteristics* | | | |
| Roof type | n=752 | n=703 | n=49 |
| Metal/iron sheets | 621 (82.58) | 577 (82.08) | 44 (89.80) |
| Grass/thatch/ wood | 131 (17.42) | 126 (17.92) | 5 (10.20) |
| Own mosquito net | n=755 | n=706 | n=49 |
| No | 331 (43.84) | 306 (43.34) | 25 (51.02) |
| Yes | 424 (56.16) | 400 (56.66) | 24 (48.98) |
| Relative wealth | n=728 | n=680 | n=49 |
| Poorer 50% | 372 (51.1) | 338 (49.71) | 34 (70.83) |
| Wealthier 50% | 356 (48.9) | 342 (50.29) | 14 (29.17) |
| Livestock ownership | | | |
| Any livestock | n=753 | n=704 | n=49 |
| No | 414 (54.26) | 382 (54.26) | 32 (65.31) |
| Yes | 339 (45.02) | 322 (45.74) | 17 (34.69) |
| Chickens | n=754 | n=705 | n=49 |
| No | 556 (73.74) | 515 (73.05) | 41 (83.67) |
| Yes | 198 (26.26) | 190 (26.95) | 8 (16.33) |
| Goats | n=754 | n=705 | n=49 |
| No | 521 (69.1) | 479 (67.94) | 42 (85.71) |
| Yes | 233 (30.9) | 226 (32.06) | 7 (14.29) |
| Animals inside night | n=686 | n=637 | n=49 |
| Never/no animals | 533 (77.7) | 487 (76.45) | 46 (93.88) |
| Sometimes/often | 153 (22.3) | 150 (23.55) | 3 (6.12) |

Univariable Analyses

Among the non-modifiable risk factors evaluated, individuals over 50 years of age appeared to be at increased odds (OR 1.49, 95% CI 0.73-3.04) for malaria parasitemia (relative to younger individuals), although this result was not precise with wide confidence intervals (Table 4.3). Among modifiable risk factors for malaria, relative wealth had the strongest association with parasitemia. Relative poverty was associated with higher odds for parasitemia, having 2.48 times the odds compared to the wealthier individuals (95% CI 1.30-4.66). Not owning a bed net, and iron sheet roofing compared to thatched roofs increased the odds of parasitemia, although these estimates were imprecise. Not owning livestock (OR 1.59, 95% CI 0.87-2.91), and not understanding the importance of avoiding mosquito bites (OR 2.11, 95% CI 0.89-5.06) increased odds of positivity for malaria parasitemia; again, however, estimates were imprecise with wide confidence intervals.

Reduced multivariable model

In reduced multivariable analyses, Batwa ethnicity (OR 1.88, 95% CI 1.00-3.58), poverty (OR 1.96, 95% CI 0.98-3.94), and iron sheet roofing (OR 2.54, 95% CI 0.96-6.72) had increased odds of positive RDT.

There was no association between LC and parasitemia, nor was there a significant difference between models that controlled for clustering at the LC-level and those that did not. There was minimal difference in the fit of the model with and without random intercepts. The model results were not sensitive to survey date, and showed consistent results on the removal of ethnicity and/or wealth.

Table 4.3. Univariable and multivariable explanatory logistic regression analyses of malaria parasitemia for Batwa and non-Batwa of Kanungu District, Uganda, July 2013 and April 2014.

| **Risk factor** | **Univariable models**<br>**Unadjusted odds (OR [CI])§** | **Reduced Multivariable model**<br>**Adjusted odds (OR [CI]) §** |
|---|---|---|
| | | N=717 |
| Non-modifiable | | |
| Age | N=688 | |
| <50 years | Ref | |
| ≥50 years | 1.49 [0.73-3.04] | |
| Sex | N=749 | |
| Female | Ref | |
| Male | 0.99 [0.55-1.81] | |
| Ethnicity | N=758 | |
| Non-Batwa | Ref | Ref |
| Batwa | 2.21 [1.23-3.98] | 1.88 [1.00-3.58] |
| Modifiable | | |
| Relative wealth | N=728 | |
| Wealthier 50% | Ref | Ref |
| Poorer 50% | 2.48 [1.30-4.66] | 1.96 [0.98-3.94] |
| Bed net ownership | N=755 | |
| Yes | Ref | |
| No | 1.36 [0.76-2.43] | |
| Livestock ownership | N=753 | |
| Yes | Ref | Ref |
| No | 1.59 [0.87-2.91] | 1.44 [0.75-2.79] |
| House construction (roof) | N=752 | |
| Thatch | Ref | Ref |
| Iron sheets | 1.92 [0.75-4.94] | 2.54 [0.96-6.72] |
| Malaria knowledge (avoid mosquito bites) | N=755 | |
| Yes | Ref | Ref |
| No | 2.11 [0.89-5.06] | 1.92 [0.79-4.63] |

§Unadjusted odds represents the logistic regression model for each variable alone and the outcome of interest (RDT positivity). Adjusted odds is the odds ratio when all listed variables are included in the logistic regression model. These results are consistent on sensitivity analysis for survey date.

Zooprophylaxis

Amongst the 339 livestock owners, 17 individuals had a positive RDT outcome. Keeping animals inside the house at night was significantly protective against malaria (OR 0.29, 95% CI 0.09-0.94) in adjusted analyses (Table 4.4). The sample size was insufficient to disaggregate by livestock species (chickens and goats). Sensitivity analyses indicated consistency of results across species, as well as no effect on the results when adding age and/or sex in the model.

Table 4.4. Multivariable logistic regression analysis of malaria risk for Batwa and non-Batwa livestock owners (zooprophylaxis) in Kanungu District Uganda, July 2013 and April 2014.

| **Variables** | **Adjusted odds (OR [CI])** |
|---|---|
| | n=325 |
| *Variable of interest* | |
| Keep animals inside at night | |
| No | Ref |
| Yes | 0.29 [0.09-0.94] |
| *Control variables* | |
| Ethnicity | |
| Non-Batwa | Ref |
| Batwa | 1.79 [0.59-5.38] |
| Relative wealth | |
| Wealthier 50% | Ref |
| Poorer 50% | 3.39 [1.06-10.85] |
| Bed net ownership | |
| Yes | Ref |
| No | 0.88 [0.29-2.74] |

Adjusted odds is the odds ratio when all listed variables are included in the logistic regression model. These results are not sensitive to age and sex on sensitivity analysis.

## 4.6 Discussion

The period prevalence of *P. falciparum* parasitemia for July 2013 and April 2014 for adult Batwa was 9.35%, which is higher than the 4.1% rate previously reported for Batwa over the age of 5 years (Lewnard et al., 2014). A bed net distribution was carried out in November 2012, which could explain the low prevalence rate found previously in this population in January 2013 (S. Clark et al., 2016). These findings are consistent with parasite prevalence estimates for Kanungu District as being relatively low (10-40%

prevalence when including children) compared to other parts of Uganda (Okello et al., 2006; Yeka et al., 2012).

Ethnicity was associated with malaria parasitemia, with Batwa at higher risk. This is an important result given that we controlled for wealth and other theorized risk factors for parasitemia; there remains a residual effect of ethnicity beyond these factors. There are marked differences in livelihoods between the two populations that may be driving these results. Batwa are currently undergoing a transition as they adapt to life outside of the forest. This transition is reflected in the low levels of education and livestock ownership relative to non-Batwa. There may also be unmeasured genetic differences between these ethnic groups that influence malaria prevalence (Fortin, Stevenson, & Gros, 2002; Frodsham & Hill, 2004; Mackinnon et al., 2000; Mackinnon, Mwangi, Snow, Marsh, & Williams, 2005). For instance, ethnic differences in immune responses (Arama et al., 2011; Bolad et al., 2005) and lower susceptibility to malaria infection among ethnic minority Fulani tribes relative to sympatric ethnic groups in West Africa have been attributed to genetic differences at various loci (Israelsson et al., 2009; Maiga et al., 2014). We would expect, given their higher prevalence of infection, that Batwa mount a weaker immune response relative to non-Batwa in the face of exposure. Immunological studies would be required to test this hypothesis, but it is unclear how the results of such studies would lead to intervention strategies (Breman, 2001).

These results provide tentative indication that there may be important modifiable risks for malaria infection among Batwa and non-Batwa. Iron sheet roofing may play a role in malaria risk. House construction is an important risk factor for malaria infection (Kirby, West, Green, Jasseh, & Lindsay, 2008; Liu et al., 2014; Ogoma et al., 2010) and thatched houses have previously been related to higher malaria prevalence of inhabitants in other parts of sub-Saharan Africa (Temu et al., 2012) due to the propensity of mosquitoes to rest indoors (Ghebreyesus et al., 2000). However, a systematic review and meta-analysis on the effect of house construction on malaria found that modern roof materials (iron sheets, tiles) were not consistently associated with decreased odds of infection (Tusting et al., 2015). Thatched or wooden roofs may confer some protection to individuals relative to corrugated iron sheets. It is possible that the open eaves of iron sheet roofs facilitate mosquito house entry and thereby increase malaria risk. Open eaves and gaps in housing materials are frequently associated with higher rates of parasitemia (Bradley et al., 2013; Hiscox et al., 2013; Tusting et al., 2015). However, this result may be confounded by wealth. Among non-Batwa, iron sheet roofs are a reflection of wealth since they must be purchased at a high cost compared to thatch or banana fibre, which may be obtained at no cost from the surrounding environment. In contrast, iron sheet roofing is purchased for Batwa by a local NGO with priority given to the most impoverished families as identified by the community. A Ugandan study carried out in part in Kanungu District found that closed eaves and modern house construction were associated with significantly decreased Human Biting Rates and incidence rates of malaria in children when controlling for age, sex, and household wealth (Wanzirah et al., 2015). Further evaluation of the impact of house construction on malaria risk among Batwa may help to inform and improve these community development strategies.

The analysis of livestock owners suggested that when controlling for wealth and bed net use, keeping animals inside at night reduced the odds of malaria infection. Previous studies suggest that keeping animals indoors at night increases malaria risk where mosquitoes are zoophilic (Donnelly et al., 2015). Entomological studies in the region suggest that *Anopheles funestus* and *Anopheles gambiae* sensu lato are the predominant vector species (Okello et al., 2006). *An. funestus* tends towards anthropophily; however, *An. gambiae* s.l. consists of seven morphologically indistinguishable species (Besansky et al., 1994) of which the most important vectors may be more zoophilic, as with *An. arabiensis*, or anthropophilic, as with *An. gambiae* s.s. This finding might suggest that the predominant local species are anthropophilic and, in turn, that keeping animals indoors at night results in reduced malaria risk among livestock owners, however further entomological evaluation of local vector populations is required. The mechanism through which livestock infer protection against malaria remains poorly understood and its role in malaria transmission has been much contested (Bogh et al., 2001; Bogh et al., 2002; Bouma & Rowland, 1995; Charlwood, 2001; Saul, 2003; WHO, 1982). Livestock may draw mosquitoes away from humans, reducing their exposure to malaria (Maia et al., 2012; Tirados et al., 2011), or may provide an abundance of blood meals, increasing vector density and longevity (Bogh et al., 2001; Bogh et al., 2002; Bouma & Rowland, 1995). The zooprophylatic effect is, however, complicated by the relationship between livestock and wealth (Bogh et al., 2002; Donnelly et al., 2015). It is well recognized that livestock contribute significantly to household economies for the rural poor, including the most marginalized (Alary et al., 2011; Randolph et al., 2007; Upton, 2004). Wealthy community members in Kanungu are those with the greatest livestock and land holdings. The findings of this study are consistent with others showing that poverty is positively associated with malaria prevalence (Sachs & Malaney, 2002; Somi et al., 2007; Worrall et al., 2005).

The cross-sectional nature of this study limits the ability to infer causal relationships between the risk factors and malaria infection. Unemployed people who were available to be surveyed during data collection events were overrepresented in the sample. This may have reduced variation within the population and perhaps led to an underestimation of the importance of employment for malaria infection. Similarly, men were more likely to be working away, leading to an overrepresentation of women. Given that the role of sex in malaria risk remains unclear, it is difficult to predict the direction of this effect. The small sample size and number of cases limited statistical power to detect effect sizes. In highly vulnerable remote Indigenous populations, however, sample sizes are typically small and demographics frequently differ from non-Indigenous populations; lack of statistical power must be balanced with the importance of prioritizing research within vulnerable and at-risk sub-populations.

### 4.7 Conclusions

Indigenous Batwa in Kanungu District, Uganda experience a two-fold increase in malaria risk compared to their non-Indigenous neighbours. This inequitable burden mirrors health disparities experienced by Indigenous peoples worldwide. Tentative support for the role of housing construction and wealth in accounting for some of the risk differential was found. Investigation of roof construction and related vector entry may be a prudent follow-up measure given these results. High baseline poverty among both populations, but particularly among Batwa, will remain a major determinant of health inequity and transmission risk. The influence of livestock may be related to asset-based wealth and suggests that keeping livestock indoors at night may play a role in reducing human exposure to malaria in this setting. This evidence may support livestock-based interventions as both a poverty reduction strategy as well as a component of malaria vector control.

# Chapter Five: Livestock keeping for climate change adaptation among Ugandan Batwa

## 5.1 Overview

In this chapter, I address the third objective of this dissertation, and the overarching goal of this thesis, to characterize the potential of livestock to reduce climate change vulnerability of Batwa. The first and second manuscripts examined the association between livestock and malaria as a specific, climate-sensitive health outcome, and livestock's potential to reduce health burden. Research for the second manuscript highlighted significant differences in livestock ownership and health burden between ethnic groups and as such, non-Batwa were selected as a comparison group. Since we believe that non-Batwa may represent the future development trajectory of Batwa, non-Batwa coping and adaptation strategies in the present may provide insights into future strategies for Batwa. This is referred to as temporal analogy within the global environmental change literature. I apply principles of effectiveness, feasibility, sustainability, equity and potential for maladaptation to qualitative data to ascertain potential appropriateness of livestock keeping for Batwa. The study presented in this chapter contributes to the evidence base for climate change adaptation among Indigenous Ugandans and is intended for publication in the journal *Regional Environmental Change*.

Donnelly, B., Berrang-Ford, L., Labbé, J., Twesigomwe, S., Lwasa, S., Namanya, D., Ross, N., Harper, S., Ford, J., IHACC Research Team, Michel, P. (*In preparation*) Livestock livelihoods for climate change adaptation among Ugandan Batwa. *Regional Environmental Change.*

## 5.2 Abstract

Climate change is having, and will likely continue to have, significant effects on health. These impacts will be inequitably distributed among global populations. Livelihood diversification to include livestock offers one strategy for coping with climate variability and change. There is, however, a paucity of assessments of the potential contribution of livestock for climate change adaptation. The goal of this research was conduct an *a priori* assessment of the appropriateness of livestock keeping as an adaptation option among

Ugandan Batwa, an Indigenous population with no history of livestock keeping. We employed concurrent mixed-methods, including a quantitative survey, community mapping and semi-structured interviews, to compare Batwa to a non-Indigenous, livestock keeping population. We find that livestock have significant potential to increase resilience of Batwa to climate change through livelihood diversification, asset accumulation and poverty reduction, and social acceptability. Successful adoption and sustainability of livestock keeping is, however, constrained by barriers related to land availability, access to capital, and veterinary care. In order for Batwa to take advantage of this adaptation option and minimize potential risks, they will require training in animal husbandry, and improved access to sanitation. Despite its potential appropriateness as a strategy consistent with pro-poor vulnerability reduction and mainstreaming of adaptation with development needs, severe baseline impoverishment among Batwa constrains the feasibility of livestock keeping as an adaptation option. Our results highlight the challenge of ensuring that global adaptation financing benefits the world's most vulnerable populations, where high levels of poverty may present important barriers to uptake of adaptation investment. These results have implications for the equity of access to adaptation in a changing climate.

### 5.3 Introduction

Climatic change is affecting the health of global populations, and these effects are anticipated to worsen over time (McMichael et al., 2012; Watts et al., 2015). Rising temperatures and sea levels, extreme weather events, and changes in seasonality and precipitation will alter food and water security, disease patterns, and personal safety (Haines & Patz, 2004; McMichael et al., 2006; Watts et al., 2015). These effects, however, will not be evenly distributed. Individuals with pre-existing health conditions, and the severely impoverished are among those particularly susceptible to harm from climate change (Haines et al., 2014; Watts et al., 2015). Health adaptations to climate change are strategies that promote well-being, and reduce vulnerability by addressing the distal drivers of health (Campbell-Lendrum, Bertollini, Neira, Ebi, & McMichael, 2009; Hales, Kovats, Lloyd, & Campbell-Lendrum, 2014; Watts et al., 2015). In order for adaptation strategies to be effective — particularly in developing regions — they must be congruent with existing development strategies, such as poverty reduction, maternal and child health, education and gender equity enhancement (Adger et al., 2009; McCarthy, Canziani, Leary, Dokken, & White, 2001; McMichael, 2013; Ribot, 2011).

Livestock-related strategies have been used by rural households to cope with climate-related stress, yet there has been little research to assess the role of livestock keeping as an adaptation option (Alary et al., 2014; Berman et al., 2015; Kansiime, 2012; Mertz et al., 2011; Roncoli, Ingram, & Kirshen, 2001; Thornton et al., 2007). Uptake of livestock allows farmers to diversify livelihoods, thereby spreading risk over activities with varying climate-sensitivities (Thornton et al., 2007). Livestock are particularly attractive due to minimal requirements for inputs and land, relative climate-insensitivity compared to crops, and accessibility to both men and women (Anik & Khan, 2012; Arku, 2013; Goulden et al., 2013; Pouliotte et al., 2009). Livestock may represent a 'no regrets' or 'win-win' form of adaptation, meaning that they can have additional positive effects on health and development. Livestock play a key role in nutrition and food security, and provide a source of income, fertilizer, and fuel (Alary et al., 2011; Azzarri et al., 2015; Delgado et al., 2001; Herrero et al., 2013; McDowell & Hess, 2012; Murphy & Allen, 2003; Randolph et al., 2007; Scoones, 1992). Further, livestock play other important roles such as assets, insurance, and socio-cultural symbols of well-being (Alary et al., 2011; Blackwell, 2010; Bosman et al., 1997; Delgado et al., 2001; Doran et al., 1979; Hoddinott, 2006; Hoffmann, 2013; Kitalyi et al., 2005; Moll, 2005).

Indigenous populations globally are expected to be particularly vulnerable to climate change due to their history of social, economic, and political marginalization, current disease burdens, and reliance on and close relationship with the land (Berrang-Ford et al., 2012; Cunsolo Willox et al., 2012; Ford, 2012; Ford, Cunsolo Willox, et al., 2014; Harper, Edge, Cunsolo Willox, & Rigolet Inuit Community, 2012; Ohenjo et al., 2006). Climate change threatens to worsen inequalities as populations with limited access to social, economic, and political resources will be the least able to respond (McMichael et al., 2012). The Batwa (singular: Mutwa) of Kanungu District, Uganda, are an Indigenous population who currently experience health and socioeconomic disparities relative to their non-Indigenous neighbours (Berrang-Ford et al., 2012). These ethnic and social gradients in health among the Batwa are widely attributed to an historical context of forced relocation, discrimination, political marginalization, extreme poverty, and loss of traditional livelihoods (Berrang-Ford et al., 2012; S. Clark et al., 2015; Donnelly et al., 2016; Lewnard et al., 2014). Given the anticipated Ugandan climate change context of increasingly unpredictable and extreme rainfall, and higher temperatures (Hussein, 2011; Kansiime, 2012; Magrath, 2008; Namanya, 2009) and associated increases in crop failures, drought, vector-borne and diarrheal disease, Batwa health is expected to worsen (Berrang-Ford et al., 2012).

Herein, we adapted a set of criteria – guided by emerging literature theorizing key principles of successful adaptation – to assess livestock as a climate change adaptation option. We then applied these criteria to livestock keeping as an adaptation option among a highly impoverished Indigenous population with no history or tradition of livestock keeping: the Batwa of Kanungu District, Uganda. Given that few Batwa engage in livestock livelihoods and have no history of livestock keeping, we use the neighbouring non-Indigenous, livestock-keeping population as a comparison group to reflect the potential benefits, constraints, barriers, and experiences of livestock among the rural poor in the region. Our objectives included: 1) to characterize and compare existing livestock use among the Batwa and their non-Indigenous neighbours; and, 2) to assess livestock keeping as an adaptation option for Batwa.

The structure of this paper is as follows: first, we provide an overview of the criteria for evaluating livelihood adaptation options to promote resilience to climate change based on the climate change adaptation literature. Second, we present the methods used to collect the quantitative and qualitative data on livestock keeping in the study area. The results section contains two components. The first explores the role of livestock among Indigenous and non-Indigenous members of Kanungu District, using a combination of quantitative and qualitative data. Second, each of the criteria are applied to livestock, using guiding questions and a literature review to structure the results. In this way we seek to assess the appropriateness of livestock as an adaptation option for Batwa. Finally, these findings are contextualized within the broader climate change adaptation and livelihoods literatures.

## 5.4 Methods

### *5.4.1 Criteria for livelihood adaptation for resilience to climate change*

We adapted criteria for assessing livestock as an adaptation option to reduce vulnerability to climate change. These criteria are guided by two approaches that have been extensively applied in tandem to the study of climate change adaptation and livelihoods in developing country contexts: the vulnerability approach and sustainable livelihoods approaches (Alary et al., 2014; Badjeck, Allison, Halls, & Dulvy, 2010; Berman et al., 2015; Brockhaus, Djoudi, & Locatelli, 2013; Goulden et al., 2013; Joshi et al., 2013; McDowell & Hess, 2012; Paavola, 2008; Park, Howden, & Crimp, 2012; Pouliotte et al., 2009). We define vulnerability as susceptibility to damage or loss (Chambers, 1989, McCarthy et al, 2001) and emphasize that vulnerability is mediated by social, political, and economic factors, i.e., "contextual vulnerability" (Chambers & Conway, 1991; O'Brien et al., 2007). We view resilient livelihoods as those that reduce vulnerability through access to resources, and enable individuals, households, or communities to further engage in livelihood strategies through diversification, intensification, extensification, and migration (Scoones, 1998).

Drawing on existing vulnerability and sustainable livelihoods literature and theory, we outline five criteria to assess the appropriateness of livelihood adaptation options (Table 5.1): effectiveness, feasibility, sustainability, equity, and potential for maladaptation. Similar to the approach taken by Ford et al. (2014), guiding questions are utilized to support the decision making process. In order for the adaptation option to be considered appropriate, each criterion must be satisfied.

**Effectiveness** describes the potential for the adaptation option to reduce vulnerability or improve resilience to climate change (Adger, Arnell, & Tompkins, 2005; Kristie L Ebi & Burton, 2008). We consider the ability of livestock livelihoods or development interventions to provide social, economic, and health benefits regardless of climate change predictions (no-regrets adaptation) as contributing to effectiveness (Adger et al., 2005; de Bruin et al., 2009; Kristie L Ebi & Burton, 2008; Heltberg, Siegel, & Jorgensen, 2009; Smit & Pilifosova, 2001; J. B. Smith, 1997). Further, adaptation options should enhance the adaptive capacity of community members, improving their ability to engage in future adaptations through increased social cohesion, technical skills, learning, and empowerment (Fazey et al., 2010; Scoones, 1998). Effectiveness of an intervention may also be determined by its ability to diversify livelihoods and contribute to poverty reduction (Kelly & Adger, 2000; Scoones, 1998). **Feasibility** describes the potential barriers and facilitators to uptake of the adaptation option including technical, financial, social, and cultural acceptability (Adger et al., 2005; Kristie L Ebi & Burton, 2008; Fazey et al., 2010; Fussel, 2007; Smit & Pilifosova, 2001; J. B. Smith, 1997). We also assess consistency of the adaptation option with other policies and its potential to take advantage of current opportunities as a component of feasibility (Kristie L Ebi & Burton, 2008; Smit & Pilifosova, 2001). We define **sustainability** as self-sufficiency (Chambers & Conway, 1991) or the ability of the system to support and benefit from the adaptation option without external intervention. The **equity** of the adaptation option is examined through the accessibility of the option to all segments of the population, and the potential for some sub-sections of the population to be negatively affected or further marginalized (winners and losers) (Adger et al., 2005; Chambers & Conway, 1991). Finally, we examine the **potential for maladaptation**, that is, inadvertent negative health or environmental effects, or increased vulnerability (Adger et al., 2005; Kristie L Ebi & Burton, 2008; Fazey et al., 2010).

Table 5.1. Criteria for livelihood adaptation for resilience to climate change

| Criteria | Guiding questions | References |
|---|---|---|
| Effectiveness | Does the adaptation option facilitate income/livelihood diversification?<br>Is the adaptation option consistent with poverty reduction?<br>Does the adaptation option build adaptive capacity to take advantage of future adaptation options?<br>Does the adaptation option reduce vulnerability to shocks under a wide range of conditions (flexibility/no regrets)? | (Adger et al., 2005; Chambers & Conway, 1991; de Bruin et al., 2009; de Loe, Kreutzwiser, & Moraru, 2001; Fazey et al., 2010; Kelly & Adger, 2000; Scoones, 1998; Smit & Pilifosova, 2001; J. B. Smith, 1997) |
| Feasibility | Is the adaptation option constrained by institutional, sociocultural, financial, or technological barriers?<br>Is the adaptation option compatible with current policy?<br>Does the adaptation option target current areas of opportunity?<br>Is the adaptation option consistent with adaptation efforts in other sectors? | (Adger et al., 2005; de Loe et al., 2001; Kristie L Ebi & Burton, 2008; Fussel, 2007; Kelly & Adger, 2000; Smit & Pilifosova, 2001; J. B. Smith, 1997) |
| Sustainability | Does the adaptation option require sustained inputs from outside the system? | (Chambers & Conway, 1991) |
| Equity | Is the adaptation option available to all sub-groups of the population?<br>Will the vulnerability of some segments of the population be increased relative to others as a result of the adaptation option? | (Adger et al., 2005; Chambers & Conway, 1991; de Loe et al., 2001) |
| Potential for maladaptation | Does the adaptation option contribute to the drivers of climate change?<br>Are there negative health consequences of the adaptation option?<br>Are there negative environmental consequences of the adaptation option? | (Adger et al., 2005; de Loe et al., 2001; Fazey et al., 2010; Smit & Pilifosova, 2001) |

### *5.4.2 Study design*

This study took place within the Indigenous Health Adaptation to Climate Change (IHACC) project, with parallel study sites in the Peruvian Amazon and Canadian Arctic. The research program uses a community-based participatory research (CBPR) approach, working closely with partner communities (Ayers & Forsyth, 2009; K. L. Ebi & Semenza, 2008; Forsyth, 2013). The Batwa, as an Indigenous hunter-gatherer population, have no historic tradition of livestock keeping, yet have been forced to sedentarize, adapting to the agrarian and livestock traditions of their non-Indigenous neighbours. In order to evaluate the potential role of livestock to contribute to Batwa health, we sought to characterize and compare the Batwa to their non-Indigenous neighbouring population, who have a longstanding history of livestock keeping. The use of a comparative population or location as a lens to evaluate possible adaptation or impact scenarios is frequently used in the global environmental change literature, and is referred to as a temporal analogue approach (Ford et al., 2010). Qualitative and quantitative data were collected and analyzed concurrently to triangulate results and validate themes (Creswell & Plano Clark, 2007; Harper et al., 2015). Data collection was carried out in the 10 Local Councils (LCs, the smallest government administration unit in Uganda) containing both Batwa and non-Batwa settlements, within the subcounties of Kayantorogo, Kayonza, Kirima, Mpungu and Butogota Town Council. The study thus included the equivalent of 20 communities: 10 LCs containing Batwa settlements from which non-Batwa households were selected and the 10 Batwa settlements within the LCs.

*5.4.3 Study location and population*

Kanungu District is located in southwestern Uganda bordering the Democratic Republic of Congo to the west, Rukungiri District to the east, and Kabale and Kisoro Districts to the south. It contains part of Bwindi Impenetrable National Park (Bwindi) (Barasa et al., 2010) and has a total population of approximately 250,000 people, 80% of whom are located in rural areas (UBOS, 2014). The non-Batwa population is largely made up of the Bakiga ethnic group (Berrang-Ford et al., 2012; Tabuti et al., 2012). This population relies on subsistence farming consisting of cash- and food-cropping, and small-scale livestock holdings (Barasa et al., 2010; Labbé et al., 2015; Tabuti et al., 2012) but tourism centred on gorilla trekking in Bwindi also provides local employment (Berrang-Ford et al., 2012). Kanungu District is remote and as a result experiences limited infrastructure and service delivery (Tabuti et al., 2012).

The Batwa population of Kanungu District comprises approximately 750 people (BCH, 2010). The Batwa transition to settled agriculture has been hindered by a lack of compensation for loss of lands, and no prior experience with crop or livestock agriculture

(Patterson, Berrang-Ford, Lwasa, Namanya, Ford, Twebaze, et al., In review). Despite ongoing external support, significant health, social and economic gradients persist. The life expectancy among Batwa (28 years) is more than a decade below the national average, and child mortality rates are >3 times the regional rate and >4 times the national rate (Berrang-Ford et al., 2012) (Table 5.2). Rates of food insecurity (Patterson, Berrang-Ford, Lwasa, Namanya, Ford, & Harper, In review) and acute gastro-intestinal disease (S. Clark et al., 2015) are among the highest documented globally, and malaria prevalence is twice that of non-Batwa. While little is known about Batwa livelihoods, livestock have not played a significant role to date, likely due to financial barriers and their hunter-gatherer tradition (Berrang-Ford et al., 2012; Donnelly et al., 2016).

Table 5.2: Comparison of socioeconomic and health indicators for Ugandan Batwa relative to regional and national averages, adapted from (Berrang-Ford et al., 2012).

| **Indicator** | | **Batwa** | **Southwest Uganda [a]** | **Uganda** |
|---|---|---|---|---|
| Health | Life expectancy at birth (years) | 28[b] | n/a | 59[c] |
| | Child mortality (% under 5 years) | 38[b] | 12.8[d] | 9[d] |
| | Malaria parasitemia (% >18 years) | 9.4[f] | 4.5[f] | n/a |
| | HIV/AIDS (%) | 2.3[g] | 3.8[g] | 7.4[h] |
| Education | Adult literacy (% 15-49 years) | <10[i] | Women: 75.5<br>Men: 77.7[d] | Women: 64.2<br>Men: 77.5[d] |
| Income | GDP per capita (constant 2000 USD) | 160[j] | n/a | 696[k] |

[a] Kiruhura, Isingiro, Mbarara, Ibanda, Bushenyi, Ntungamo, Rukungiri, Kabale, Kisoro, and Kanungu Districts.
[b] as of 2000 (BDP, 2003), [c] As of 2013 (World Bank, 2015), [d] As of 2011 (UBOS, 2011), [e] -2 standard deviations weight-for-age, [f] for ten Local Councils in Kanungu District containing Batwa settlements (Donnelly et al., 2016) , [g] As of 2009 for Mpungu and Kayonza subcounties in Kanungu District (Birungi, 2010), [h] As of 2014 (UNAIDS, 2015), [i] As of 2012 (Berrang-Ford et al., 2012), [j] (Patterson, Berrang-Ford, Lwasa, Namanya, Ford, Twebaze, et al., In review), [k] As of 2014 (World Bank, 2015)

### *5.4.4 Comparative characterization of livestock use*

Quantitative data collection and analysis

A cross-sectional, in-person questionnaire was administered in the Batwa and non-Batwa communities in July 2013 (Table 5.3). The survey was administered by trained local surveyors (Appendix 2). Data were collected in hard copy and entered into Microsoft Excel (Microsoft Corp, USA).

*Analysis:* Descriptive statistics were used to summarize individual and household characteristics, including livestock ownership. We compared these characteristics between Batwa and non-Batwa communities using basic inferential statistics (chi square and Fisher's exact tests). Data were managed and analysed in Excel (Microsoft Office 2011) and Stata version 12 (StataCorp12).

Table 5.3: Description of data collection for concurrent mixed-methods analysis of livestock livelihoods in Kanugnu District, Uganda.

| Data collection method | Aim | Activity description | Participant description and sampling | Total |
|---|---|---|---|---|
| Survey | To estimate livestock ownership within Batwa and non-Batwa populations. | Part I (individual questionnaire): demographic and personal information, health and risk behaviour, and livelihoods. Part II (household questionnaire): household structure, housing materials, assets, water, and sanitation. | A census of adult Batwa (> 18 years) was attempted. Each Mutwa completed Part I, with the household head completing part two. Individual and household questionnaires were linked. A two-step proportional (40% of households per LC) systematic random sample of adult non-Batwa was conducted. One adult was sampled from each selected household (sampling frames provided by non-Batwa LC1 chairpersons). Each individual completed Parts I and II. Mean length = 30 min. Conducted in Rukiga [#] | 222 Batwa, 446 non-Batwa) |
| Community mapping | To identify important physical aspects of each community and their perceived impacts on health and well-being. | 1) Participants asked to draw a map of the important aspects of their community. Participants were offered their choice of flip chart paper and markers or items found in the environment to create representations (Mascarenhas & Kumar, 1991). 2) Participants invited to explain map components, reasons for its inclusion, and potential health impacts (Kesby, 2000). | All Batwa participants invited to volunteer for either mapping or CM SSI. Non-Batwa participants randomly sampled using sampling strategy above. Non-Batwa participants also self-selected to participate in either mapping of CM SSI activity. One male and one female mapping exercise was conducted in each Batwa settlement and non-Batwa LC for each of the 10 communities with five to ten participants per gender-and ethnicity-specific group. Mean length = 45 min. Conducted in Rukiga with simultaneous English interpretation [@]. | 39* |
| Key informant (KI) Semi-structured interview | To compare Batwa and non-Batwa livestock livelihoods, perceived benefits and challenges. | Participants asked to describe livelihood activities of Batwa and non-Batwa, compensation from livelihood activities, benefits and challenges of livestock livelihoods. | Sampled purposively from individuals working closely with Batwa and leaders within non-Batwa communities. Participants included BCH administrators, BDP staff, local government staff including public health and veterinary officials, and Batwa and non-Batwa chairpersons. Mean length = 60 min. Conducted in English or Rukiga with simultaneous English interpretation, based on participant preference [@]. | 41 |
| Community member (CM) semi-structured interview | To understand roles, and perceived benefits, challenges, and impacts of livestock on human health. | Participants asked to describe their livelihood activities and explain their benefits and challenges. We also explored perceived health challenges and their associated causes. | Sampling strategy as for mapping activity. Four male and four female individuals were invited to participate in each Batwa and non-Batwa settlement/LC. One Batwa settlement only had three male participants available for interview activity. Mean length = 30 min. Conducted in Rukiga with simultaneous English interpretation [@]. | 159 |

* Number of participants in Buhoma Batwa settlement prevented gender-specific grouping, [#] local language spoken by Batwa and non-Batwa. LC = Local council, [@] = audio recorded

Qualitative data collection and analysis

Two qualitative approaches were used to triangulate and characterize the role and perceived health impacts of livestock among Batwa and non-Batwa populations: community mapping, and semi-structured interviews (SSI) (Table 5.3). Two types of SSI were carried out: key informant interviews, and community member interviews. Qualitative data collection took place during July and August 2012 and June to August 2013.

*Community mapping:* Participatory, social, or community mapping is the visualization of cognitive spatial information about peoples' environments and their relationships to these environments (Cornwall & Jewkes, 1995; Herlihy & Knapp, 2003). They have been used in climate change adaptation and vulnerability research with Indigenous populations and are considered to enhance adaptive capacity through community empowerment (Eisner et al., 2012; Fu, Chen, Liu, & Ieee, 2007; Valdivia et al., 2010).

*Semi-structured interviews (SSI):* SSIs are employed to study individual experiences of structures and places (L. Brown & Durrheim, 2009; Kitchin & Tate, 2000). All interviews followed an interview guide, consisting of a series of key themes and open-ended questions (Dearnley, 2005; Dunn, 2010). To allow for participants to become comfortable with the interview context we utilized a pyramid structure where interviews began with 'easier' questions such as "what kinds of activities do you and your family do to make a living?" and increased in complexity as the interview progressed (Dunn, 2010).

*Analysis:* The English interpreted portions of the audio recordings were transcribed verbatim. Latent content analysis was used to extract themes and meanings from interview transcripts (Silverman, 2010). A set of *a priori* codes was created prior to the transcription process based on the research question. During the transcription and coding process, additional codes were added to capture repeating ideas of relevance to the research question. Transcripts were uploaded to qualitative data management software NVivo 10 (QSR International). Repeating ideas were grouped to create themes, and similar themes were grouped as constructs (Auerbach & Silverstein, 2003). The qualitative data were critically analyzed using the criteria for livelihood adaptation. A review of the adaptation, health, and livestock livelihoods literatures was used to contextualize the results, and answer questions beyond the local scale addressed by study participants.

The research team reflected on their positionality throughout the planning and data collection phases (Rose, 1997). Power dynamics undoubtedly played a role in the quality of data collected (Wallerstein, 1999). Quantitative questionnaires were administered by local students in the local language who thereby held a position of power relative to research participants. Qualitative data collection was carried out by two white, Canadian, female researchers with simultaneous interpretation by one male non-Mutwa and one female Mutwa research assistant who also held relative positions of power compared to participants. For all qualitative activities, male participants worked with the male research assistant and females with the female research assistant. The impoverishment of the region may have resulted in interviewer bias among participants. We believe that the greater number of participants present during group discussions, combined with a focus on making and discussing the map, rather than the individual, contributed to a balancing of power and an increased level of comfort in this activity type. While we attempted to balance power differentials in all activities through verbal and non-verbal cues, unequal power dynamics would inevitably persist and were considered in analyses (England, 1994).

*5.4.5 Ethics*

Written or verbal informed consent was obtained from all participants. The research protocols were approved by Research Ethics Boards at McGill University and the University of Guelph.

## 5.5 Results

*5.5.1 Characterizing livestock use among Batwa and non-Batwa*

Batwa and non-Batwa livestock keeping

Livestock ownership differed significantly between Batwa and non-Batwa: 38% of Batwa owned livestock compared to 55% of non-Batwa (Table 5.4). For all livestock types except pigs, prevalence of ownership was significantly lower for Batwa compared to non-Batwa. Chickens were the most common species owned among Batwa (22%). Beekeeping was not captured by the survey. Education and non-livestock asset ownership also differed significantly between Batwa and non-Batwa. Twenty-six percent of non-Batwa reported not having any formal education compared to 63% of Batwa. Similarly, the prevalence of asset non-ownership was lower among non-Batwa with 12% of non-Batwa reporting owning no assets compared to 43% of Batwa.

Participants reported keeping a variety of livestock species, including cattle, goats, sheep, pigs, ducks, chickens, rabbits, and bees. Goats and chickens were reported most frequently, while rabbits, sheep, and ducks were present but rarely mentioned. Pigs were less common than goats, among Batwa and non-Batwa, reportedly due to their greater feeding requirements. Beekeeping was reported by two Batwa and one non-Batwa mapping group. One Batwa group described beekeeping as a cultural activity while another explained that they learned it from their elders. All three groups described it as a lucrative activity, citing high demand and market prices: "*There is high demand of honey but there is not enough honey within the community" (Non-Batwa Male Map Group 007)*. One group described making and selling traditional beehives as another income generating activity: "*When we make these beehives, we usually sell some and others we use ourselves. We get honey to eat and to sell and get money for buying clothing and buying food" (Batwa Male Map Group 001)*.

Table 5.4: Demographics and livestock livelihood-related characteristics for Batwa and non-Batwa study communities, July 2013.

| **Characteristic** | **Batwa**<br>Frequency (%) | **Non-Batwa**<br>Frequency (%) |
|---|---|---|
| *Demographics* | 225 (33.5) | 447 (66.5) |
| Gender | | |
| Female | 135 (60.8) | 280 (62.8) |
| Male | 87 (39.2) | 166 (37.2) |
| Age (mean years) | 35.4 [95% CI 33.3-37.4] | 37.8 [95% CI 36.3-39.3] |
| Education*** | | |
| No formal schooling | 139 (62.9) | 116 (26.1) |
| Primary incomplete | 64 (29.0) | 232 (52.3) |
| At least primary complete | 18 (8.1) | 96 (21.6) |
| Crowding (number of people per sleeping room)* (mean) | 2.75 [95% CI 2.6-2.9] | 2.52 [95% CI 2.4-2.6] |
| *Asset ownership* | | |
| Radio*** | | |
| Yes | 120 (53.3) | 335 (75.1) |
| No | 105 (46.7) | 111 (24.9) |
| Cell phone*** | | |
| Yes | 32 (14.2) | 226 (50.7) |
| No | 193 (85.8) | 220 (49.3) |
| Any assets*** | | |
| Yes | 129 (57.3) | 394 (88.3) |
| No | 96 (42.7) | 52 (11.7) |
| *Livestock livelihoods* | | |
| Own livestock*** | | |
| Yes | 85 (37.8) | 243 (55.0) |
| No | 140 (62.2) | 199 (45.0) |
| Poultry*** | | |
| Yes | 50 (22.2) | 142 (32.1) |
| No | 175 (77.8) | 300 (67.9) |
| Goats/sheep*** | | |
| Yes | 47 (20.9) | 185 (41.9) |
| No | 178 (79.1) | 256 (58.1) |
| Pigs | | |
| Yes | 23 (10.2) | 57 (12.9) |
| No | 202 (89.8) | 385 (87.1) |
| Cattle*** | | |
| Yes | 0 (0) | 35 (7.9) |
| No | 225 (100) | 407 (92.1) |
| Rabbits* | | |
| Yes | 2 (0.9) | 15 (3.4) |
| No | 223 (99.1) | 427 (96.6) |

* p<0.05, **p<0.01, ***p<0.001 based on Pearson's chi square test

Only the wealthiest non-Batwa community members reported keeping cattle, and mapping participants described how cattle were grazed extensively on "farms" (large contiguous tracts of privately owned land). Most community members (Batwa and non-Batwa alike) reported that keeping a cow was beyond their means. In fact, cattle were specifically described as an indicator of wealth by 47 community members. No Mutwa reported owning a cow; KI and CM participants explained that Batwa did not have the financial resources to purchase a cow, nor the land to graze it. According to a Mutwa mapping participant:

> It's important to have a cow because you can get milk and feed your children. When the children are drinking milk they don't get malnutrition. But nobody in this settlement has a cow. For the cow, if you don't have enough land to make a farm, you find it's very hard to rear cows, another thing if you don't have money for de-worming the cow, you find out they are getting sick and dying (Batwa Male Mapping group 005).

This finding was supported by survey results, which showed that no Batwa owned cattle. Batwa and non-Batwa community members who owned goats reported grazing them on smaller plots of land around their compounds or within their settlements. No community member SSI participants reported grazing on communal lands. Participants in both ethnic groups largely reported keeping goats and sheep inside the household at night. Pigs were typically tied under trees or kept in small shelters. Chickens and ducks were kept free-range and were also brought indoors at night according to Batwa and non-Batwa community members. Few households kept livestock in separate shelters; participants described the high costs associated with building shelters and felt that animals could not be left outside for fear of theft and predation. As one participant explained:

> The pig is tied under the mango tree on my compound, and the goats have their own shelter. The goats feed on grass but I feed sweet potato leaves to the pig. I would have also built a shed for pigs but the problem is that I have not yet gotten money to buy the materials (SSI_2013_26, Female, non-Batwa community member).

Participants reported that most livestock were purchased from the weekly market in Butogota Town, but buying them from neighbours was also common. Some described that livestock such as pigs or goats were reared for someone else in exchange for future offspring. Livestock were also acquired as gifts (e.g., weddings), received as dowries, or bequeathed at death. In this way, those who could not afford to purchase an animal outright became livestock owners also.

Despite differences in prevalence of livestock keeping, Batwa community members expressed a desire to engage in livestock livelihoods to aid in the transition to life outside of the forest. It was broadly reported by key informants that livestock keeping would be an effective and culturally appropriate adaptation strategy for Batwa. Non-Batwa community members considered livestock keeping as a necessity, and in fact not owning any livestock was considered a sign of extreme poverty. One non-Batwa participant described her experience, *"I was taught from childhood you cannot rest if you don't have any animals, so it's a must for everyone to have livestock" (SSI_2013_27 Female, non-Batwa community member).* Cultural appropriateness was also reflected in local knowledge. Non-Batwa reported passing knowledge and experience about animal husbandry and livestock rearing from generation to generation, as one participant described: *"When I was young, I used to graze animals for my father so I saw that the goats were beneficial and I also decided to raise goats" (SSI_2013_9, Female, non-Batwa community member).* Participants described relying on local experts and knowledgeable friends for advice when animals became sick. This was particularly important for the communities located farther from large trading centres where drug shops are located, and for those who reported being unable to afford veterinary fees.

Coping: livestock as assets

Mapping, key informant, and community member interview results showed that Batwa and non-Batwa used livestock as a strategy to cope with a variety of shocks. Surplus income from other livelihood activities was invested in livestock that could be sold as needs arose.

Non-Batwa mapping participants most commonly reported school fees as one of the main incentives for selling livestock. Key informants explained that while the government provides free primary education, it was common practice to pay additional fees to support teachers. One mapping participant described the asset value of livestock: *"We would prefer to sell [livestock]. We would like to eat it but we are poor. We can't slaughter a goat which costs a lot of money. We would rather keep it and sell it if we become sick or to pay school fees" (non-Batwa Male Map Group 002).* Batwa community members did not report financial constraints due to school fees since they are currently provided by BDP. Similarly, Batwa medical expenses and transportation costs were provided by BDP, but non-Batwa community members reported this as another key reason for the sale of livestock assets: *"I have [goats] for when I am sick. I have been at [the hospital] for an operation. When I was going there [I] sold my goats; I had many goats and I had to sell them to get my medication" (SSI_2013_155 Male non-Batwa community member).* Batwa and non-Batwa community members reported that livestock were not used as a food source during times of food insecurity due to their high cost; instead, livestock were sold to purchase cheaper foodstuffs, typically carbohydrate-dense foods such as maize flour. One LC chairperson described the recent decrease in livestock ownership in their community: *"Now there are two pigs in this settlement… there had been some goats in some families… but there has been famine and they had to sell those goats to buy food" (KI_2013_10 Male Batwa key informant).*

<u>Livestock health benefits</u>

Secondary to the role of livestock as an asset, livestock were recognized for their value as a food source. In particular, livestock were considered an important source of protein. Eggs and milk were sold for income or consumed by household members. Meat was rarely consumed by the household, except for special occasions, because of its high cost; some participants sold a goat or a chicken and used a portion of the proceeds to purchase a kilogram of meat. Participants discussed using livestock products to treat malnutrition and illness. In some instances participants explained that milk and chicken broth were given to entice an inappetent family member to eat. Milk was often discussed as an important food product for malnourished children. However, traditional medicinal purposes were also noted: *"Sometimes we eat raw eggs to soothe chest pains" (non-Batwa Male Map Group 004)."* Owning livestock was linked to mental well-being by participants. Community members associated having livestock in their compound with peace of mind, knowing that they had a safety net in case of a problem.

Livestock and poverty reduction

Livestock were used as a wealth accumulation and poverty reduction strategy to improve access to financial assets. Smallstock, such as chickens, are relatively inexpensive, require few inputs, and reproduce quickly. They were perceived to be an efficient source of income. As one key informant noted, a small flock of chickens could be sold to purchase larger livestock such as a goat or sheep: *"A cow is very expensive and our income is not fit to buy a cow. You see someone starts buying a hen, from a hen he goes to a goat, then from a goat to a cow but it takes a long time to go through those stages" (KI_2013_25 Male non-Batwa key informant).* Larger livestock such as goats or cattle could then be sold to purchase more expensive assets such as land, or to invest in other livelihoods such as small businesses: *"Maybe somebody would have only one half-acre and three goats, he could sell them, adds on some money, and buys land. People use [livestock] to expand their land" (KI_2013_5 Male non-Batwa key informant).*

Participants often expressed a desire for their animals to reproduce so that offspring could be sold for income. As one Mutwa woman explained: *"I want [the pig] to grow and produce so I can sell those piglets to get money and I will use that money for buying saucepans, plates and food" (SSI_2013_108 Female, Batwa community member)*. This income provides access to a variety of goods and services. Participants often discussed putting manure on their crops, particularly in banana plantations and vegetable gardens. For most households, staple crops are primarily for household consumption but surplus may be sold for income. Income can also be generated through increased crop yields. Livestock were reported as having the potential to alleviate some land-related challenges. For example, the issue of poor soil fertility was raised frequently by respondents. Batwa were provided with small plots of land, which have since been subdivided to provide for adult offspring as they begin their own families. As such, insufficient land is available for crop rotation, and the same plots are cultivated season after season, resulting in *"over-cultivation" (Batwa Female map group 004)*.

Barriers to livestock ownership

Initial cost, land availability, veterinary care, and predation were described as barriers to livestock keeping for both Batwa and non-Batwa. As described by one community member, financial barriers of livestock livelihoods go beyond that of the initial investment required to purchase them; feeding, housing, and provision of veterinary care are also costly:

> For someone who has livestock, there are a lot of costs incurred. You have to buy barbed wire for fencing, when the animal is sick there is the expense to look for the veterinary officer to come treat it, there are even some minerals they give the cows or goats, like sodium, and that costs money. So it's costly to have livestock (SSI_2013_132 Male non-Batwa community member).

Key informants commonly described limited land availability and the resultant livestock feeding challenges as barriers to livestock keeping for Batwa and non-Batwa. The land issue however, was thought to be much greater for Batwa than for non-Batwa. One participant described how the size of land provided to the Batwa might affect livestock agriculture: *"They don't have land because the land they are settled on is very little and you know, I think a cow needs almost two acres for grazing" (KI_2012_4 Male non-Batwa key informant).* The land that is available is largely consumed by crop production, limiting the amount available for grazing. This frequently brings community members into conflict when livestock encroach on their neighbour's crops. When these events occur, the animal owner is obligated to repay the cost of the destroyed crops. In addition to being costly, these occurrences can undermine social cohesion as one community member described: *"If they [livestock] go to eat someone's crops and the person makes you pay for those crops you* *can be angry with the person, so you keep anger in your heart" (SSI_2013_9 Female non-Batwa community member).*

Access to disease prevention and veterinary care limits livestock keeping in Kanungu. Participants rarely discussed dosing livestock with antiparasitics to increase the potential production of livestock; financial restrictions were cited. Vaccination was reported only by the wealthier members of the community; poorer households may be more susceptible to losses when local disease outbreaks occur. When animals become ill, most participants reported that they were forced to leave them to die, as calling a veterinarian or purchasing drugs from veterinary pharmacies was beyond their means.

An additional challenge for livestock owners was predation by wildlife, although this varied in severity with park proximity; wildlife predation was particularly problematic for those settlements closest to the forest edge. Participants from all communities experienced predation of poultry by birds of prey, mongooses, and foxes, but those along the park border found their livestock at risk of being eaten by baboons and other primates. Predation was sufficiently high that some communities located on the park border reported that they could not keep poultry at all.

Unlike carpentry and brick making, which are considered traditional male activities, gender was not reported as a substantial barrier to livestock keeping. High rates of alcoholism particularly among men, however, were highlighted as an important contextual factor affecting women's ability to manage and control livestock assets. Many women reported purchasing and raising animals, although they also reported sale of livestock by male household members. Batwa and non-Batwa women reported that male family members had sold livestock to purchase alcohol but the women could not afford to replace them. Some who could afford to replace the livestock decided against it for fear that their husbands might sell the new animals also. This highlights the fluidity of livestock as an asset, but also underlines the vulnerability of women to maintain control over household assets. As one community member described: *"When I buy animals like a goat, my husband might sell it because he is a drunkard. So he can sell it and take the money to the bar instead of using it for something important so I decided not to keep them" (SSI_2013_124 Female*

*Batwa community member).* This is particularly challenging since it is typically the responsibility of women to provide food for children in the household.

Batwa experience unique barriers to livestock keeping relative to their non-Indigenous neighbours. Forced settlement introduced new norms and traditions dominated by planning, and investment of time and energy to plant and harvest crops. Similarly, tending to livestock, waiting months for them to produce offspring requires long-term investment and delayed benefit. In this context, transitioning to livestock and agrarian livelihoods has conflicted with traditional Batwa culture. Batwa who do own livestock have been disadvantaged by a lack of numeracy and market knowledge. Attempting to access cash quickly, Batwa have reportedly sold livestock for well under market value. Combined with low negotiating power due to social marginalization and desperation, this has contributed to Batwa failing to benefit fully from this source of income.

Negative effects of livestock keeping

Livestock keeping may pose unintended negative consequences to the environment and to human health in the study population. Many community members fetch water from streams, ponds, and other sources of surface water. These water sources serve a variety of purposes for community members such as bathing, washing clothes, and watering animals. This water is also used for cooking and drinking. Participants described their concerns over water contamination by livestock:

> First of all, [livestock] dirty the environment and you find people here don't have enough water. If the water flows freely, cows are normally watered there and the people share the water with the cows. At their compounds, people may not have places to house their hens. Some people might end up sleeping with hens in the houses, and so sometimes it might not be good for their health. (KI_2013_3 Female non-Batwa key informant).

Living in close contact with animals was considered a health concern amongst participants. Sleeping with animals inside at night, and having them roam freely around the compound were thought to increase the likelihood of disease transmission. Many participants described that keeping animals inside at night was bad for them and could make them sick, though disease-specific knowledge was poor: *"Let's say when you have a pig and you don't have a shed for it and touches the food that the children will eat, you can get Ebola, you can even get typhoid and cholera because pigs are always dirty" (SSI_2013_88 Male non-Batwa community member).* Eating sick animals was a common practice described by participants and they often reported this as a risky behaviour that could result in illness or death; key informants explained, however, that the high value of animals and the high level of poverty and hunger in the District drove the frequency of this behaviour. Boiling drinking water was identified as a mechanism to alleviate disease transmission through water contamination, however this practice was uncommon. Lack of pots and firewood for boiling water, lack of containers for storing boiled water, and a dislike for warm, smoky-tasting water were identified as constraints.

> We do [not boil water] because we don't have containers to keep the boiled water; because if you boil [water] in a saucepan and you want to use that saucepan for cooking you find you don't have anywhere to put that water and you end up not boiling water for drinking (SSI_2013_66 Male Batwa community member).

In addition, it was a common misconception that drinking boiled water was the cause of illness. As one community member stated: *"If we take boiled water, we suffer from 'flu" (SSI_2013_84 Male Batwa community member).*

*5.5.2 Assessment of livestock as an adaptation option: application of criteria for livelihood adaptation for resilience to climate change.*

To conduct an *a priori* assessment of the appropriateness of livestock keeping as an adaptation option for Batwa, we synthesize the data in light of the five criteria adapted from the climate change health adaptation and livelihoods literatures: effectiveness, feasibility, sustainability, equity, and potential for maladaptation. This synthesis includes integration of the scientific and grey literatures to aid in the contextualization of results and complement topics raised by study participants.

Effectiveness

We consider that in order to be effective as an adaptation option, livestock keeping must have the potential to facilitate livelihood diversification and poverty reduction. It should also build adaptive capacity of community members to take advantage of future adaptation options, and reduce vulnerability to various shocks under a range of conditions. Livestock satisfy the effectiveness criterion for Batwa.

Livestock contribute to livelihood diversification in Kanungu District. Participants described using multiple livelihood activities to provide for their households and for some households this included a livestock component. Income generation was widely considered one of the primary functions of livestock, and the role of livestock in asset accumulation was a predominant theme identified by participants. Livestock may reduce poverty through asset accumulation, which promotes access to off-farm sources of income such as small businesses (Djoudi & Brockhaus, 2011; Eriksen, Brown, & Kelly, 2005; Mertz et al., 2011). Livelihood diversification, including the transition to off-farm sources of income is considered an important strategy to reducing vulnerability to climate change (Eriksen & O'Brien, 2007; Hahn, Riederer, & Foster, 2009; Kansiime, 2012).

Livestock build adaptive capacity to take advantage of future adaptation options and reduce sensitivity to climate change. Community members and key informants explained that farming and livestock rearing are the main livelihoods available for individuals with no education. Relying on crop agriculture makes households particularly sensitive to climate variability. Livestock keeping may improve access to education improving the likelihood of stable, salaried, off-farm employment (Djoudi & Brockhaus, 2011). Reducing reliance on highly climate-sensitive forms of income may increase adaptive capacity for rural communities (Aryal, Cockfield, & Maraseni, 2014; Ford & Goldhar, 2012). Education and wealth are predictors of resilient communities (Sovacool, D'Agostino, Rawlani, & Meenawat, 2012) with benefits that occur regardless of climate change.

Potential effectiveness of livestock keeping is also demonstrated by its current flexibility as a coping mechanism. Among Batwa and non-Batwa, the sale of livestock was used as a coping strategy in the face of various challenges, including food shortages and medical expenses. The flexibility of livestock as a generic asset and coping strategy in various contexts is consistent with 'no regrets' adaptation, whereby the asset can be utilized for a range of shocks and future scenarios. Livestock sales have been used as a coping strategy for climate variability among smallholder farmers in other settings, including Uganda, where farmers perceive livestock keeping as a method of livelihood diversification and risk spreading (Goulden et al., 2013; Sarker, Alam, & Gow, 2013; Thornton et al., 2010). However, livestock have trade-offs. While some species are more sensitive than others (Kansiime, 2012), livestock are not climate-proof. Water shortages and extreme temperatures can result in decreased production and fatalities. Livestock are susceptible to pests and pathogens which are themselves climate-sensitive. Steps can be taken to temper these vulnerabilities, such as selecting for drought resistant breeds, diversification of livestock species which are susceptible to different diseases, de-stocking during climate extremes, and vaccination (Chakrabarti, 2015; Joshi et al., 2013; Pouliotte et al., 2009).

Feasibility

An adaptation option may be considered feasible if it is not constrained by technological, and socioeconomic barriers and is consistent with current policy, adaptation in other sectors, and targets areas of opportunity. Livestock keeping may be socially and culturally acceptable to Batwa as an adaptation option, however it is constrained by economic and technological barriers and as such, does not fulfill the feasibility criterion.

Batwa express a desire to engage in livestock keeping, suggesting that this option may align with their cultural transition from hunter-gatherers to settled subsistence farmers. Livestock are complementary to other Batwa livelihood strategies, particularly food crop agriculture. Successful adaptation options must not only be socioculturally appropriate but should also be consistent with individual preferences (Kristie L Ebi & Burton, 2008; Fussel, 2007; James, 2010; Smit & Pilifosova, 2001). Beekeeping is one strategy that could address past and present cultural preferences for Batwa. Currently, few households engage in beekeeping despite high local demand for honey. Beekeeping aligns with Batwa traditions through cultural significance as a traditional medicine and food source for Batwa, and requires minimal inputs. This part of Uganda is particularly well suited to apiculture, but there is a paucity of research on climate change effects on apiculture in Uganda (Didas, 2005).

Technical and financial barriers currently hinder livestock keeping in Kanungu District, reducing its feasibility as an adaptation option for Batwa. Based on our findings we suggest that overcoming the initial investment in smallstock such as poultry, or bees, is the greatest barrier, although ongoing feeding, housing, and veterinary care costs are not negligible. Other studies in Botswana, Senegal, and Vietnam have described similarly impoverished communities who rely on the sale of casual labour as their main livelihood activity and lack the capital to invest in livestock (Pica-Ciamarra, Tasciotti, Otte, & Zezza, 2015). External interventions would be required to enable Batwa to overcome this barrier. Veterinary services were considered inaccessible to most livestock keepers in our study population, and yet the provision of veterinary services has been identified as one of the most successful interventions for improving production in smallholder livestock systems (Oosting, Udo, & Viets, 2014). While agriculture extension services are available through the National Agricultural Advisory Services, these services are targeted to farmers who have demonstrated skill in agriculture (James, 2010). Improving access to veterinary services in Kanungu represents an entry point for intervention. The sustainability of any livestock activity as an adaptation intervention in the Kanungu context is dependent upon continued support with regards to husbandry and access to veterinary care.

Land availability represents a barrier to livestock keeping among the study population and is a constraint to feasibility. In the current free-grazing system, livestock compete with staple and cash crops for land. Batwa settlement and plot sizes already limit household food production preventing the provision of grazing lands for ruminants. That is not to say that engaging in livestock keeping is rendered impossible. First, poultry do not require grazing land and are commonly kept within the compound. Second, zero-grazing (sometimes called cut and carry systems) of small ruminants using gathered forage could be used to address animal feeding needs and prevent crop destruction (Lusiana, van Noordwijk, & Cadisch, 2012). Using this strategy increases labour demands and its feasibility may depend on labour availability.

While not addressed by study participants, livestock keeping is compatible with Uganda's current agricultural development and adaptation policies, thereby contributing to the feasibility criterion. Close to three-quarters of the Ugandan population are reliant on subsistence agriculture, many of these the rural poor (GoU, 2015). Therein, agriculture and livestock development have been identified as priority policy areas for climate change adaptation and development in Uganda (GoU, 2012, 2015). Investment in beef and fish are among key development strategies, but a substantial gap persists between agricultural production and potential, of which livestock is an important component (GoU, 2015). Increasing food security and reducing poverty through the agricultural sector are among the goals for mainstreaming adaptation for Uganda (GoU, 2015), with recognition of the need for national support of livestock development (GoU, 2014).

Sustainability

Adaptation options may be considered sustainable if they do not require ongoing inputs from outside of the system. Livestock in Kanungu are managed extensively with minimal external inputs; they are kept on small plots of land and fed with crop residues and locally available fodder. This type of livestock rearing limits productivity and is associated with low to moderate outputs (Powell, Pearson, & Hiernaux, 2004), and is also consistent with mixed crop-livestock systems in other regions where livestock eat crop residues and produce manure that can be applied to crops (Thornton et al., 2010). Studies show that integrated crop-livestock systems are more efficient than either system managed independently since they have smaller land requirements, produce less waste, and require fewer external inputs (Anik & Khan, 2012; Pouliotte et al., 2009). While livestock interventions represent an adaptation option that is theoretically consistent with locally sustainable activities, extensive and prolonged support for the Batwa — in the form of training and access to livestock husbandry and veterinary care in particular — would be required in the short to medium-term. Livestock interventions may thus satisfy the sustainability criterion only within the context of extended support beyond short-term or initial intervention.

Lack of ongoing support was highlighted by key informants as being partially to blame for the downfall of a previous livestock intervention. As they reported, an international NGO provided milking goats to Batwa at the settlement level to be collectively owned and cared for. This intervention was unsuccessful, and interviewees offered four reasons for the failure. First, goat milking is an uncommon practice in Kanungu District, and neither Batwa, nor non-Batwa consume goat milk. Second, by implementing communal ownership, no one felt responsible for the well-being of the goats and a few individuals were ultimately burdened with the task of grazing them. Third, Batwa felt that they had little assistance from the project with regards to veterinary care, and when animals became sick, many were sold or eaten in fear of an outbreak. Finally, given the extreme poverty experienced by the community, many of the animals were slaughtered immediately for food.

Equity

Equity of an adaptation option refers to its availability to all segments of the population and ensuring that the adaptation option does not inadvertently increase vulnerability of some individuals relative to others. Our findings suggest that sociocultural norms do not exclude any segments of the Kanungu District population from livestock keeping, including marginalized Batwa and women. In theory then, livestock have the potential to be equitably accessed within this population. It remains unclear whether this access translates into medium and long-term benefits that are also equitably distributed. Gendered power dynamics and control of household assets may represent a constraint to equity of this adaptation option. Male control and sale of livestock purchased within the household to access alcohol or other items prevents the household from reaping the health and income benefits afforded by livestock. Inequitable distribution of power over household assets is not specific to the Kanungu context; women in rural communities globally are found to have less control over household and productive assets for agricultural development (Perez et al., 2015; Quaye, Dowuona, Okai, & Dziedzoave, 2016; Quisumbing et al., 2015). While the literature on gender dimensions of vulnerability is growing, operationalizing adaptation for vulnerable groups and the understanding of the intersectionality of gender and Indigeneity is limited (Arora-Jonsson, 2011; Demetriades & Esplen, 2008; Onta & Resurreccion, 2011; Shabib & Khan, 2014; Sugden et al., 2014).

Pre-existing financial capital may also determine the distribution of benefits from livestock within the population. Maximizing livestock production requires appropriate feeding and preventive care (Nampanya et al., 2014). Those who are unable to invest in livestock will not receive the same benefits as those who are able to make such investments, undermining potential resiliency among the financially constrained. Further, wealthier community members with larger herds or flocks can afford to sell offspring to cope with shocks knowing that their mature females will reproduce again. However, the sale of livestock may undermine the asset base of the poorest community members with small herds ultimately leaving them more vulnerable to future stresses (Eriksen et al., 2005; Goulden et al., 2013).

Potential for maladaptation

An adaptation option should not contribute to the underlying drivers of climate change, nor should it result in negative health and/or environmental outcomes in order to be considered appropriate. Livestock keeping may have negative health and environmental consequences for Batwa as demonstrated by participants' concern over shared water sources. Further, two concerns not raised by study participants may contribute to potential for maladaptation. First, livestock produce greenhouse gas emissions (GHG). And second, poorer subsections of the population may not be as well buffered from shocks as a result of livestock keeping compared to wealthier community members. Nonetheless we consider livestock keeping to have limited potential for maladaptation, and therefore to satisfy this criterion.

Study participants had concerns regarding livestock impacts on human health. The main concern, environmental and water contamination can be addressed through health education and promotion activities particularly relating to sanitation and hygiene. Understanding both livestock diseases and zoonotic disease risk to humans would have to be addressed through collaborative efforts between veterinarians and community health workers. Net benefits to health of livestock, however, are likely to substantially exceed negative health impacts in this context.

While not discussed by study participants, livestock, and ruminants in particular (cattle, goats, and sheep), contribute to GHG emissions through methane production (Herrero, Thornton, Gerber, & Reid, 2009), and may therefore be maladaptive at the global scale. Relative to intensive cattle feedlot systems in developed countries, extensive mixed crop-livestock and pastoral systems of developing countries play a minor role producing GHGs (McMichael, Powles, Butler, & Uauy, 2007). Emissions in extensive systems can be minimized through a combination of ruminant diet management, optimized breeds for higher productivity, and close integration of crop and livestock systems to maximize use of manure and crop byproducts (Herrero et al., 2009). Notwithstanding options for minimization of emissions, it has been proposed that impoverished populations, such as the Batwa, should not be hindered from accessing livestock as a development strategy since they have contributed least to global environmental change (Fussel & Klein, 2006). International equity (Adger, 2006; Fussel, 2007) dictates that the potential benefits of livestock, particularly in highly impoverished populations, are greatly outweighed by the environmental disadvantages (Jones & Thornton, 2009; McMichael et al., 2007).

### 5.6 Discussion

To date, the health adaptation to climate change literature has focused on specific health outcomes, typically climate-sensitive infectious diseases (Campbell-Lendrum et al., 2015;

Kristie L Ebi, 2013; Kristie L Ebi et al., 2013; Haines et al., 2014). Evidence-based selection of adaptation options that address broad determinants of health, with implications for multiple health outcomes, and to reduce burden on health systems is needed (Watts et al., 2015). We applied adapted criteria to assess the potential appropriateness of livestock keeping as an adaptation option to improve health resilience of Batwa to climate change in Kanungu District, Uganda.

Our understanding of the complex relationship between livestock and human health and well-being remains underdeveloped (Thumbi et al., 2015). According to our findings, livestock played a number of roles in this rural community. They were used as investments, allowing participants to store money until needed for school fees, medical expenses, and food shortages. This is consistent with rural smallholders in developing countries who rely on livestock as a main household asset (Herrero et al., 2013; Randolph et al., 2007; Siegmund-Schultze, Rischkowsky, da Veiga, & King, 2007). They were also perceived as an important source of income. In other studies, the sale of animal products were perceived as a benefit of keeping poultry and dairy cattle while small ruminants, such as sheep and goats, have been used as a tool to accumulate assets (Udo et al., 2011). However, whether income generation translates into poverty reduction is not well documented, potentially due to challenges with measuring wealth in non-monetary economies (Alary et al., 2011).

Our analysis was limited to communities in LCs containing Batwa settlements in Kanungu District and as such, caution should be exercised in generalizing results beyond southwestern Uganda. The qualitative data are also subject to limitations; we aimed to increase credibility (comparable to internal validity for quantitative studies) of results by including participants of each gender from all ten Batwa settlements and the ten LCs in which Batwa settlements are located. As a result, we carried out a large number of interviews, well beyond the point of saturation of ideas (Baxter & Eyles, 1997). However, women were underrepresented among key informants reflecting the relative paucity of women in positions of power in Kanungu District. Triangulation of qualitative and quantitative data was also utilized to strengthen the credibility of results. The quantitative survey may also be subject to selection bias through non-response. We randomly selected equal numbers of male and female non-Batwa participants but elected not to replace households whose selected member was not available for participation. This likely resulted in an underrepresentation of males. For both Batwa and non-Batwa survey participants, there may be a systematic difference between individuals who made themselves available and those who did not (Dohoo, Martin, & Stryhn, 2009). Both the quantitative and qualitative methods are subject to interviewer-induced bias (Choi & Pak, 2005; Rea & Parker, 2005). Training of survey administrators and interpreters aimed to mitigate this type of bias.

We have adapted criteria drawn from the climate change adaptation literature and influenced by sustainable livelihoods approaches, however other models exist to guide decision making for health interventions such as multi-criteria decision analysis (MCDA), and health impact assessment (HIA) (Baltussen, Youngkong, Paolucci, & Niessen, 2010; Hebert, Wendel, Kennedy, & Dannenberg, 2012). The benefits of these approaches are the systematic and transparent analysis of complex qualitative and quantitative data. However, these approaches involve comparisons of alternatives for which data are currently unavailable, and represents an area of future research within this study population. MCDA and HIA also frequently incorporate stakeholder participation and community engagement. For ethical reasons and to avoid bias, we were unable to ask community members directly about their perceptions of livestock interventions to improve health and cope with climate variability. In an extremely impoverished population, questions such as these would create expectations that could not be fulfilled in the context of this research. Further, participants may have presented unrealistically positive perspectives on livestock in the hopes such an intervention would result. We did ask non-livestock owning participants why they chose not to keep animals and what they considered the benefits and drawbacks of this activity to be. Even in these cases, and despite explicit descriptions of the research purpose and activities, participants often inquired as to possible interventions. This highlights the ethical risks of carrying out research in highly vulnerable populations and the importance of appropriately managing expectations.

Our analysis shows that livestock may offer Batwa considerable benefits, including income generation, asset accumulation, access to animal source foods, financial safety net, access to health care, feelings of mental well-being, and indirect benefits from manure application to staple and cash crops. Livestock may also offer long-term benefits, where asset accumulation and investment in education facilitate movement to climate-robust, off-farm sources of income. This strategy has minimal potential for maladaptation. Livestock keeping is consistent with Uganda's policies on climate change adaptation, poverty reduction, development, and modernization of agriculture. It may serve to increase food security locally, and if scaled up, could take advantage of regional demands for livestock products. Moreover, Batwa express a desire to engage in livestock keeping and have begun to engage autonomously in this activity. Despite these benefits and motivation, lack of financial capital, land, and limited access to veterinary services remain barriers to livestock keeping within this population. Further challenges to livestock keeping for Batwa include extreme poverty that may drive individuals to consume high-value animals in times of food shortage preventing them from reaping the benefits of animal ownership over time. For Batwa, and for women more broadly, limited control over household assets and alcohol abuse among family members, particularly men, undermines the household livestock asset base.

It could be argued that livestock keeping represents an ideal no-regrets activity; a socially and culturally acceptable pro-poor solution that has the potential to reduce vulnerability in this Indigenous population. However, in order for Batwa to realize the potential of this strategy, they will require land, training on livestock husbandry, accessible veterinary support, and education on preventive health care specific to livestock-related risks, which are not feasible under current conditions of extreme poverty. The poverty level within the population is so severe as to make increased livestock holdings an unsustainable option in the short-term. It is not clear what adaptation options are feasible for Batwa in this context. A randomized control trial of a multifaceted intervention for ultra-poor community members in six countries (e.g., BRAC's Graduation Program) showed that combining a productive asset (such as livestock) with regular cash or food transfers (for up to one year), technical skills training for the productive asset, regular coaching and supervision, access to a savings account, and basic health services resulted in lasting benefits for treatment group participants with respect to food security, household assets, household income, household consumption, and mental health relative to controls (Banerjee et al., 2015). The consumption support cash transfers were specifically designed to reduce the likelihood that the productive assets would be sold. Development interventions such as the Graduation Program may represent a strategy for mainstreaming adaptation among highly impoverished populations. This type of approach may address the limited capacity to take advantage of opportunities that unfairly exclude such populations from autonomous adaptation. It is possible that multipronged approaches that address immediate, short-term need while building future capacity will be required to facilitate the transition from ultra-poverty and increase medium-to-long-term resilience.

# Chapter Six - General discussion

## 6.1 Overview

Climate change is expected to exacerbate pre-existing health burdens in populations such as the Batwa who currently experience socioeconomic and political marginalization. An evidence base for appropriate interventions is required. This dissertation aimed to contribute to the evidence base by assessing the burden of malaria in this Indigenous population, and examining potential modifiable variables for intervention. It sought to investigate the role of livestock in malaria risk for humans and for Batwa specifically, and to interrogate the potential of livestock to improve the resilience of Batwa to climate variability and other shocks.

The objectives of this dissertation were:

1. to systematically synthesize the evidence on the impacts of livestock on human malaria risk;

2. to determine the prevalence of, and identify modifiable risk factors for, malaria infection among the Batwa and non-Batwa of Kanungu District, with particular focus on livestock ownership; and,

3. to characterize the potential of livestock keeping to reduce the vulnerability of Batwa to climate change.

This chapter presents the key findings of the empirical chapters and demonstrates how the objectives of the dissertation have been met. I discuss the knowledge and methodological contributions of this dissertation and its policy implications. I present the limitations of the research, future research directions and reflect upon the ethical and personal challenges in engaging in community-based research with a vulnerable population.

## 6.2 Key findings and knowledge contributions

Malaria is a significant global health issue. In 2015, approximately 214 million cases of malaria occurred, resulting in an estimated 450,000 deaths of which 91% occur in sub-Saharan Africa (WHO, 2015). This disease is highly climate-sensitive with significant changes anticipated in the range, distribution, and incidence of disease under climate change (Porter et al., 2014). This thesis provides substantive contributions to the malaria literature, particularly within the context of a changing climate.

Chapter Three: The first manuscript addressed the first research objective. A realist analysis of twenty empirical studies showed that livestock have the potential to reduce the exposure of humans to malaria in specific contexts. Where livestock are kept out of human sleeping quarters during peak mosquito feeding times, and where the predominant mosquito species present in the location do not have a strong preference for human hosts, humans tend to experience lower rates of malaria. Where individuals are using bed nets, mosquitoes may be forced to feed on livestock as an alternative host. My results indicated that socioeconomic status may determine livestock ownership, access to bed nets, and livestock housing locations, and therefore represents an unmeasured confounder of the relationship between livestock and malaria. This research suggested that livestock may reduce human vulnerability to malaria where these contextual factors are met. This chapter contributed to the malaria literature by identifying common themes (mosquito host preference, livestock location, non-animal prophylaxis, and socioeconomic status) in a previously contradictory literature on malaria zooprophylaxis using a realist perspective. Through critical analysis and realist review I found that neither the theories of zooprophylaxis nor zoopotentiation can be refuted, and rather that these effects are dependent on geographical and ecological conditions. I identified and reviewed the state of knowledge on which conditions determine the likely direction of effect (zooprophylaxis vs zoopotentiation), and outline key research gaps to further our ability to distinguish appropriate conditions for zooprophylaxis. These findings have implications for the use of livestock as a component of Integrated Vector Management for malaria control policy and programming globally.

Chapter Four: The second empirical chapter addressed the second objective. By pooling survey data in Batwa and non-Batwa communities in Kanungu District, Batwa adults were found to experience twice the odds of malaria infection compared to non-Batwa adults. Previous studies had identified differences in risk factors between the two groups (Namanya, 2013), and higher malaria rates have been shown for ethnic minorities in other geographical locations (Abe et al., 2009; Achidi et al., 2012; Garnelo et al., 2005; Haque et al., 2011; Hotez et al., 2014). This was the first study, however, to provide evidence for a higher prevalence of malaria, or any climate-sensitive health outcome, among Batwa relative to non-Batwa. Risk factors for parasitemia included poverty and iron sheet roofing, suggesting that modification of these risk factors has the potential to decrease malaria prevalence in the study community. This represents a substantial contribution to the literature on Indigenous health by showing that two ethnic groups living side-by-side for over two decades (with identical ecological conditions) can have significantly different disease burdens with respect to malaria. The literature on Indigenous health shows that Indigenous populations have consistently poorer health outcomes than their non-Indigenous compatriots, but our understanding of Indigenous health remains limited (Ohenjo et al., 2006). Relatively little is known about the health of Indigenous Africans. For example, a search Web of Science using the keywords "Indigenous health" and "Africa" (all years) yields a total of 388 results; this compares to 725 results for "indigenous health" in 2014 alone. However, the literature is growing rapidly, seeing steady increases since the mid 2000s. This thesis contributes to the knowledge base by estimating malaria in a remote Indigenous Ugandan population for whom little health data are available. This is particularly important, as African countries including Uganda often do not disaggregate health data by ethnicity nor recognize certain ethnic groups as Indigenous (Gracey & King, 2009).

The second manuscript also tested the zooprophylaxis hypothesis among livestock keepers in the study population. Controlling for use of bed nets, and socioeconomic status, as indicated by the findings of Chapter Three, and controlling for ethnicity, housing livestock within the home at night decreased malaria risk for livestock keepers in Kanungu.

Through the first and second manuscript, I have shown that livestock may be protective against malaria among Batwa and non-Batwa livestock keepers in Kanungu District when kept indoors at night, and may therefore reduce vulnerability to this climate-sensitive health outcome.

Chapter Five: The third empirical chapter directly addressed the overall aim of the dissertation, and the third objective. Surveys and semi-structured interviews were conducted with Batwa and non-Batwa community members and key informants, and community mapping activities to examine the ways in which livestock contribute to, and detract from, the lives of Batwa and non-Batwa. Non-Batwa were included as relative livestock owners compared to Batwa, and as such, provided an image of what effects livestock could have on Batwa in the future. Livestock were considered important to health and well-being for both ethnic groups, providing nutrition, income, social standing, and a form of asset, providing a safety net to cope with shocks. However, barriers to livestock ownership would need to be addressed to facilitate the success of livestock keeping as an adaptation option. These include, but are not limited to, access to technical assistance and training in the form of animal husbandry, veterinary care, and market information. I found that success of livestock interventions would, critically, depend on immediate survival needs of Batwa being met.

Much of the livelihood adaptation literature describes the autonomous adaptations employed by rural communities in response to various shocks, and the factors that predict adaptation (Anik & Khan, 2012; Arku, 2013; Goulden et al., 2013; Paavola, 2008; Pouliotte et al., 2009). There are currently no studies that compare adaptation options in mixed crop-livestock systems of sub-Saharan Africa such as those in Kanungu (Thornton & Herrero, 2015). This dissertation engages with a single potential intervention, examining advantages and disadvantages which may later contribute to such comparative assessments. In addition, this thesis contributes to the research on Indigenous health interventions more broadly, for which a research gap has been identified (Angell, Muhunthan, Irving, Eades, & Jan, 2014).

This research also makes contributions to the literature on climate change and Indigenous health, particularly in a developing country context. While our understanding of climate change effects on Indigenous Canadians, Australians, and New Zealanders is growing rapidly, the same cannot be said for Indigenous Africans. Given that African populations with their context of poverty, limited services and infrastructure, and reliance on rain-fed agriculture are expected to be particularly vulnerable to the health effects of climate change, Indigenous Africans represent a sub-group who are expected to fare worse than their non-Indigenous neighbours (Nkem et al., 2013). Yet, little research is available describing this relationship (Ford, 2012). This thesis highlights the particular sensitivity of Indigenous Batwa to a climate-sensitive disease, despite similar exposures as non-Indigenous individuals, and illustrates their relative adaptive capacity in response to climate variability. This thesis draws attention to differential vulnerability within Batwa communities. The second empirical chapter suggested that while Batwa are generally more impoverished relative to non-Batwa, the ultra-poor face higher odds of malaria. The third empirical chapter suggested gender-based differences in vulnerability relating to control over households assets. This work adds to our understanding of socioeconomic and health gradients within vulnerable Indigenous populations.

### 6.3 Methodological contributions

This thesis makes methodological contributions through the integration of mixed-methods for environmental health research: systematic literature review, and quantitative and qualitative methods. The individual application of these methods is not novel, however their concurrent and complementary use for climate change health adaptation remains underdeveloped, and responds to calls for interdisciplinary approaches to Indigenous health and climate change (Ford, 2012). Mixing methods in this manner takes advantage of the strengths of each method, and is particularly appropriate for complex research questions such as the one presented here. The application of this set of tools required technical expertise and an interdisciplinary lens that sets this work apart from both the qualitative vulnerability approaches often used in adaptation research, and the quantitative epidemiologic approaches that typify health research. This is consistent with approaches such as Ecohealth and One Health that promote interdisciplinarity and participatory methods to address complex problems involving human, animal and environmental health (Charron, 2012). Climate change has been described as a "threat multiplier," exacerbating “wicked” problems of poverty, food insecurity and gender inequity (Black & Butler, 2014). As such, climate change may be considered a "super wicked" problem requiring "messy" solutions. Wicked and super wicked problems lack clear solutions and often have unknown consequences, and as such cannot rely on traditional approaches to health intervention (Levin, Cashore, Bernstein, & Auld, 2012). These methodological contributions are underscored by the challenges of carrying out this work within the context of a remote, changeable, and resource-poor environment and in collaboration with an international, interdisciplinary research team.

### 6.4 Policy implications

This research is timely in combining global development and climate adaptation priorities, and aligns with the United Nations' Sustainable Development Goals 2030, specifically goals 1 (no poverty), 2 (zero hunger), 3 (good health and well-being), 5 (gender equality), and 13 (climate action). I have identified potential entry points for intervention among community members in Kanungu District, Uganda, and rural communities more broadly. Attending to housing location of livestock can reduce malaria risk in locations where malaria vectors are highly attracted to animal hosts. Bed nets remain a highly effective intervention to reduce malaria transmission. Understanding of zooprophylaxis and zoopotentiation and could help community health outreach teams and agricultural extension officers to reduce malaria risk for humans, in addition to provision and promotion of bed nets and other preventive measures.

Batwa face a higher burden of malarial disease than their non-Batwa counterparts. This research provides evidence to support targeted interventions to this particularly vulnerable group. In addition, poverty among Batwa and non-Batwa almost doubled the odds of infection in our study population. Malaria interventions should also be aimed at this susceptible sub-section of the population. Housing construction is also an important predictor of malaria infection. Closing eaves, and other openings in house materials would provide increased protection against mosquito house entry for Kanungu community members.

Livestock are valued for their contributions to nutrition, access to health care, social standing, and income generation in Kanungu District. This research provides evidence to support livestock keeping as an adaptation option for Batwa. It suggests that mainstreaming adaptation in the form of socioculturally desirable pro-poor policy interventions such as these are highly appropriate, posing minimal risk for maladaptation and unintended health and environmental impacts. However, extreme poverty prevents this population from taking advantage of livelihood opportunities in the short term. Combining productive assets, such as livestock with food stipends and technical support has proven effective in graduating the ultra-poor out of the poverty trap (Banerjee et al., 2015).

The role of intensive livestock systems such as feedlots has gained attention in the climate change literature, and livestock management has been described as an important mitigation strategy (IPCC, 2014a). These systems produce 80% of the agricultural sector's greenhouse gas emissions and 15% of global anthropogenic emissions annually (Friel et al., 2009; Gerber et al., 2013), however, smallholder mixed systems, the mainstay of African livelihoods, have been largely overlooked (Thornton & Herrero, 2015). The lack of understanding of smallholder mixed systems represents a serious gap given their importance to hundreds of millions of people for food security and income generation, and the potential adaptive capacity therein (Thornton & Herrero, 2015). Smallholder mixed farming systems must also be part of the climate change policy agenda, and these systems are garnering more attention within the IPCC debates and literature. In light of recent progress on climate change negotiations and adaptation funding commitments in Paris 2015 (UNFCCC, 2015), this research aims to provide support for the adaptation funding and policy planning decisions that will follow.

### 6.5 Limitations

The purpose of this thesis was to provide evidence to inform the selection of adaptation interventions for a specific population. In this case, the study population, source population, and target population, are one and the same. It follows that generalization of findings should be exercised with caution. The specificity of analysis to the research locale, and the uniqueness of the study population, suggest that application of any specific results to other populations is limited. Some general findings and contributions to the literature at-large, however, remain valid beyond our understanding of Batwa experiences.

Chapters Three and Four showed associations between livestock and human malaria risk, yet this does not imply a causal link. These studies may lend themselves to future debate on the zooprophylaxis theory, providing evidence for the consistency and plausibility of an effect of livestock on malaria outcome in the first manuscript, and strength of association in the second.

It should be noted that the vulnerability of livestock keeping in Kanungu District to climate change was not directly assessed but focused rather on livestock as an adaptation option *in response* to climate change impacts on health. While I did explore the challenges of livestock health issues, it is possible that community member perception did not accurately reflect the local livestock disease profile. Unlike other parts of Uganda where climate change is projected to increase water scarcity, livestock in the Ugandan highlands are unlikely to exacerbate water competition issues (Thornton & Herrero, 2015). Similarly, although the complement of cash and staple crops is projected to vary in the study area under climate change, it is unlikely that these variations will result in a decreased availability of livestock feeds (Thornton, van de Steeg, Notenbaert, & Herrero, 2009). Regardless, a place-based vulnerability assessment of livestock in southwestern Uganda would address this yet unanswered question.

In the third manuscript, I employed a temporal analogue approach. Temporal analogues may employ historical analysis to understand the predictors of current vulnerability. The analysis examines the strategies and experiences of non-Batwa responding to stressors in the present to provide insight on how Batwa may respond to stressors in the future. This is a particularly appropriate comparison given that Batwa and non-Batwa share similar ecological, political, and social environments. Some critiques of this approach suggest that future responses to climate change will differ greatly relative to those used in the present since climate change is expected to create new, unseen challenges and other contextual factors such as technological advances cannot be taken into account (Giles & Perry, 1998). Indeed it is possible that Batwa development regarding livestock uptake may not progress along the same pathway as non-Batwa, or that Batwa culture and history are sufficiently different from non-Batwa that the latter do not represent a suitable comparison. However, it should be noted that the purpose of analogue approaches is to provide a general understanding of determinants of vulnerability rather than exact predictions (Ford et al., 2010). Given that our findings regarding non-Batwa vulnerability and resilience are consistent with rural farmers in Uganda, sub-Saharan Africa, and smallholder farmers in other regions, it is reasonable to suspect that Batwa adaptation and adaptive capacity will also be consistent. In addition, Batwa development since eviction from the forest has to date followed a path of assimilation towards non-Batwa livelihoods, and Batwa themselves frequently express the desire to model the livestock keeping traditions of non-Batwa neighbours.

### 6.6 Future research questions

The literature on livestock, health, and climate change is limited. Due to the variability of production system types, livestock species, and local climate contexts, it remains unclear how livestock production will respond under a changing climate. It is clear that demand for livestock-related products will increase globally (FAO, 2009). As such, research is required to inform the livestock sector as it faces increasing demand and climate variability (Thornton & Gerber, 2010). Further research in the Kanungu context could involve exploring the ways in which livestock keepers respond to increasing temperatures, varied seasonality, and extreme precipitation or temperature events. Currently, there is limited research on livestock disease in the southwest of Uganda, with much of the work focusing on the human-livestock-wildlife health interface as a result of Uganda's protected conservation areas and typically motivated by wildlife conservation aims. Although the complement of cash and staple crops is projected to vary in the study area under climate change, it is unlikely that these variations will result in a decreased availability of livestock feeds (Thornton et al., 2009). A baseline regional understanding of livestock production and zoonotic diseases, would contribute to the knowledge of livestock and human health vulnerability under climate change.

Future research directions could also include a more specific understanding of livestock impacts on other aspects of human health. Nutrition, AGI, respiratory infections, ectoparasites, and intestinal parasites could all be affected by human-livestock interactions and therefore are appropriate for further study.

Research on livestock keeping as an adaptation option is limited. Studies describe communities utilizing livestock as an autonomous adaptation, a way to diversify livelihoods to cope with shocks rather than a planned adaptation to predicted climate change. Future studies should include analysis of livestock as an intervention with measurements of various health outcomes. Qualitative aspects of this intervention should also be included to understand perceived changes in health burden as a result of the intervention. Any intervention should involve consultation with community members and could involve randomized control trials whereby settlements receive interventions at different times. The impact of multiple livestock species could also be explored, for example a comparison of the effect of poultry and goats on health and resilience.

In Chapter Four, I postulated the dominant mosquito species present in Kanungu District based on the results of the model. However, entomological studies would be required to confirm these suspicions. Further research including an analysis of local mosquito species and their feeding behaviour as measured by human blood index would contribute to the zooprophylaxis literature. Further, longitudinal cohort analysis of malaria infection in livestock owners and non-owners controlling for livestock location, livestock species, SES, and bed nets would provide evidence to support or refute the trends identified in Chapter Three. In addition, experimental designs measuring the effect of livestock kept at various distances from human sleeping quarters would not only contribute to the zooprophylaxis literature, but could also inform community health workers and agricultural extension workers when providing malaria prevention and livestock management information, respectively.

### 6.7 Ethical and personal challenges

Carrying out this research required constant and ongoing engagement with ethical issues. For example, obtaining informed consent and the true ability of participants to decline participation. Prior to quantitative and qualitative data collection, we held large group meetings with participants explaining research purpose, the voluntary nature of participation, and the potential to withdraw from the process at any stage without penalty. Question and answer periods were held during which participants clarified the process and addressed concerns. However, it became our understanding that once the community chairperson had given permission for our team to carry out the research, it was more difficult (although not impossible) for the individual to decline. In addition, it was also clear that the level of poverty and desperation in the non-Batwa communities was much higher than we had previously realized. It seemed that individuals would have done almost anything to receive the participant compensation gift. In fact, many community members who were not randomly selected complained that they had been excluded. Our local team members spent a great deal of time apologizing to individuals who felt they were unfairly excluded from the research. These occurrences raised questions as to whether these community members really had the power or freedom to decline participation given their extreme level of need.

I was also acutely aware of inadvertently raising expectations. Our research team went to great lengths attempting to differentiate ourselves from non-governmental organizations and other development project deliverers, and yet, we were regularly met with questions about what would be brought to the communities beyond compensation for participation. Questions about health, poverty, livelihoods, and livestock may have raised the hope of community members regarding future interventions despite our explanations. This resulted in high levels of stress among research students and staff, who were not in a position to make high-level decisions on project interventions. This left us with feelings of guilt, and I particularly felt that I was extracting much more from the community than I was able to reciprocate. While my project is part of a larger research program working in these communities, the larger partnership context of this research is not readily evident within a single student PhD. I still have not come to terms with these feelings.

I am also concerned with communicating the findings of my third manuscript due to potential unintended negative consequences. While I believe that Batwa could greatly benefit from livestock, a number of concurrent interventions would be required for the communities to succeed in this livelihood strategy. I am concerned that government agencies and/or NGOs might use this evidence in a way that causes Batwa to lose out on much needed interventions. Attempting to be balanced and objective does not remove my inherent subjectivity, nor does it allay my concerns that others may use the work in a way that is incongruent with its intent.

Finally, I was particularly concerned with some of the external influences on the Batwa and non-Batwa communities. For example, there is a large disparity in the interventions received by each Batwa settlement. Those closest to Buhoma Town Centre receive many interventions while the more remote settlements receive few-to-none. Not only is this unfair but it creates conflict among Batwa. Working alongside organizations that foster and exacerbate inequity among beneficiaries is a great challenge and I remain unsure of my role in addressing these types of problems.

This work also reflects the challenges associated with transitioning from traditional lifestyles. In the case of Batwa, this cultural loss has been associated with alcohol abuse and domestic violence (Gracey & King, 2009; King, Smith, & Gracey, 2009). To date, no research has been done regarding Batwa mental health and yet there seem clear parallels with other Indigenous populations experiencing or having experienced cultural loss. This represents another area of research that is required to understand and address Batwa well-being.

## 6.8 Final comments

This dissertation provided substantive contributions to three key knowledge areas: livestock impacts on human health, Indigenous health, and climate change adaptation. It has shown that Batwa, an Indigenous population, are differentially susceptible to the negative health effects of climate change, using malaria as an example. It has also shown that livestock livelihoods may provide an appropriate adaptation intervention to reduce this differential susceptibility while contributing to health, in the form of better nutrition, and access to health care, providing a source of income, and as an asset that can be sold in times of need to cope with shocks. Moreover, it contributes to work that highlights the Batwa situation. It is my hope that this work provides further evidence that targeted interventions are required to address serious and avoidable health inequities of this population.

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# Appendix 1: Articles excluded from zooprophylaxis full article review and reasons for exclusion

| Stage | Reason for exclusion | Article | Total | Remaining |
|---|---|---|---|---|
| *Stage 1: Document retrieval* | | | | |
| | Non-scientific literature. Source type: patent | Lee DW, Zooprophylaxis vaccinating apparatus for inoculating vaccine to domestic animal such as pig, is provided with press bayonet lock for firing capsule to domestic animal. | 1 | |
| Total excluded at stage 1 | | | **1** | 75 |
| *Stage 2: Title review* | | | | |
| | Non-malarial disease | Cruz-Pacheco et al, 2012. Control Measures for Chagas Disease. MATHEMATICAL BIOSCIENCES. | | |
| | | Kasili et al, 2009. Comparative attractiveness of CO2-baited CDC light traps and animal baits to *Phlebotomus duboscqi* sandflies. JOURNAL OF VECTOR-BORNE DISEASES. | | |
| | | Chelbi et al, 2008. Zooprophylaxis: Impact of Breeding Rabbits Around Houses on Reducing the Indoor Abundance of *Phlebotomus papatasi*. VECTOR BORNE AND ZOONOTIC DISEASES. | | |
| | | Kirby et al, 2008. Risk factors for house-entry by culicine mosquitoes in a rural town and satellite villages in The Gambia. PARASITES AND VECTORS. | | |
| | | Achukwi et al, 2007. Successful vaccination against *Onchocerca ochengi* infestation in cattle using live *Onchocerca volvulus* infective larvae. PARASITE IMMUNOLOGY. | | |
| | | Seidenfaden et al, 2001. Combined benefits of annual mass treatment with ivermectin and cattle zooprophylaxis on the severity of human onchocerciasis in northern Cameroon. TROPICAL MEDICINE AND INTERNATIONAL HEALTH. | | |
| | | Vasquez et al, 1999. Effects of non-susceptible hosts on the infection with *Trypanosoma cruzi* of the vector *Triatoma infestans*: an experimental model. MEMORIAS DO INSTITUTO OSWALDO CRUZ | | |
| | | Cecere et al, 1997. Effects of chickens on the prevalence of infestation and population density of *Triatoma infestans* in rural houses of north-west Argentina. MEDICAL AND VETERINARY ENTOMOLOGY. | | |
| | | Gurtler et al, 1997. Shifting host choices of the vector of Chagas disease, *Triatoma infestans*, in relation to the availability of hosts in houses in north-west Argentina. JOURNAL OF APPLIED | | |

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| | ECOLOGY.<br><br>Mutinga et al, 1990. Epidemiology of leishmaniases in Kenya – natural host preference of wild caught phlebotomine sandflies in Baringo District, Kenya. EAST AFRICAN MEDICAL JOURNAL.<br>Hess & Hayes, 1970. Relative potential of domestic animals for zooprophylaxis against mosquito vectors of encephalitis. AMERICAN JOURNAL OF TROPICAL MEDICINE AND HYGIENE.<br>Nelson et al, 1968. Studies on heterologous immunity in schistosomiasis. 1. Heterologous schistosome immunity in mice. BULLETIN OF THE WORLD HEALTH ORGANIZATION.<br>Amin et al, 1968. Studies on heterologous immunity in schistosomiasis. 2. Heterologous schistosome immunity in Rhesus monkeys. BULLETIN OF THE WORLD HEALTH ORGANIZATION.<br>Sim et al, 1987. Human in vitro immune-reactions to animal filariids. TROPICAL MEDICINE AND PARASITOLOGY.<br>Gurtler et al, 2014. Domestic Animals Hosts Strongly Influence Human-Feeding Rates of the Chagas Disease Vector *Triatoma infestans* in Argentina. PLOS NEGLECTED TROPICAL DISEASES.<br>Kaabi & Ahmed, 2013. Assessing the effect of zooprophylaxis on zoonotic cutaneous leishmaniasis transmission: A system dynamics approach. BIOSYSTEMS.<br>Richter et al, 2013. Spatial stratification of various Lyme disease spirochetes in a Central European site. FEMS MICROBIOLOGY ECOLOGY. | 17 |
| Mathematical model | Hassanali et al, 2008. Zooprophylactic diversion of mosquitoes from human to alternative hosts: A static simulation model. ECOLOGICAL MODELING.<br>Kelly and Thompson, 2000. Epidemiology and optimal foraging: modelling the ideal free distribution of insect vectors. PARASITOLOGY.<br>Sota & Mogi, 1989. Effectiveness of zooprophylaxis in malaria control – a theoretical inquiry, with a model for mosquito populations with 2 bloodmeal hosts. MEDICAL AND VETERINARY ENTOMOLOGY. | 3 |

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|---|---|---|---|---|
| | Editorial/other | Rowland et al, 1996. 'O come, let us wallow...' A reply - Muddying the waters, or turning zooprophylaxis from failure to success. TRANSACTIONS OF THE ROYAL SOCIETY OF TROPICAL MEDICINE AND HYGIENE.<br>Iliev T, 1981. Pure and applied scientific work of Prof. G. Pavlov in the field of zooprophylaxis. VETERINARNO-MEDITSINKI NAUKI. | 2 | |
| | Review | Service, MW, 1991. Agricultural development and arthropod-borne diseases: a review. REVISTA DE SAUDE PUBLICA. | 1 | |
| Total excluded at Stage 2 | | | **23** | 52 |
| *Stage 3: Abstract review* | | | | |
| | Mathematical model | Nah et al, 2010. The dilution effect of the domestic animal population on the transmission of *P. vivax* malaria. JOURNAL OF THEORETICAL BIOLOGY.<br>Le Menach et al, 2005. The unexpected importance of mosquito oviposition behaviour for malaria: non-productive larval habitats can be sources for malaria transmission. MALARIA JOURNAL.<br>Killeen et al, 2004. Rationalizing historical successes of malaria control in Africa in terms of mosquito resource availability management. AMERICAN JOURNAL OF TROPICAL MEDICINE AND HYGIENE.<br>Kawaguchi et al, 2004. Combining zooprophylaxis and insecticide spraying: a malaria-control strategy limiting the development of insecticide resistance in vector mosquitoes. PROCEEDINGS OF THE ROYAL SOCIETY B-BIOLOGICAL SCIENCES.<br>Saul A, 2003. Zooprophylaxis or zoopotentiation: the outcome of introducing animals on vector transmission is highly dependent on the mosquito mortality while searching. MALARIA JOURNAL.<br>Franco et al, 2014. Controlling Malaria Using Livestock-Based Interventions: A One Health Approach. PLOS ONE. | 6 | |
| | Review | Randolph et al, 2012. Pangloss revisited: a critique of the dilution effect and the biodiversity-buffers-disease paradigm. PARASITOLOGY.<br>Bettini & Romi, 1998. Zooprophylaxis: old and new problems. PARASSITOLOGIA.<br>AULT, SK, 1994. Environmental management – | | |

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|---|---|---|---|---|
| | | A reemerging vector control strategy. AMERICAN JOURNAL OF TROPICAL MEDICINE AND HYGIENE<br>Lacey & Lacey, 1990. The medical importance of riceland mosquitoes and their control using alternatives to chemical insecticides. JOURNAL OF THE AMERICAN MOSQUITO CONTROL ASSOCIATION. Supplement.<br>Goriup, S., 1989. Analysis of available measures for malaria control in Africa south of the Sahara. TRANSACTIONS OF THE ROYAL SOCIETY OF TROPICAL MEDICINE AND HYGIENE. | 5 | |
| | Editorial/other | Kweka et al, 2008. Impact of *Anopheles arabiensis* feeding and resting behaviour in zooprophylaxis for malaria control. AMERICAN JOURNAL OF TROPICAL MEDICINE AND HYGIENE.<br>Dobson et al, 2006. Sacred Cows and Sympathetic Squirrels: The Importance of Biological Diversity to Human Health. PLOS MEDICINE<br>Charlwood, D., 2001. Zooprophylaxis: are we in Plato's cave? TRENDS IN PARASITOLOGY | 3 | |
| | Non-malarial disease | Basanez et al, 2007. Density-dependent host choice by disease vectors: epidemiological implications of the ideal free distribution. TRANSACTIONS OF THE ROYAL SOCIETY OF TROPICAL MEDICINE AND HYGIENE<br>Renz et al, 1994. Cattle, worms and zooprophylaxis. PARASITE-JOURNAL DE LA SOCIETE FRANÇAISE DE PARASITOLOGIE. | 2 | |
| | Non-malaria specific (febrile illness) | Deressa et al, 2007. Household and socioeconomic factors associated with childhood febrile illnesses and treatment seeking behaviour in an area of epidemic malaria in rural Ethiopia. TRANSACTIONS OF THE ROYAL SOCIETY OF TROPICAL MEDICINE AND HYGIENE | 1 | |
| | Research framework | Gu et al, 2008. Habitat-based larval interventions: A new perspective for malaria control. AMERICAN JOURNAL OF TROPICAL MEDICINE AND HYGIENE | 1 | |
| *Total excluded at Stage 3* | | | **18** | 34 |
| Stage 4: Full article review | | | | |

| | |
|---|---|
| Non-malaria specific (all cause child mortality) | Komazawa et al, 2012. Are Long-Lasting Insecticidal Nets Effective for Preventing Childhood Deaths among Non-Net Users? A Community-Based Cohort Study in Western Kenya. PLOS ONE. |
| No measure of human malaria risk or exposure | Lyimo et al, 2012. Does cattle melieu provide a potential point to target wild exophilic *Anophelies arabiensis* (Diptera: Culicidae) with entomopathogenic fungus? A bioinsecticide zooprophylaxis strategy for vector control. JOURNAL OF PARASITOLOGY RESEARCH |
| Inappropriate measure of livestock impact. | Bugoro et al, 2011. Bionomics of the malaria vector *Anopheles farauti* in Temotu Province, Solomon Islands: issues for malaria elimination. MALARIA JOURNAL. |
| Livestock exposure measured at the village level but impact on malaria risk not investigated. | Muturi et al, 2008. Effect of Rice Cultivation on Malaria Transmission in Central Kenya. AMERICAN JOURNAL OF TROPICAL MEDICINE AND HYGIENE. |
| Mosquito mortality as outcome measure, not human malaria risk or exposure. | Mahande et al, 2007. Role of cattle treated with deltamethrine in areas with a high population of *Anopheles arabiensis* in Moshi, Northern Tanzania. MALARIA JOURNAL |
| Impact of livestock on malaria risk not investigated | Gopaul, R., 1995. Surveillance entomologique à Maurice. CAHIERS SANTÉ. |
| Review | Rasnitsyn & Lebedeva, 1995. The prospects of the use of attractants for the mosquito control (Diptera, Culicidae). ZOOLOGICHESKY ZHURNAL |
| No statistical analysis | Kirnowordoyo & Supalin, 1985. Zooprophylaxis as a useful tool for control of *A. aconitus* transmitted malaria in Central Java, Indonesia. JOURNAL OF COMMUNICABLE DISEASE. |
| No measure of human malaria risk or exposure | Naz et al, 2013. Efficacy of Ivermectin for Control of Zoophilic Malaria Vectors in Pakistan. PAKISTAN JOURNAL OF ZOOLOGY |
| Unable to draw conclusions based on results presented | Kaburi et al, 2009. Effects of long-lasting insecticidal nets and zooprophylaxis on mosquito feeding behaviour and density in Mwea, central Kenya. JOURNAL OF VECTOR-BORNE DISEASES. |
| No control/comparison group | Bhatt et al, 2008. Dynamics of *Anopheles culidifacies* - transmitted malaria in the absence of effective zooprophylaxis in a riverine settlement in Gujarat, India. CURRENT SCIENCE. |
| No statistical analysis with regards to outcomes of interest to this review | Mahande et al, 2007. Feeding and resting behaviour of malaria vector, *Anopheles arabiensis* with reference to zooprophylaxis. MALARIA JOURNAL. |
| Sample size | McCall et al, 2001. Evidence for memorized site-fidelity in *Anopheles arabiensis*. TRANSACTIONS |

| | | | | |
|---|---|---|---|---|
| | | OF THE ROYAL SOCIETY OF TROPICAL MEDICINE AND HYGIENE | | |
| | Livestock exposure not measured | Muriu et al, 2008. Host choice and multiple blood feeding behaviour of malaria vectors and other anophelines in Mwea rice scheme, Kenya. MALARIA JOURNAL. | | |
| Total excluded at stage 4 | | | 14 | 20 |

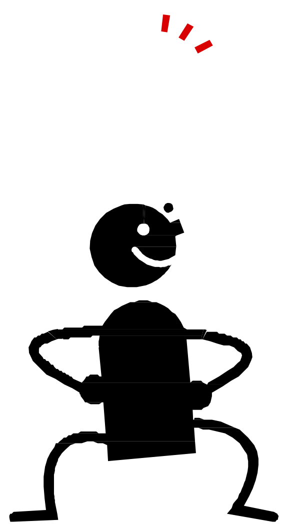
# Appendix 2: IHACC individual and household surveys



## IHACC

**EBIBUUZO: BY’ OMUNTU AH’ABWE | INDIVIDUAL QUESTIONNAIRE: July 2013 Version**

| | | | |
|---|---|---|---|
| **EKICWEKA A:** EBIRI KUKWATA AHA KICWEKA/EKYARO/OMUNTU OGW’ ORIKUBUUZIBWA | EBIBUUZO ABIRI NA BINA | **PART A:** Demographics | 16 questions |
| **EKICWEKA B:** EBY’AMAGARA | EBIBUUZO BIRI | **PART B:** Clinical evaluation | 2 questions |
| **EKICWEKA C:** EBIRI KUREETAHO ENDWARA | EBIBUUZO MWENDA | **PART C:** Risk factors | 8 questions |
| **EKICWEKA E:** ENDWARA Z’OKUTANAKA, N’OKWIRUKANA, NA EZAMAANI | EBIBUUZO IKUMI MWENDA | **PART E:** Acute gastrointestinal illness | 19 questions |
| **EKICWEKA F:** EBIRI KUKWATA AHA MUSHWEIJA | EBIBUUZO MWENDA | **PART F:** Self-reported fever | 13 questions |
| **EBIBUUZO EBIRI KUHENDERA EKIGAANIIRO** | EBIBUUZO BIBIRI | **Completion questions** | 1 question |
| **EBIBUUZO BYOONA HAMWE:** | **EBIBUUZO NKAAGA NA BITAANO** | **Total:** | **59 questions** |



## INFORMED CONSENT

**This questionnaire will take about 20 minutes to complete.**

**You can choose not to participate, or to withdraw at any time without a problem.**

**If you do not want to answer a question, you do not have to and we will move on to the next one.**

**You are welcome to share in the food we bring whether you participate or not.**

**This research will be shared with other people and the information can be used to help other communities like yours in other places.**

**Do you have any questions before we begin?**

**If you have questions later about the project, contact:**

**Dr. Shuaib Lwasa: 256 772 461727**
**Mr. Didas Namanya: 256 772 484771**

ORIKUBUUZIBWA YAAHA ORUSA:
- ☐ EEGO
- ☐ INGAAHA

Informed consent:
- ☐ Respondent agrees to be interviewed
- ☐ Respondent does not agree to be interviewed

## EKICWEKA A - EBIRIKUKWATA AHA KICWEKA/EKYARO/OMUNTU OGW'ORIKUBUUZIBWA

*PART A – Demographics*

1. EKICWEKA (*EKYARO/LC*): ______________________________
2. EBIRO BY'OKWEEZI: ____________________________ (dd; mm; yr)
3. EIZIINA RY'ORI KUBUUZA EBIBUUZO: ______________________________
4. EIZIINA RY'ORIKUBUUZIBWA *(AHA KUHANDIIKWA HONKA)*: ______________________________
5. AKAMANYISO K'OMUNTU ORIKUBUUZIBWA *(AKAMANYISO K'OMUNTU AHA KUHANDIIKWA HONKA)*: ______________________________
6. AKAMANYISO KAMAKA *(AKAMANYISO KAMAKA AHA KUHANDIIKWA HONKA)*: ______________________
7. YOREKA KU AKAMANYISO K'OMUNTU ORIKUBUUZIBWA AKASYA KAHANDIKIRWE
   - ☐ EEGO
   - ☐ INGAAHA
   - ☐ AKAMANYISO KAYIKIRIZIBWA MUKURUWABACOONDOZI: _______________
8. OBUHANGWA BW'OMUNTU *(AHA KUHANDIIKWA HONKA)*:
   - ☐ MUSHAIJA
   - ☐ MUKAZI
9. ORIKUBUZIBWA NAMANYA EMYAKA YE?
   - ☐ EEGO
   - ☐ INGAAHA
10. OINE EMYAKA ENGAHI? ______________________________

    *TEBEREZA EMYAKA **EKI KIKORWE HONKA YABA ARIKUMANYA MYAKA YE**:*

    - ☐ AHANNSI Y'OMWAKA GUMWE
    - ☐ OMWAKA GUMWE KUHIKA AHA MYAKA ETAANO
    - ☐ EMYAKA MUKAAGA KUHIKA AHA MYAKA IKUMI N'EBIRI
    - ☐ EMYAKA IKUMI N'ESHATU KUHIKA AHA MYAKA ABIRI N'ESHATU
    - ☐ EMYAKA ABIRI N'ENA KUHIKA AHA MYAKA ASHATU N'ETAANO
    - ☐ EMYAKA ASHATU NA MUKAAGA KUHIKA AHA MYAKA ANA NA MUSHANJU
    - ☐ EMYAKA ANA NA MUNAANA KUHIKA AHA MYAKA ATAANO NA MWENDA
    - ☐ EMYAKA NKAAGA, NINGA AHAIGURU
    - ☐ INGAAHA

Location (i.e. village):_

Today's Date:_______(dd; mm; yr)

Interviewer name: ___________

Participant name):

________________

Individual ID:

___________________

Household ID:

____________________

Indicate if a new code was generated for this participant
- ☐ Yes
- ☐ No

Code approved: ___________

Sex:
- ☐ Male
- ☐ Female

Does this participant know his/her age?
- ☐ Yes
- ☐ No

Age: _____

*Estimate age range (only if unknown*
- ☐ < 1 year
- ☐ 1-5 years
- ☐ 6-12 years
- ☐ 13-23 years
- ☐ 24-35 years
- ☐ 36-47 years
- ☐ 48-59 years
- ☐ ≥60 years
- ☐ No response

11. EBY'OBWEGYESE: RONDAHO AHARI EBI EKIRIKWIRIRIRA OBWEGYESE BWAWE?
- ☐ TINKAZAGA MU ISHOMERO, TINDIKUBAASA KUHANDIIKA NINGA KUSHOMA
- ☐ TINKAZAGA MU ISHOMERO, NIMBAASA KUHANDIIKA N'OKUSHOMA
- ☐ NASARE
- ☐ NKASHOMAHO PURAYIMARE, TINDAGIMAZIRE
- ☐ NKAMARA PURAYIMARE
- ☐ NKAMARA SINIYA YAKANA
- ☐ ITENDEKYERO BWANYIMA YA SINIYA
- ☐ TARI KUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

What is the highest education you have attained?
- ☐ No formal schooling (cannot read or write)
- ☐ No formal schooling (can read or write)
- ☐ Primary incomplete
- ☐ Primary complete
- ☐ Secondary complete
- ☐ Higher education of any form
- ☐ Unsure
- ☐ No response

12. *ABO BOONA ABIANE OBWEGYESE AHIAGURU* OMU ISHOMERO OKAMARA MU EMYAKA ENGAHI? *(AHA KUHANDIIKWA HONKA)*
- ☐ EMYAKA YENYINI:____________________
- ☐ TARI KUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

*If yes to formal education:* How many years of formal schooling do you have in total?
- ☐ Specify: _______years
- ☐ Unsure
- ☐ No response

13. OINE OMURIMO OGURI KUKUHA ENTAASYA EBIRO EBI? INGAAHA, GYENDA AHA KIBUUZO 17.
- ☐ EEGO: NINTUNGA OMUSHAARA, RIJARIJA
- ☐ EEGO: NINYEKOZESA
- ☐ EEGO: KWONKA TINYINE NTAASYA
- ☐ INGAAHA *[GYENDA AHA KIBUUZO 19]*
- ☐ TARI KUKIHAMYA KURUNGI *[GYENDA AHA KIBUUZO 19]*
- ☐ YAAHUNAMA *[GYENDA AHA KIBUUZO 19]*

Are you currently employed? *If no, skip to Question 17.*
- ☐ Yes: Paid employment
- ☐ Yes: Self-employment
- ☐ Yes: Non-paid employment
- ☐ No
- ☐ Unsure
- ☐ No response

14. *YAABA NATUNGA OMUSHAARA, NINGA RIJARIJA OMU KIBUUZO 15,* OMURIMO KI OGWORIKUKORA?
- ☐ OBWIRE BWONA
- ☐ NINKORA RIMWE NA RIMWE, BUTOOSHA
- ☐ NINKORA OMU SIZOONI EMIRIMO YAAREEBEKA
- ☐ OBU NAGUBONA BWONKA; NOKURONDARONDA
- ☐ TARI KUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

*If yes to above question: In what capacity are you currently employed?*
- ☐ *Full-time employment*
- ☐ *Part-time stable employment*
- ☐ *Seasonal employment*
- ☐ *Ad-hoc or odd-jobs*
- ☐ *Unsure*
- ☐ *No response*

15. *YAABA NATUNGA OMUSHAARA, NINGA RIJARIJA OMU KIBUUZO 15:* OMURIMO GWAAWE GWENYINI NI GUHA?
- ☐ EKYO EKI ARIKUKORA/OMURIMO GWENYINI: ______________
- ☐ TARI KUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

*If yes to above question:* What is your main occupation?
- ☐ Specify: _____________
- ☐ Unsure
- ☐ No response

16. *YAABA NATUNGA OMUSHAARA, NINGA RIJARIJA OMU KIBUUZO 15*: NI MIRIMO KI ENDIIJO ERIKUKUTAAHIZA AKASENTE?
- ☐ EKYO KYENYINI EKI ARIKUKORA: ______________
- ☐ TAINE MIRIMO ENDIIJO
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

*If yes to above question:* What are your secondary occupations?
- ☐ Specify: _____________
- ☐ No secondary occupations
- ☐ Unsure
- ☐ No response

## EKICWEKA B - OKUCOONDOZA AHA BY'AMAGARA

*PART B Clinical evaluation*

17. OINE ENDWARA YOONA EY'ORUBEERERA? *(NKA TB/KAKONKO; OMUTIMA, SHUKAARI)*
    - ☐ EEGO/ NDWARA KI YENYINI: ___________________________
    - ☐ INGAAHA
    - ☐ TARIKUKIHAMYA KURUNGI
    - ☐ YAAHUNAMA

Do you have any chronic pre-existing medical conditions? (TB, heart disease, respiratory disease, diabetes)
- ☐ Yes (specify): _____________
- ☐ No
- ☐ Unsure
- ☐ No response

*18.* WAAHURIRA KUBI OMU MAGARA, NINGA WAARWARA, NOOKIRA KWERAGURIRA OTA OMU BWIIRE OBWO? *TOORANAHO EBIGARUKWAMU BYOONA EBIRIKUBAASIKA.*
    - ☐ NINKOZESA EMIBAZI Y'EKISHAKA HAIHI N'EKA, KURUGA OMU BISHAKA BYA HAIHI
    - ☐ NINZA KW'EBUUZA AHA MUSHAHO W'EKIRAGUJU
    - ☐ NINZA OMU IRWAARIRO ERINDI HAIHI
    - ☐ NINGURA OMUBAZI AHA DUUKA
    - ☐ TINYINE EKI NDIKUKORA, "NINDWARA MABOGO"
    - ☐ HAABA HARIHO EKINDI EKI ORI KUKORA WAAHURIRA WAARWARA, NI KI: ____________________________
    - ☐ TARIKUKIHAMYA KURUNGI
    - ☐ YAAHUNAMA

When you feel sick, how do you regularly treat ailments? *Select all that apply*
- ☐ Use traditional herbs or medicines grown around house or nearby
- ☐ Consult a traditional medical practitioner
- ☐ Visit local hospital or nearest health centre
- ☐ Take over-the-counter medication
- ☐ Do nothing
- ☐ Other (specify): ___________
- ☐ Unsure
- ☐ No Response

## EKICWEKA C - EBIRIKUREETA ENDWARA ENSHONGA EZIMWE EZIRIKURETERA ABANTU BAATUNGA EBIZIBU/OBURWAIRE

*PART C: Risk factors*

19. OMU KIRO ONYAMIRE OMU KATIIMBA K'ENSIRI
    - ☐ EEGO
    - ☐ INGAAHA
    - ☐ TARIKUKIHAMYA KURUNGI
    - ☐ YAAHUNAMA

Did you sleep under a mosquito net **last night?**
- ☐ Yes
- ☐ No
- ☐ Unsure
- ☐ No response

20. *YAABA YAAGIRA NGU "EEGO" OMURI 19,* AKO KATIIMBA AKU ONYAMIREMU OMU KIRO NI AKO AKAKOREIRWEMU OMUBAZI GWAKO OMU FAKITORE, NINGA OMUBAZI GW'AKO GUTEIRWEMU BUTEEKWA OMU EMYEEZI NKA IKUMI N'EBIRI EHINGWIRE?
    - ☐ EEGO
    - ☐ INGAAHA
    - ☐ TARIKUKIHAMYA KURUNGI
    - ☐ YAAHUNAMA

*If yes to question 19,* Was the net you slept under either a factory-treated bednet or one that was treated with insecticide in the past 12 months?
- ☐ Yes
- ☐ No
- ☐ Unsure
- ☐ No response

21. *WHERE DID YOU GET YOUR NET?*

_______________________________________

Where did you get your net?

_______________________

22. IJUUKA NK'ESAANDE EBIRI EZIHINGWIRE, KUTWARIRA HAMWE NOOMARA OBWIRE BURI KWINGANA KI **OMU IZOOBA** (AKASHEESHE KUHIKA OMU MWABAZYO) OMU MYANYA EGI AHEIFO? *KYEBERA AKABOKISI KAMWE KONKA BURI RUNYIRIRI.*

Thinking about the past 2 weeks, on average, approximately what proportion of the day (from sunrise to sundown) do you spend in the following locations? Check only one box for each row.

| | TIBURIHO<br>None | AHANSI Y'EKICWEKA KY'EIZOOBA<br>Less than half the day | NK'EKICWEKA KY'EIZOOBA<br>About half the day | AHAIGURU Y'EKICWEKA KY'EIZOOBA<br>More than half the day | EIZOOBA RYONA<br>All day | TARIKUKIHAMYA KURUNGI<br>Unsure | YAAHUNAMA<br>No response |
|---|---|---|---|---|---|---|---|
| HAIHI N'EKA/ENJU<br>In/ around the home | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| HAIHI N'EISIBIKIRO/ENJU ZA MATUNGO<br>In/around animal sheds | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| OMU MISIRI NINGA EIRISIZO<br>In the fields/ cropland/ pasture | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| OMU KIBIRA<br>In the forest/ woodland | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| HAIHI N'OMUGYERA NINGA ENYANJA<br>On/ by the river or lake | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| EBINDI, SHOBORORA<br>Other (specify):<br>__________________ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

23. IJUUKA NK'ESAANDE EBIRI EZIHINGWIRE, KUTWARIRA HAMWE, NOOMARA OBWIRE BURI KWINGANA KI **OMU KIRO** (OMWABAZYO KUHIKA OMU KASHEESHE) OMU MYANYA EGI AHEIFO? *KYEBERA AKABOKISI KAMWE KONKA BURI RUNYIRIRI.*

Thinking about the past 2 weeks, on average, approximately what proportion of the night (from sundown to sunrise) do you spend in the following locations? *Check only one box for each row.*

| | TIBURIHO<br>None | AHANSI Y'EKICWEKA KY'EIZOOBA<br>Less than half the night | NK'EKICWEKA KY'EIZOOBA<br>About half the night | AHAIGURU Y'EKICWEKA KY'EIZOOBA<br>More than half the night | EIZOOBA RYONA<br>All night | TARIKUKIHAMYA KURUNGI<br>Unsure | YAAHUNAMA<br>No response |
|---|---|---|---|---|---|---|---|
| HAIHI N'EKA/ENJU<br>In/ around the home | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| HAIHI N'EISIBIKIRO/ENJU ZA MATUNGO<br>In/around animal sheds | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| OMU MISIRI NINGA EIRISIZO<br>In the fields/ cropland/ pasture | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| OMU KIBIRA<br>In the forest/ woodland | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| HAIHI N'OMUGYERA NINGA ENYANJA<br>On/ by the river or lake | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| EBINDI, SHOBORORA<br>Other (specify):<br>_________________ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

24. *OMU BIRO ABIRI NA MUNAANA EBIHINGWIRE, OMU BIRO EBYO ABIRI NA MUNAANA, NIBINGAHI EBI OTARAIRE OMURI EKI KYARO AHEERU Y'EKYARO?*

- ☐ TINKARAARAGA AHEERU Y'EKYARO
- ☐ EIZOOBA RIMWE
- ☐ EBIRO BIBIRI- KUHIKA MUSHANJU
- ☐ EBIRO MUNAANA –KUHIKA IKUMI NA BINA
- ☐ EBIRO IKUMI NA BINA N'OKWEYONGYERAYO
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

In the past month (28 days), approximately how many days (or nights) did you sleep outside of the settlement?

- ☐ Never
- ☐ One day
- ☐ 2-7 days
- ☐ 8-14 days (one to two weeks)
- ☐ More than 14 days (>2 weeks)
- ☐ Unsure
- ☐ No response

25. *YAGIRA NGU EEGO AHAIGURU, YOREKA AHI YATAMBURIRE:*

_______________________________________________

If yes to above, indicate where the participant travelled:

_______

26. *OKUTWARIRA HAMWE/ OINE OKUNANUKA/OKUSHEMERERWA KURI KWINGANA KI OMU MAGARA GAAWE?*

- ☐ TINYINE KUNANUKA NA KAKYE
- ☐ TINYINE KUNANUKA KURI AHO
- ☐ TINDI KUBAASA KUGIRA NGU NYINE OKUNANUKA NINGA TINKWINE
- ☐ NYINE OKUNANUKA KUKYE KUKYE
- ☐ NSHEMEREIRWE KANDI NYINE OKUNANUKA KWINGI
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

Taking it all together, how satisfied are you currently with your life as a whole?

- ☐ Very dissatisfied
- ☐ Moderately dissatisfied
- ☐ Neither dissatisfied or satisfied
- ☐ Moderately satisfied
- ☐ Very satisfied
- ☐ Unsure
- ☐ No response

## EKICWEEKA E: ENDWARA Z'OKUTANAKA, N'OKWIRUKANA, EZAMAANI

*PART E: Acute Gastrointestinal Illness*

27. OMU SAANDE IBIRI EZIHINGWIRE, OTUNGIREHO ENDWARA Y'OKUTANAKA NINGA OKWIRUKANA? ENDWARA Y'EKIRUKANO/EKIRUKANO NIKIMANYISA KWEJUNA EMIRUNDI ERI KURENGA ESHATU OMU SHAAHA ABIRI N'INA, OBWO ORIKUSHOHOZA AMAAZI GOOROBIRE/GATOTSIRE MUNONGA. *YAAGIRA NGU INGAAHA, GYENDA AHA KICWEKA F, EKIBUUZO 46.*
    - ☐ EEGO
    - ☐ INGAAHA, *[GYENDA AHA KIBUUZO 46]*
    - ☐ TARIKUKIHAMYA KURUNGI, *[GYENDA AHA KIBUUZO 46]*
    - ☐ YAAHUNAMA, *[GYENDA AHA KIBUUZO 46]*

In the past two weeks, did you experience any illness that included vomiting or diarrhoea? Diarrhoea is considered to be 3 or more loose stools in a 24 hour period. *If no, skip to Part F, question 46.*
- ☐ Yes
- ☐ No *[Skip to Q46]*
- ☐ Unsure *[Skip to Q46]*
- ☐ No response *[Skip to Q46]*

| | |
|---|---|
| ***YAAGIRA ATI: EEGO,*** GUMIZAMU<br>***YAAGIRA ATI: INGAAHA,*** Guruka ebibuzo eby'ekirukano ebirikweyongyerayo ogyende aha kibuzo 42 | ***If YES***: *Continue*<br>***IF NO:*** *Please skip the remaining AGI questions and proceed to Q46* |

| | |
|---|---|
| ***NINKUSHABA OGARUKEMU EBIBUUZO EBI, NIBIKWATA AHA NDWARA Y'OKUTANAKA NINGA EKIRUKANO EBI OGIZIREHO JUBA JUBA OBWIRE BWA HAIHI.*** | ***Please answer the rest of these questions for your most recent experience of vomiting or diarrhoea.*** |

28. OBU WAAKIMANYA NGU OINE ENDWARA Y'EKIRUKANO NINGA OKUTANAKA, BIKABA BIRI EBIRO BINGAHI?

    *ORIKUBUUZA EBIBUUZO: OMUNTU YAAGARUKAMU OBWIRE BURIKWOREKA NGU ESAANDE EMWE YOONA EHWEIREHO. NOOSHABWA KUHANDIIKA EBIRO EBIRI AHAGATI Y'ESAANDE EYAYOREKWA*
    - ☐ EBIRO BY'OKWEZI (SHOBORORA): ____________________
    - ☐ TARIKUKIHAMYA KURUNGI
    - ☐ YAAHUNAMA

What was the date you first noticed you were ill? *Interviewer: If a week is given, then default to middle of week.*
- ☐ Date (specify): ____________
- ☐ Unsure
- ☐ No response

29. OBU OSHEMBIREYO KURWARA OKATUNGA OKUTANAKA? *YAAGIRA NGU INGAAHA/ GYENDA AHA KIBUUZO 32.*
    - ☐ EEGO
    - ☐ INGAAHA *[GYENDA AHA KIBUUZO 32]*
    - ☐ TARIKUKIHAMYA *[GYENDA AHA KIBUUZO 32]*
    - ☐ YAAHUNAMA *[GYENDA AHA KIBUUZO 32]*

During your most recent illness, did you experience any vomiting? *If no, skip to question 32.*
- ☐ Yes
- ☐ No *[Skip to Q32]*
- ☐ Unsure *[Skip to Q32]*
- ☐ No response *[Skip to Q32]*

30. *YAAGIRA NGU EEGO OMU KIBUUZO 29:* OKUTANAKA KUKAMARA EBIRO BINGAHI? *TOORANA EBYO BYOONA EBIRI KUKUKWATAHO.*
    - ☐ AMAZOOBA / (OMUHEENDO GWONA): ______AMAZOOBA
    - ☐ NINKITANAKA MPAKA N'ERIZOOBA
    - ☐ TARIKUKIHAMYA
    - ☐ YAAHUNAMA

*If yes to question 29:* How many days did it last? *Select all that apply.*
- ☐ Specify: ______days
- ☐ Still vomiting today
- ☐ Unsure
- ☐ No response

31. *YAAGIRA NGU EEGO OMU KIBUUZO 29:* OBW'OKUTANAKA KWABIRE KURI KWINGI, OKATANAKA EMIRUNDI ENGAHI OMU MUSHANA N'EKIRO?
    - ☐ SHOBORORA (OMUHENDO GWONA): _______________
    - ☐ KUKAGUMIZAMU OBUTAISYA
    - ☐ TARIKUKIHAMYA
    - ☐ YAAHUNAMA

*If yes to question 29:* When your illness was its most severe, what was the maximum number of times you vomited in a 24 hour period?
- ☐ Specify: _____________
- ☐ Constant vomiting
- ☐ Unsure
- ☐ No response

32. OBU OSHEMBIREYO KURWARA, OTUNGIRE EKIRUKANO? *ENDWARA Y'EKIRUKANO NIKIMANYISA KWEJUNA EMIRUNDI ERI KURENGA ESHATU OMU SHAAHA ABIRI N'INA, OBWO ORIKUSHOHOZA AMAAZI GOOROBIRE/GATOTSIRE MUNONGA . YAAGIRA NGU INGAAHA, GYENDA AHA KIBUUZO 36.*
    - ☐ EEGO
    - ☐ INGAAHA *[GYENDA AHA KIBUUZO 36]*
    - ☐ TARIKUKIHAMYA *[GYENDA AHA KIBUUZO 36]*
    - ☐ YAAHUNAMA *[GYENDA AHA KIBUUZO 36]*

During your most recent illness, did you experience any diarrhoea? *Diarrhoea: 3 or more loose stools in 24 hours. If no, skip to question 36.*
- ☐ Yes
- ☐ No *[Skip to Q36]*
- ☐ Unsure *[Skip to Q36]*
- ☐ No response *[Skip to Q36]*

33. *YAAGIRA NGU EEGO OMU KIBUUZO 32:* KIKAMARA EBIRO BINGAHI? *TOORANA BYOONA EBIRI KUKUKWATAHO.*
    - ☐ OMUHENDO: _______EBIRO
    - ☐ NINKIRUKANA MPAKA N'ERIZOOBA
    - ☐ TARI KUKIHAMYA
    - ☐ YAAHUNAMA

*If yes to question 32:* How many days did it last? *Select all that apply.*
- ☐ Specify: _______days
- ☐ Still have diarrhoea today
- ☐ Unsure
- ☐ No response

34. *YAAGIRA NGU EEGO OMU KIBUUZO 32:* OBU EKIRUKANO KYAABIRE KIIRI KYINGI MUNONGA, OKABA OYEJUNA EMIRUNDI ENGAHI OMU BWIRE BW'ESHAAHA ABIRI N'INA?
    - ☐ SHOBORORA: _____________(EMIRUNDI)
    - ☐ EKIRUKANO KIKAGUMIZAMU
    - ☐ TARIKUKIHAMYA
    - ☐ YAAHUNAMA

*If yes to question 32:* When your diarrhoea was the most severe, what was the maximum number of loose stools you had in a 24 hour period?
- ☐ Specify: ____________
- ☐ Continual diarrhoea
- ☐ Unsure
- ☐ No response

35. *YAAGIRA NGU EEGO OMU KIBUUZO 32*: OBUWAABIRE NOYIRUKANA, OKAREEBAHO ESHAGAMA YOONA?
    - ☐ EEGO
    - ☐ INGAAHA
    - ☐ TARIKUKIHAMYA
    - ☐ YAAHUNAMA

*If yes to question 32:* At any time during your illness, did you have any blood in your stool?
- ☐ Yes
- ☐ No
- ☐ Unsure
- ☐ No response

36. OBU WAABIRE ORWAIRE NK'OKU WAANGAMBIRA, OBU WAABIRE NOTANAKA NOYIRUKANA, OKATUNGAHO OKUSHAASHA OKUNDI NK'OKU? *(TOORANA EBY'O BYOONA EBIRI KUKUKWATAHO)*
- ☐ KWENDA KUTANAKA/ KUGIRA ESHESHEMI
- ☐ KUHURURWA OMUNDA
- ☐ KUGIRA EKITEENGO/ KUGIRA OMURIRO
- ☐ KUTETEMA
- ☐ KUHURURWA OMU NYAMA/ENGINGO, KUNANA
- ☐ KUTEERWA OMUTWE
- ☐ KUGIRA EIRIHO RIINGI/ EKYAKA
- ☐ KUHURIRA AKAZEINGERERA/KURUHA/KUHURIRA OBURUHE BWINGI
- ☐ KURUMWA, KUSHAHSA EMIMIRO/ KUGIRA SENYIGA, EBIHIINZI
- ☐ KUKORORA NINGA KWETSYAMURA
- ☐ OBUMANYISO BW'ENDWARA OBUNDI (SHOBORORA): ________
- ☐ INGAAHA, TINDATUNGIRE BUNDI BUMANYISO/ OKUSHAASHA OKUNDI
- ☐ TARIKUKIHAMYA
- ☐ YAAHUNAMA

During the illness you just described, where you had vomiting or diarrhoea, did you also experience any of the following (*please select all symptoms that you DID experience*)?
- ☐ Nausea
- ☐ Stomach cramps or abdominal pain
- ☐ Fever
- ☐ Chills
- ☐ Muscle or joint pain or stiffness
- ☐ Headache
- ☐ Excessive thirst
- ☐ Lethargy or extreme tiredness
- ☐ Sore throat or runny nose
- ☐ Coughing or sneezing
- ☐ Other symptom (specify): ____
- ☐ No, I did not have any other symptoms
- ☐ Unsure
- ☐ No response

37. **OTAKAKWASIRWE KUTANAKA N'ENCUGURA NK'OKU WANGIRA**, OKAMIRAHO EMIBAZI EGI *(SHOBORORA EMIBAZI YOOZA EYI WAAKOZEISE)?*
- ☐ NKA SEPTRINE, EHEIRWE OMUSHAHO *(e.g. Septrine)*
- ☐ Laxatives *(EMIBAZI ERIKUTAMBA EKYATA)*
- ☐ Antacids *(EMIBAZI ERIKUTAMBA EKYATA)*
- ☐ EMIBAZI ENDIIJO YOONA ERIKUMANYWA KUCENDEEZA AMAANI G'OMUBIRI KURWANISA ENDWARA
- ☐ EMIBAZI Y'EBISHAKA ENDIIJO ERIKUMANYWA KURETERA OGWO OWAGIKOZESA OKUTANAKA NINGA EKIRUKANO
- ☐ INGAAHA, TINDAKOZEISE MUBAZI GWONA **NTAKATUNGIRE** KIRUKANO N'OKUTANAKA
- ☐ TARIKUKIHAMYA
- ☐ YAAHUNAMA

Before you developed the vomiting or diarrhoea you just described, did you take any of the following medications (*please select all medications that you DID take*)?
- ☐ Prescription antibiotics
- ☐ Laxatives
- ☐ Antacids
- ☐ Medications or medical treatments known to weaken the immune system
- ☐ Medications, known to cause diarrhoea or vomiting as a side effect
- ☐ No, I did not take any medication before my illness
- ☐ Unsure
- ☐ No response

38. AHABW'OKURWARA OKWO OKU WAANGAMBIRAHO, OKAREMWA KUKORA EMIRIMO YAWE? *(SHOBORORA EBYO BYOONA EBIWAAREMIRWE KUKORA AHABW'OKURWARA).*
- ☐ EMIRIMO YAAWE YA BUTOOSHA
- ☐ KWOSHA AHA MURIMO OGURI KUKUTAAHIZA SENTE, KW'EKOZESA NINGA EISHOMERO
- ☐ EMIRIMO Y'OBUHANGWA NK'OKUHIIGA, KUSHOHA EBYENYANJA, KUKORA EBINTU BY'EMIKONO
- ☐ INGAAHA, ENDWARA TERANDEMESIZE KUKORA EMIRIMO YANGYE YA BUTOOSHA
- ☐ INGAAHA, ENDWARA TERANDEMESIZE KUKORA EMIRIMO YANGYE YA BUTOOSHA, **KWONKA**, OMUNTU ONDIIJO OMUKA YANGYE AKAREMWA KUZA KUKORA YAAGUMA AHO KUMPA OBUYAMBI AHABW'OKUGIRA NGU NKABA NDWAIRE.
- ☐ TARIKUKIHAMYA
- ☐ YAAHUNAMA

As a result of your illness, did you have to miss any (*please select all items that you DID miss*):
- ☐ Usual daily activities
- ☐ Paid employment, including self-employment, or school
- ☐ Traditional activities (e.g. hunting, fishing, crafting, etc.)
- ☐ No, the illness did not stop me from performing my usual activities
- ☐ No, the illness did not stop me from performing my usual activities, but someone in my family had to miss employment to care for me as a result of my illness
- ☐ Unsure
- ☐ No response

39. HARIHO OMUNTU ONDIIJO WEENA, NK'OMUSHAHO, NAANSI, OMUFUMU OU WAAHIKIRIRE KUKUYAMBA?
- ☐ EEGO *[GYENDA AHA KIBUUZO 41]*
- ☐ INGAAHA *[GUMIZAMU AHA KIBUUZO 40]*
- ☐ TARIKUKIHAMYA KURUNGI *[GYENDA AHA KIBUUZO 43]*
- ☐ YAAHUNAMA *[GYENDA AHA KIBUUZO 43]*

Did you see someone for this illness? *For example, a physician, nurse, pharmacist, herbalist, or spiritual or traditional medicine practitioner.*
- ☐ Yes *[Skip to Q41]*
- ☐ No *[Continue to Q40]*
- ☐ Unsure *[Skip to Q43]*
- ☐ No response *[Skip to Q43]*

40. *YAAGIRA NGU INGAAHA OMU KIBUUZO 39:* NI NSHONGA KI EYARETSTIRE WASHARAMU OBUTAZA W'OMUSHAHO KUMWEBUUZAHO AHA BURWAIRE OBWO? OTASHOMERA ORIKUBUUZIBWA EBIGARUKWAMU. *TOORANA ENSHONGA EISHATU EZ'OKUBANZA, REERU OKYEBERE. HAANDIIKA OMU BURAINGWA EBYO BYOONA EBI YAAGAMBA. KYABA NIKYETENGESA, NOOBAASA KUBUUZA OTI: HARIHO ENSHONGA ENDIIJO YOONA?*
- ☐ TINDAKIFIREHO, EBY'OKURAGUZA TINDABIFIREHO
- ☐ OKUBURWA SENTE
- ☐ NKABA NDI AH'EITAKA
- ☐ OMUSHAHO ARI HARE NAANYE, ORUGYENDO RWA HARE
- ☐ OMUSHAHO/NAANSI TARIKUREEBEKA OMU BWIRE OBU ORIKUBA NOMWENDERAMU
- ☐ KUREEBA OMUSHAHO NIKYETENGESA OKURINDA OBWIRE BWINGI
- ☐ KUREEBA OMUSHAHO KIKABA KITARIKWIJA KUMPWERA MUNONGA
- ☐ NKABA NYINE BINGI EBY'OKUKORA/ NKABA NTAINE BWIRE
- ☐ OBURWAIRE BUKEGYENDERA BWONKA NTAKAHIKIRE AHAKUZA OW'OMUSHAHO
- ☐ AH'OKUZA NKABA NTARIKUHAMANYA
- ☐ OBUREMEEZI BW'ENGYENDA N'ENTAMBURA
- ☐ OBUREMEEZI BW'ORURIMI
- ☐ OBUJUNAANIZIBWA OBINDI NK'OMUNTU/HAMWE N'E BY'AMAKA/
- ☐ OBUTAKUNDA/OBUTEESIGA BASHAHO/NAANSI, KUTIINA ABASHAHO
- ☐ EBINDI, SHOBORORA:_________________
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

*If no to question 39:* What was the reason you decided not to see someone for this illness? *Do not read reasons. Select first three reasons mentioned or write verbatim what the respondent said. If necessary, prompt by asking, "Were there any other reasons?"*
- ☐ Was not serious enough to seek health care services
- ☐ Financial difficulty
- ☐ Was out on the land
- ☐ Not available in the area, don't have a physician
- ☐ Not available at the time required (e.g. doctor or nurse on holidays, inconvenient hours)
- ☐ Waiting time too long
- ☐ Felt it would be inadequate / wouldn't make a difference to the outcome
- ☐ Too busy
- ☐ Didn't get around to it / Illness were over before care could be sought
- ☐ Didn't know where to go
- ☐ Transportation problems
- ☐ Language problems
- ☐ Personal or Family responsibilities
- ☐ Dislikes or distrusts doctors or nurses, afraid
- ☐ Other (specify):___________
- ☐ Unsure
- ☐ No response

***GYENDA AHA KIBUUZO 43***

***SKIP to Question 43***

41. *YAAGIRA NGU EEGO OMU KIBUUZO 39:* OKARAGUZA HABASHAHO KI OBU WAABIRE ORWAIRE?
- ☐ OMUSHAHO
- ☐ MUKURU W'EDINI
- ☐ NAANSI
- ☐ OMUSHAHO W'EMIBAZI Y'EBISHAKA
- ☐ AHA MUNTU ORI KUTUNDA EMIBAZI
- ☐ ABANDI, SHOBORORA:_______________________
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

*If yes to question 39:* What types of health care providers did you see for this illness?
- ☐ Physician
- ☐ Spiritual/Religious healer
- ☐ Nurse
- ☐ Herbalist
- ☐ Pharmacist
- ☐ Other (specify):___________
- ☐ Unsure
- ☐ No response

42. *YAAGIRA NGU EEGO OMU KIBUUZO 39:* NI NSHONGA KI EZAKURETEIRE WAARAHUKA KUGIRA NGU ORAGUZE OW’OMUSHAHO/NAANSI NINGA OMUSHAHO W’EMIBAZI Y’EKISHAKA?

*OTASHOMERA ORIKUBUUZIBWA EBIGARUKWAMU EBI. TOORANA ENSHONGA EISHATU EZ’OKUBANZA, REERU OKYEBERE. HAANDIIKA OMU BURAINGWA EBYO BYOONA EBI. KYABA NIKYETENGESA, NOOBAASA KUBUUZA OTI: HARIHO ENSHONGA ENDIIJO YOONA? KOZESA EBY’OKUREEBERAHO KYABA NIKYETENGESA.*

- ☐ OBUMANYISO BW’ENDWARA BUKAMARA OBWIRE BURAINGWA/
- ☐ NKAHURIRA OBURWAIRE BUNDI KUBI KYAYETENGESA KURAGUZA
- ☐ OBUMANYISO BW’ENDWARA NKABA NTAKABUREEBAHOGA
- ☐ NKABA NYINE OMUSHWEIJA MWINGI
- ☐ NKABA NINTANAKA
- ☐ NKABA NYINE EKIRUKANO
- ☐ NKABA NINSHOHOZA AMAZI GARIMU ESHAGAMA
- ☐ NKABA NINYENDA EMIBAZI
- ☐ EBINDI/ SHOBORORA:____________________
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

*If yes to question 39:* What were the main factors that influenced your decision to see a doctor, nurse, or other health care provider for your illness?
*Do not read reasons. Select first three reasons mentioned or type verbatim what the respondent said. If necessary, prompt by asking, “Were there any other reasons?” You can provide examples if needed for prompts.*

- ☐ Symptoms lasted a long time
- ☐ Felt sick enough to go
- ☐ Symptoms were unusual
- ☐ Had a fever
- ☐ Had vomiting
- ☐ Had diarrhoea
- ☐ Stools were bloody
- ☐ Wanted medication(s)
- ☐ Other (specify):__________
- ☐ Unsure
- ☐ No response

43. OKAKOZESAHO EMWE AHA MIBAZI EGI KWERAGURIRA OBURWAIRE OBWO? *TOORANAHO EGYO YOONA EYI OBAASA KUBA WAAKOZESIZE. [ENSI/ EBICWEKA NIBIBAASA KWONGYERA AHA MUSHORORONGO GW’EMIBAZI OGU KURUGIRIRA AHA MIRINGO Y’AYO NINGA AMAZIINA G’AYO, KYABA NIKYETAAGISA*

- ☐ EMIBAZI Y’EBISHAKA KURUGA OMU MUSIRI
- ☐ EMIBAZI Y’EKISHAKA KURUGA OW’OMUSHAHO W’EMIBAZI Y’EKISHAKA
- ☐ OKUSHABIRWA,EIROGO
- ☐ OMUBAZI KURUGA OW’OMUSHAHO (SHOBORORA):______________
- ☐ EMIBAZI ERI KURWANISA OBUHURUZI/OBUSAASI NKA PANADO NA ASIPIRINI
- ☐ EMIBAZI Y’EKIRUKANO
- ☐ EBY’ONYO EBIRI KUGARURA AMAIZI OMU MUBIRI
- ☐ OMUBAZI OGUNDI GWONA OGUTARA KUHEIRWE MUSHAHO/ (MUBAZI KI/ SHOBORORA): ____________________
- ☐ INGAAHA, TINDAKOZESIZE MUBAZI GWONA
- ☐ TARIKUHAMYA KURUNGI
- ☐ YAAHUNAMA

Did you take any of the following medications for this illness? *Select all that apply.*

- ☐ Herbal remedies from garden
- ☐ Herbal remedies from traditional practitioner
- ☐ Spiritual remedies (e.g. spells, prayer)
- ☐ Prescription medication (specify): ______
- ☐ Pain killers like panadol, asprin
- ☐ Antidiarrheal like, Lomotil or Peptol Bismol
- ☐ Rehydration therapies like Pediolyte, oral rehydration
- ☐ Other non-prescription medication (specify): ______
- ☐ No, I did not take any medications
- ☐ Unsure
- ☐ No response

44. NOOTEEKATEEKA NGU ENDWARA EGYO EKARETWA KI? *OTASHOMERA ORIKUBUUZIBWA EBIGARUKWAMU. TOORANA ENSHONGA EZIRI KUBANZA ISHATU ZOONKA NINGA HAANDIIKA BYOONA NK'OKUYABIGAMBA. KYABA NIKYETENGESA, NOOBAASA KUBUUZA ENSHONGA ENDIIJO EYI ENDWARA EGYO YARABIREMU KUMUKWATA OTI: HARIHO ENSHONGA ENDIIJO EYI ORI KUMANYA? KOZESA EBY'OKUREEBERAHO*
   - ☐ SENYIGA/EKIHIINZI
   - ☐ KURYA MUNONGA EBY'OKURYA BIGAGIRE
   - ☐ KUNYWA AMAIZI GAMAROFA
   - ☐ KURYA EBY'OKURYA BIRIMU EBISHAJU/N' ENSHENDA
   - ☐ KUNYWA EBIRI KUSIINZA/AMAARWA N'EBINDI MUNONGA
   - ☐ OMUBIRI KWANGA EBY'OKURYA
   - ☐ ENDA
   - ☐ EBITEKYEREZO BINGI
   - ☐ NKAGIIHA AHA RUGYENDO, OMU MIHANDA
   - ☐ OMUBAZI OGU NAAKOZESIZE
   - ☐ NKAGABWA NYINE AMAGARA MABI
   - ☐ EBINDI, SHOBORORA:___________________
   - ☐ TARIKUKIHAMYA
   - ☐ YAAHUNAMA

In your opinion, what do you think was the cause of your illness? *Do not read reasons. Select first three reasons mentioned or type verbatim what the respondent said. If necessary, prompt by asking, "Were there any other reasons?" You can provide examples if needed for prompts.*
- ☐ A cold
- ☐ Food poisoning / Contaminated food
- ☐ Contaminated water
- ☐ Overeating / Fatty foods / Spicy foods
- ☐ Overindulgence of alcohol / other substances
- ☐ Food allergy
- ☐ Pregnancy
- ☐ Stress
- ☐ Caught something travelling
- ☐ Medication Pre-existing
- ☐ medical condition
- ☐ Other (specify):___________
- ☐ Unsure
- ☐ No response

EKICWEKA KY'EKIRUKANO KYAKOMA AHA

Ask of females only.

45. *OINE ENDA HATI?*
   - ☐ EEGO
   - ☐ INGAAHA
   - ☐ TARIKUKIHAMYA KURUNGI
   - ☐ YAAHUNAMA

Are you pregnant now?
- ☐ Yes
- ☐ No
- ☐ Unsure
- ☐ No response

## EKICWEKA F: OMUSHWEIJA OGWEGAMBIIRWE HATARIHO KUCEBERWA

*PART F: Self-Reported Fever*

46. OBAIRE WAARWAIREHO OMUSHWEIJA OMU SAANDE IBIRI EZIHINGWIRE? *OKUMANYISIBWA: KUHAMYA ORI KUKOZESA AKOMA AKARIKUKYEBERA OBUTAGATSI (SAMOMETA) TIKIRIKWETAAGISA OBWIRE OBU.TWARA EKYO EKI ORIKUBUUZIBWA YAAGAMBA KURUGIRIRA WE OKU ARI KWEHURIRA OMU MAGARA. YAAGIRA NGU INGAAHA, GYENDA AHA KIBUUZO 55.*
   - ☐ EEGO
   - ☐ INGAAHA *[GYENDA AHA KIBUUZO 55]*
   - ☐ TARIKIHAMYA KURUNGI *[GYENDA AHA KIBUUZO 55]*
   - ☐ YAAHUNAMA *[GYENDA AHA KIBUUZO 55]*

Have you been ill with a fever any time in the last 2 weeks? *Clarification: confirmation with a thermometer is not required. Response can be based on participant's personal opinion. If no, skip to question 55.*
- ☐ Yes
- ☐ No *[Skip to Q55]*
- ☐ Unsure *[Skip to Q55]*
- ☐ No response *[Skip to Q55]*

47. *WHAT DO YOU THINK **CAUSED** YOUR FEVER?*

______________________________________________

What do you think **caused** your fever?

______________________

48. *YAAGIRA NGU EEGO OMU KIBUUZO 46:* OKEEBUUZAHO AHA MUNTU WEENA NINGA KURAGUZA? *NK'OMUSHAHO, NAANSI, OMUSHAHO W'EMIBAZI Y'EBISHAKA, OMUFUMU?*
   - ☐ EEGO
   - ☐ INGAAHA *[GYENDA AHA KIBUUZO 51]*
   - ☐ TARIKUKIHAMYA *[GYENDA AHA KIBUUZO 51]*
   - ☐ YAAHUNAMA *[GYENDA AHA KIBUUZO 51]*

*If yes to question 46:* Did you seek advice or treatment for the fever from any source? *For example, a physician, nurse, pharmacist, naturopath, herbalist, or spiritual or traditional medicine practitioner. If no, skip to question 46.*
- ☐ Yes
- ☐ No *[Skip to Q51]*
- ☐ Unsure *[Skip to Q51]*
- ☐ No response *[Skip to Q51]*

49. *YAAGIRA NGU EEGO OMU KIBUUZO 48:* OKAIHAHI OKURAGURIRWA? *TOORANA EBYO BYOONA EBIRI KUKUKWATAHO.*
   - ☐ OMUSHAHO W'EMIBAZI Y"EBISHAKA
   - ☐ EIRWARIRO
   - ☐ EIRWARIRO ERIKYE
   - ☐ AHA MUSHAHO ORI KUGYENDAGYENDA
   - ☐ AHA DUUKA Y'EMIBAZI
   - ☐ AHANDI HANTU: SHOBORORA: ____________________
   - ☐ TARIKUKIHAMYA
   - ☐ YAAHUNAMA

*If yes to question 48:* Where did you seek advice or treatment? *Select all responses that apply.*
- ☐ Traditional practitioner
- ☐ Hospital
- ☐ Health centre or post
- ☐ Mobile clinic or field worker
- ☐ Pharmacy
- ☐ Other (specify): __________
- ☐ Unsure
- ☐ No response

50. *TUGAMBIRE OMUNTU OWU WAREBIRE NINGA AHU WARAGWIZE*

*Please tell us about who you saw or where you went for treatment for your fever:*

| | AMAZINA G'OMUNTU NINGA OMWANYA AHU WARAGWIZE<br>*Name of place or person you got treatment from* | OKAGYENDA ORUGYENDO RURIKWINGANAKI KUZA AHI WATUNGIRE OKURAGURIRWA (TEBEREZA OMU KM)?<br>*How far did you travel for this treatment?* | HAKAHINGURA AMAZOBA ANGAHI WAHEZA KUKWATA OMUSHIJA OBU WAREBA OMUNTU OGU NINGA OKAZA OMUMWANYA GUWARAGWIZEMU?<br>*How many days after your fever began did you first see this person/place for treatment?* |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |

51. *OMU BWIRE OBUWABEIRE ORWIRE OKIHWAHO ESHAGAMA AHA KAKUMU NINGA EKIGYERE KUGIKYEBERA?*
   - ☐ EEGO
   - ☐ INGAAHA
   - ☐ TARIKUKIHAMYA
   - ☐ YAAHUNAMA

At any time during your illness, did you have any blood taken for testing (for example from your finger or foot)?
- ☐ Yes
- ☐ No
- ☐ Unsure
- ☐ No response

52. OBU WAABIRE ORWAIRE, OKAKOZESA OMUBAZI GWONA?
   - ☐ EEGO
   - ☐ INGAAHA *[GYENDA AHA KIBUUZO 55]*
   - ☐ TARIKUKIHAMYA *[GYENDA AHA KIBUUZO 55]*
   - ☐ YAAHUNAMA *[GYENDA AHA KIBUUZO 55]*

*At any time during the illness, did you take any drugs for the fever? If no, skip to question 55.*
- ☐ *Yes*
- ☐ *No [Skip to Q55]*
- ☐ *Unsure [Skip to Q55]*
- ☐ *No response [Skip to Q55]*

53. *YAAGIRA NGU EEGO OMU KIBUUZO 52:* OKAKOZESA MIBAZI KI? *TOORANA EMIBAZI YOONA EI OBAASA KUBA WAAKOZESIZE.*
   *EMIBAZI Y'OMUSHWEIJA GW'ENSIRI*
   - ☐ FAANSIDA/ SP/Fansidar
   - ☐ KOROROKWINI/ Cholorquine
   - ☐ KOWATEMU (COARTEM) Quinine
   - ☐ ACT*(KOWATEMU)*
   - ☐ EBINDI, SHOBORORA:_______________
   - ☐ *EMIBAZI ENDIIJO*
   - ☐ ASIPIRINI
   - ☐ PANADO
   - ☐ EBINDI, SHOBORORA:_______________
   - ☐ TARIKUKIHAMYA
   - ☐ YAAHUNAMA

*If yes to question 52: What drugs did you take? Select all that apply. ANTIMALARIAL*
- ☐ *SP/Fansidar*
- ☐ *Cholorquine*
- ☐ *Amodiaquine*
- ☐ *Quinine*
- ☐ *ACT*
- ☐ *Other (specify):_____________*

*OTHER DRUGS*
- ☐ *Aspirin Acetaminophen/ Paracetamol*
- ☐ *Other (specify):__________*
- ☐ *Unsure*
- ☐ *No response*

54. *NINKUSHABA KUNGABIRAHO AHA MUBAZI GWONA OGU WAMIZIRE*

Please tell us about any medicine you took:

| | IZINA RY'OMUAZI<br>*Name of medicine* | HAKAHWAHO OBWIRE BUKWINGANAKI OMUSHWIJA GUKUKWASIRE OBU W'BANZA KUKOZESA OMUBAZI?<br>*How long after your fever started did you first take this medicine?* | OKAMARA AMAZOBA ANGAHI ORIKUKOZESA OMUBAZI OGU?<br>*How many days did you take this medicine for?* | NOKIKOZESA OMUBAZI OGU?<br>*Are you still taking this medicine?* |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |

☐ TINDAKOZISE MUBAZI GWONA
*I did not take any medicine*

55. *OINE OMUSHWEIJA, EKITEENGO ERIZOOBA?*
    - ☐ EEGO
    - ☐ INGAAHA
    - ☐ TARIKUKIHAMYA
    - ☐ YAAHUNAMA

Do you have a fever today?
- ☐ Yes
- ☐ No
- ☐ Unsure
- ☐ No response

*IF YES, PLEASE MAKE SURE THAT YOU ANSWERED 'YES' TO QUESTION 46 AND ANSWERED QUESTIONS 47-54.*

If yes, please make sure that you answered 'yes' to Q46 and answered questions 47 to 54.

56. NOOBAASA KUNGAMBIRA OKU OMUSHWEIJA GW'ENSIRI GURI KUKWATA OMUNTU? *OTASHOMERA ORIKUBUUZIBWA EBIGARUKWAMU. TOORANA EKYO EKIRI HAIHI MUNONGA N'EBYO EBIHAIRWE AHANSI, REERU OKIKYEBERE. HAANDIIKA OMU BURAINGWA EBYO BYOONA EBI YAAGAMBA. KYABA NIKYETENGESA, NOOBAASA KUBUUZA EMIHANDA ENDIIJO EYI OMUSHWEIJA GURI KURABAMU KUKWATA ABANTU/ OTI: HARIHO EMIHANDA ENDIIJO EYI ORI KUMANYA?*
    - ☐ KURUMWA ENSIRI
    - ☐ KUNYWA AMAIZI GAMAROFA
    - ☐ KURYA EBY'OKURYA EBIMWE
    - ☐ SENYIGA/EBIHIINZi
    - ☐ KUTEERWA ENJURA
    - ☐ EBYAGAANA
    - ☐ EBINDI, SHOBORORA:______________________________
    - ☐ TARIKUKIHAMYA
    - ☐ YAAHUNAMA

Can you tell me how one catches malaria? *Do not read options. Select all options mentioned or type verbatim what the respondent said. If necessary, prompt by asking, "Are there any other ways?"*
- ☐ Mosquito bites
- ☐ Drinking dirty water
- ☐ Eating some foods
- ☐ Catching cold
- ☐ Staying out in the rain
- ☐ Staying out in the sun too long
- ☐ Stagnant water
- ☐ Intestinal worms
- ☐ Other (specify): ___________
- ☐ Unsure
- ☐ No response

57. EMIHANDA ERI KUKIRAYO EY'OKUTANGIZA KUKWATWA OMUSHWEIJA GW'ENSIRI N' EHA? *OTASHOMERA ORIKUBUUZIBWA EBIGARUKWAMU. TOORANA EKYO EKIRI HAIHI MUNONGA N'EBYO EBIHAIRWE AHANSI, REERU OKIKYEBERE. HAANDIIKA OMU BURAINGWA EBYO BYOONA EBI YAAGAMBA. KYABA NIKYETENGESA, NOOBAASA KUBUUZA EMIHANDA ENDIIJO EYO KWETANGIZAMU OMUSHWEIJA, OTI: HARIHO EMIHANDA ENDIIJO EYI ORI KUMANYA?*
    - ☐ KUBYAMA OMU KATIMBA K'ENSIRI KOONA
    - ☐ KUBYAMA OMU KATIMBA K'ENSIRI AKARIMI OMUBAZI GWAKO
    - ☐ KUFUHIRIRA N'EMIBAZI
    - ☐ KWETANTARA KURUMWA ENSIRI
    - ☐ KUKOZESA EMIBAZI NINGA EBISHAKA BY'OKWERINDISA
    - ☐ KWETANTARA KUKWATWA EBIHIINZI NA SENYIGA
    - ☐ OBUTARYA BY'OKURYA EBIMWE NK'EMIYEMBE
    - ☐ OBUTAGUMA MUNONGA OMU MUSHANA
    - ☐ KUCUMA ENJU
    - ☐ KUNYWA AMAIZI GA MAYONJO
    - ☐ KUTEMERA AMAIZI G'EBYAGANA
    - ☐ EBINDI/SHOBORORA:______________________________
    - ☐ TARIKUKIHAMYA
    - ☐ YAAHUNAMA

What are the best ways to prevent getting malaria? *Do not read options. Select all ways mentioned or type verbatim what the respondent said. If necessary, prompt by asking, "Are there any other ways?"*
- ☐ Sleeping under a mosquito net
- ☐ Sleep under a treated mosquito net
- ☐ Use insecticide sprays
- ☐ Avoid mosquito bites
- ☐ Take preventive medication/herbs
- ☐ Avoid catching cold
- ☐ Avoid eating certain foods (mangoes, etc)
- ☐ Avoid staying too long in the sun
- ☐ Keep the house clean
- ☐ Drink clean water
- ☐ Drain/ treat stagnant water
- ☐ Other (specify): ____
- ☐ Unsure
- ☐ No response

58. OMUKA YAAWE NOOKORA KI KUTANGIRA OMUSHWEIJA GW'ENSIRI

What do you do in your household to

OBUTAKWATA BANTU? *OTASHOMERA ORIKUBUUZIBWA EBIGARUKWAMU AHANSI. TOORANA EKYO EKIRI HAIHI MUNONGA N'EBYO EBIHAIRWE AHANSI, REERU OKIKYEBERE. HAANDIIKA OMU BURAINGWA EBYO BYOONA EBI YAAGAMBA.*

- ☐ TIKIRIHO
- ☐ KUBYAMA OMU KATIIMBA KOONA AKENSIRI
- ☐ KUBYAMA OMU KATIIMBA K'ENSIRI AKARIMU OMUBAZI GW'AKO
- ☐ KUKUUMA OBUYONJO
- ☐ KUKINGA AMADIRISA
- ☐ KUFUHIRIRA N'OMUBAZI
- ☐ KWETANTARA KURYA EBY'OKURYA EBIMWE, NK'EMIYEMBE
- ☐ KWOTSYA AMASHA G'ENTE/EBISHAKA/EMIBAZI Y'EBISHAKA
- ☐ KUTEMERA AMAIZI G'EBYAGAANA
- ☐ KWESHWEKYERARE NA BURANGITI/EBYESHWEKO
- ☐ EBINDI, SHOBORORA:______________________________
- ☐ TARIKUKIHAMYA
- ☐ YAAHUNAMA

protect people against malaria? *Do not read options. Select all options mentioned. If necessary, prompt by asking, "Are there any other ways?" Choose the most appropriate options or type verbatim what the respondent said.*

- ☐ Nothing
- ☐ Sleeping under a mosquito net
- ☐ Sleep under a treated mosquito net
- ☐ Keep the environment clean
- ☐ Close windows
- ☐ Use insecticide sprays
- ☐ Avoid eating certain foods (mangoes, etc)
- ☐ Burn herbs/dung
- ☐ Drain stagnant water
- ☐ Cover with blanket/ sheets
- ☐ Other (specify): ____________
- ☐ Unsure
- ☐ No response

***EKYO NIKYO KIBUUZO KYANGYE EKIRI KUHERERUKAYO***

***That was my last question.***

59. OINE EBINDI BIBUUZO NINGA EKI ORI KWENDA KUSHOBORORAHO? *ORIKUBUUZA EBIBUUZO: HANDIIKA AHA AMAKURU OMURI BIKYE EBI ORIKUBUUZIBWA YAAGAMBA*

Do you have any other questions or comments? *Interviewer: write any additional comments the respondent has said that are relevant*

SHOBORORA/ Comments:

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

***YEBARE MUNONGA. EBIGARUKWAMU EBI WAAHAYO NIBAIJA KUTEERANWA N'EBYA BANDI BANTU ABAABUZIBWA OMU KUCOONDOOZA OKU. BWANYIMA HARUGYEMU AMAKURU AHA MAGARA GA BANTU OMU KICWEKA EKI. EBYO EBIRAYEGWE AHA MAGARA GA BANTU, NIBIIJA KUGUMA BIRI EBYEKIHAMA KANDI TIHARIHO EIZIINA RY'OMUNTU N'OMWE ERIRAMANYWE ABANDI BANTU NINGA GAVUMENTI. YEBARA MUNONGA KUKWATANISA NAITWE***

**Thank you very much for your participation. The answers you provided will be combined with all other participants to give us information about the health of people throughout the community. The information you provided is strictly confidential and no names will be released to the community or government.**

# IHACC

**EBIBUUZO BYA MUKURU W'EKA | HOUSEHOLD HEAD QUESTIONNAIRE: JULY 2013 Version**

| | | | |
|---|---|---|---|
| **EKICWEKA A: EBIRI KUKWATA AHA KYARO/OMUNTO OGWO ORIKUBUUZIBWA** | **EBIBUUZO IKUMI NA BISHATU** | **PART A:** Demographics | **10 questions** |
| **EKICWEKA C: EBIRIKURETAHO EBIZIBU, ENDWARA N'AMAGARA MABI** | **EBIBUUZO ABIRI NA MUSHANJU** | **PART C:** Risk factors | **28 questions** |
| **EBIBUUZO EBIRI KUHENDERA EKIGAANIIRO** | **EBIBUUZO BIBIRI EBY'OKUHENDERA** | **Completion Questions** | **1 questions** |

| | | | |
|---|---|---|---|
| **BYOONA HAMWE** | | **Total:** | **39 questions** |

## INFORMED CONSENT

**This questionnaire will take about 20 minutes to complete.**

**You can choose not to participate, or to withdraw at any time without a problem.**

**If you do not want to answer a question, you do not have to and we will move on to the next one.**

**You are welcome to share in the food we bring whether you participate or not.**

**This research will be shared with other people and the information can be used to help other communities like yours in other places.**

**Do you have any questions before we beging?**

**If you have questions later about the project, contact:**

**Dr. Shuaib Lwasa: 256 772 461727**
**Mr. Didas Namanya: 256 772 484771**

ORIKUBUUZIBWA YAAHA ORUSA:
- ☐ EEGO
- ☐ INGAAHA

Informed consent:
- ☐ Respondent agrees to be interviewed
- ☐ Respondent does not agree to be interviewed

## EKICWEKA A - EBIRIKUKWATA AHA KYARO/EIHANGA/OMUNTU OGWO ORIKUBUUZIBWA

*PART A – Demographics*

| | |
|---|---|
| 1. EKICWEKA (*EKYARO/LC*): _______________________________ | Location (i.e. village):_ |
| 2. EBIRO BY'OKWEEZI: _____________________________ (dd; mm; yr) | Today's Date:_______(dd; mm; yr) |
| 3. EIZIINA RY'ORI KUBUUZA EBIBUUZO: ________________________________ | Interviewer name: ____________ |
| 4. EIZIINA RY'ORIKUBUUZIBWA *(AHA KUHANDIIKWA HONKA)*: ________________________________________ | Participant name): __________________ |
| 5. AKAMANYISO K'OMUNTU ORIKUBUUZIBWA *(AKAMANYISO K'OMUNTU AHA KUHANDIIKWA HONKA)*: ______________________________________ | Individual ID: __________________ |
| 6. AKAMANYISO KAMAKA *(AKAMANYISO KAMAKA AHA KUHANDIIKWA HONKA)*: ________________________ | Household ID: _____________________ |
| 7. YOREKA KU AKAMANYISO K'OMUNTU ORIKUBUUZIBWA AKASYA KAHANDIKIRWE<br>☐ EEGO<br>☐ INGAAHA<br>☐ AKAMANYISO KAYIKIRIZIBWA MUKURUWABACOONDOZI: ________________ | Indicate if a new code was generated for this participant<br>☐ Yes<br>☐ No<br>Code approved: ____________ |
| 8. OBUHANGWA BW'OMUNTU *(AHA KUHANDIIKWA HONKA)*:<br>☐ MUSHAIJA<br>☐ MUKAZI | Sex:<br>☐ Male<br>☐ Female |
| 9. ORIKUBUZIBWA NAMANYA EMYAKA YE?<br>☐ EEGO<br>☐ INGAAHA | Does this participant know his/her age?<br>☐ Yes<br>☐ No |
| 10. OINE EMYAKA ENGAHI? _________________________________ | Age: ______ |
| *TEBEREZA EMYAKA **EKI KIKORWE HONKA YABA ARIKUMANYA MYAKA YE**:*<br>☐ AHANNSI Y'OMWAKA GUMWE<br>☐ OMWAKA GUMWE KUHIKA AHA MYAKA ETAANO<br>☐ EMYAKA MUKAAGA KUHIKA AHA MYAKA IKUMI N'EBIRI<br>☐ EMYAKA IKUMI N'ESHATU KUHIKA AHA MYAKA ABIRI N'ESHATU<br>☐ EMYAKA ABIRI N'ENA KUHIKA AHA MYAKA ASHATU N'ETAANO<br>☐ EMYAKA ASHATU NA MUKAAGA KUHIKA AHA MYAKA ANA NA MUSHANJU<br>☐ EMYAKA ANA NA MUNAANA KUHIKA AHA MYAKA ATAANO NA MWENDA<br>☐ EMYAKA NKAAGA, NINGA AHAIGURU<br>☐ INGAAHA | *Estimate age range (only if unknowr*<br>☐ < 1 year<br>☐ 1-5 years<br>☐ 6-12 years<br>☐ 13-23 years<br>☐ 24-35 years<br>☐ 36-47 years<br>☐ 48-59 years<br>☐ ≥60 years<br>☐ No response |

## EKICWEKA C - EBIRIKURETAHO EBIZIBU, ENDWARA N'AMAGARA MABI

*PART C Risk factors*

*11.* AMADIRISA OMUNJU? TOORANA BYOONA EBIRI KUKWATWAHO.
- ☐ TIGAITSIRWE
- ☐ GAITISE EMICINGO
- ☐ TIHARIMU MADIRISA
- ☐ EBINDI, SHOBORORA: ______________________
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

*Are windows in your house? Select all that apply.*
- ☐ *Uncovered*
- ☐ *Covered with screens*
- ☐ *There are no windows in my house*
- ☐ *Other (specify): _____*
- ☐ *Unsure*
- ☐ *No response*

12. WHAT IS YOUR ROOF MADE OF?
- ☐ *METAL (ALUMINUM)*
- ☐ *WOOD*
- ☐ *GRASS/THATCH*
- ☐ *EBINDI, SHOBORORA: ______________________*
- ☐ *TARIKUKIHAMYA KURUNGI*
- ☐ *YAAHUNAMA*

What is your roof made of?
- ☐ Metal (aluminum)
- ☐ Wood
- ☐ Grass/ thatch
- ☐ Other _______________
- ☐ Unsure
- ☐ No response

13. ENJU ERIMU EBISHENGYE BINGAHI?
- ☐ OMUHENDO GW'EBISHENGYE: _________
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

How many rooms are there in your house?
- ☐ Specify: ______rooms
- ☐ Unsure
- ☐ No response

14. NI EBISHENGYE BINGAHI AHARI EBYO EBIRIKURAARWAMU ABANTU?
- ☐ OMUHENDO: _________ EBISHENGYE BYOONA
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

How many of these rooms are used for sleeping?
- ☐ Specify: ______rooms
- ☐ Unsure
- ☐ No response

15. OMU NJU NIMUTUURAMU ABANTU BANGAHI MWENA HAMWE, OGAITSIRE NA BAANA BOONA?
- ☐ OMUHENDO GW'ABANTU MWEENA OMU NJU EGI: _____ ADULTS (>18 yrs)
  _____ CHILDREN (<18 yrs)
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

How many people, including yourself, live with you in your household now, including children?
- ☐ Specify: _____ adults (>18 yrs)
  _____ children (<18 yrs)
- ☐ Unsure
- ☐ No response

*16.* OINE BIMWE AHA BINTU EBI NK'EBYAWE AHA BWAWE? *RONDAHO BYOONA EBIRIKUBASIKA.*
- ☐ ESIMU Y'OMUNGARO
- ☐ REEDIYO
- ☐ AMASHANYARAZI
- ☐ EGAARI
- ☐ EBINDI, SHOBORORA: ________________________ Other major items/assets
- ☐ TINYINE KINTU NA KIMWE AHARI EBYO EBYASHOMWA
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

Does your household own? *Select all that apply.*
- ☐ Mobile/cellular telephone
- ☐ Radio
- ☐ Electricity
- ☐ Bicycle
- ☐ Other major items or assets. Specify _________
- ☐ None of the above
- ☐ Unsure
- ☐ No response

17. DOES YOUR HOUSEHOLD OWN LAND IN YOUR COMMUNITY OR ELSEWHERE?
- ☐ EEGO
- ☐ INGAAHA]
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

*IF YES, PLEASE EXPLAIN (how much land do you own, and what do you use it for?)*

________________________________________

________________________________________

*Does your household own land in your community or elsewhere?*
- ☐ Yes
- ☐ No
- ☐ Unsure
- ☐ No response

*IF YES, PLEASE EXPLAIN (how much land do you own, and what do you use it for?)*

____________________

____________________

18. EKA YAAWE EINE ABANYARUGANDA, ABANYWANI, AB'EMIKAGO ABIRI KUKORERA OMU BICWEKA EBINDI NINGA OMU NSI YA HEERU ABARI KUBATWEKYERA ESENTE NINGA EBINTU BUTOOSHA?
- ☐ EEGO
- ☐ INGAAHA
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

*Does your household have family members or friends working in another town or country who regularly send money or products home to you?*
- ☐ *Yes*
- ☐ *No*
- ☐ *Unsure*
- ☐ *No response*

*19.* OINE AMATUUNGO GOONA, ENYAMAISHWA? *YAAGIRA NGU INGAAHA, GYENDA AHA KIBUUZO 21.*
- ☐ EEGO
- ☐ INGAAHA *[GYENDA AHA KIBUUZO 21]*
- ☐ TARIKUKIHAMYA KURUNGI *[GYENDA AHA KIBUUZO 21]*
- ☐ YAAHUNAMA *[GYENDA AHA KIBUUZO 21]*

Does your household currently own any animals? *If no, skip to question 21.*
- ☐ Yes
- ☐ No *[Skip to Q21]*
- ☐ Unsure *[Skip to Q21]*
- ☐ No response *[Skip to Q21]*

20. *YAAGIRA NGU EEGO OMU KIBUUZO 19:* OMUHENDO GW'AMATUNGO GAAWE:
- ☐ OMUHENDO GW'ENKOKO N'EBINDI BINYONYI _______________
- ☐ OMUHENDO GW'EMPUNU ____________________
- ☐ OMUHENDO GW'EMBUZI _____________________
- ☐ OMUHENDO GW'ENTE _____________________
- ☐ OMUHENDO RABBITS _____________________
- ☐ OMUHENDO GW'EMBWA ____________________
- ☐ EBINDI, SHOBORORA/ OYOREKYE OMUHENDO: ______________________
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

*If yes to question 19:* Please list the number of animals you currently own:
- ☐ Number of Chickens or other birds __________
- ☐ Number of Pigs ____
- ☐ Number of Goats or sheep
- ☐ Number of Cattle ____
- ☐ Number of Rabbits ____
- ☐ Number of Dogs ___
- ☐ Other (specify type and number): _______
- ☐ Unsure
- ☐ No response

21. DOES ANYONE IN YOUR HOUSEHOLD RAISE ANIMALS (EITHER YOUR OWN OR FOR SOMEONE ELSE)?
- ☐ EEGO
- ☐ INGAAHA
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

Does anyone in your household raise animals (either for yourself or for someone else)?
- ☐ Yes
- ☐ No
- ☐ Unsure
- ☐ No response

22. *YAAGIRA NGU EEGO OMU KIBUUZO 21:* PLEASE LIST THE NUMBER OF ANIMALS YOU ARE CURRENTLY RAISING:
- ☐ OMUHENDO GW'ENKOKO N'EBINDI BINYONYI ________________
- ☐ OMUHENDO GW'EMPUNU ____________________
- ☐ OMUHENDO GW'EMBUZI _____________________
- ☐ OMUHENDO GW'ENTE _____________________
- ☐ OMUHENDO RABBITS _____________________
- ☐ OMUHENDO GW'EMBWA ____________________
- ☐ EBINDI, SHOBORORA/ OYOREKYE OMUHENDO: ______________________
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

*If yes to question 21:* Please list the number of animals you are raising:
- ☐ Number of Chickens or other birds __________
- ☐ Number of Pigs ____
- ☐ Number of Goats or sheep
- ☐ Number of Cattle ____
- ☐ Number of Rabbits ____
- ☐ Number of Dogs ___
- ☐ Other (specify type and number): ________
- ☐ Unsure
- ☐ No response

23. *If you own or raise animals,* DO YOUR ANIMALS COME INTO THE HOUSE DURING THE **DAY**?
- ☐ NIKIRA KUBAHO
- ☐ RIMWE NA RIMWE
- ☐ INGAAHA
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA
- ☐ I DON'T OWN OR RAISE ANIMALS

*If yes to above,* Do your animals come into the house during the **day**?
- ☐ Often
- ☐ Sometimes
- ☐ Never
- ☐ Unsure
- ☐ No response
- ☐ I don't own or raise animals

24. *If you own or raise animals,* DO YOUR ANIMALS COME INTO THE HOUSE DURING THE **NIGHT**?
- ☐ NIKIRA KUBAHO
- ☐ RIMWE NA RIMWE
- ☐ INGAAHA
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA
- ☐ I DON'T OWN OR RAISE ANIMALS

*If yes to above,* Do your animals come into the house during the **night**?
- ☐ Often
- ☐ Sometimes
- ☐ Never
- ☐ Unsure
- ☐ No response
- ☐ I don't own or raise animals

25. OMUNDA Y'ENJU EGI HABEIRE HAFUHIRIRWEMU N'OMUBAZI GW'ENSIRI OMU MYEEZI NKA IKUMI N'EBIRI EHWEIRE? *YAAGIRA NGU INGAAHA, GYENDA AHA KIBUUZO 27.*
- ☐ EEGO
- ☐ INGAAHA [*GYENDA AHA KIBUUZO 27]*
- ☐ TARIKUKIHAMYA KURUNGI *[GYENDA AHA KIBUUZO 27]*
- ☐ YAAHUNAMA *[GYENDA AHA KIBUUZO 27]*

At any time in the past 12 months, has anyone sprayed the interior walls of your dwelling against mosquitoes? *If no, skip to question 27.*
- ☐ Yes
- ☐ No *[Skip to Q27]*
- ☐ Unsure *[Skip to Q27]*
- ☐ No response *[Skip to Q27]*

26. *YAAGIRA NGU EEGO OMU KIBUUZO 25*, ENJU EFUHIRIRWE, HATI HARABIREHO EMYEEZI ENGAHI?
- ☐ EMYEEZI ERABIREHO BWANYIMA YAFUHIRIRWA: __________ EMYEEZI
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

*If yes to question 25*, how many months ago was the house sprayed?
- ☐ Specify: _____months
- ☐ Unsure
- ☐ No response

27. OMU KA EGI, OINEMU OBUTIIMBA BW'ENSIRI OBURI KUBAASA KURARWAMU ABAUNTU? *YAAGIRA NGU INGAAHA, GYENDA AHA KIBUUZO 31.*
- ☐ EEGO
- ☐ INGAAHA *[GYENDA AHA KIBUUZO 31]*
- ☐ TARIKUKIHAMYA KURUNGI *[GYENDA AHA KIBUUZO 31]*
- ☐ YAAHUNAMA *[GYENDA AHA KIBUUZO 31]*

Does your household have any mosquito nets that can be used while sleeping? *If no, skip to question 31.*
- ☐ Yes
- ☐ No *[Skip to Q31]*
- ☐ Unsure *[Skip to Q31]*
- ☐ No response *[Skip to Q31]*

28. *YAAGIRA NGU EEGO OMU KIBUUZO 27:* OINEIBUTIIMBA BW'ENSIRI BUNGAHI BWONA HAMWE KANDI OMAZIRE NABWO BWIRECHI? ORIKUBUUZA EBIBUUZO: KYEBERA KANDI AHAMYE EKYO, N'OMUHENDO GWABWE.
   - ☐ OMUHENDO GW'OBUTIIMBA BW'ENSIRI: _________ OBUTIMA BW'ENSIRI
   - ☐ OMAZIRE NABWO BWIRECHI? ______________________
   - ☐ TARIKUKIHAMYA KURUNGI
   - ☐ YAAHUNAMA

*If yes to question 27:* How many mosquito nets does your household have and how long have you had them?
*Interviewer: Please observe the number of mosquito nets to confirm number.*
- ☐ Specify: ___ mosquito nets
- ☐ How long have you had them? ______(years)
- ☐ Unsure
- ☐ No response

29. *YAAGIRA NGU EEGO OMU KIBUUZO 27*: WHERE DID YOU GET YOUR NETS FROM? PLEASE LIST ALL SOURCES.

   -____________________________________________________________

*If yes to question 27:* Where did you get your nets from? Please list all sources.
_____________________

**30.** *YAAGIRA NGU EEGO OMU KIBUUZO 27*: NISHABA KWONGYERA KWETEGYEREZA BIKYE EBIRIKUKWATA AHA BUTIIMBA BW'ENSIRI. KYEBERA BYONA EBIRI KUKWATWAHO.

*If yes to question 27:* We would like to know more about each of your mosquito nets. *Select all that apply.*

| | OBU WAATUNGA, NINGA OBU WAAGURA AKATIIMBA AKA, KAKABA KARIMU OMUBAZI GW'AKO? *When you got the net, was it already factory treated with an insecticide to kill or repel mosquitoes?* | | | | AKATIIMBA KATEIRWEMU OMUBAZI GWAKO BWANYIMA? *Has the mosquito net been soaked or dipped in a liquid to repel mosquitoes or bugs in the past 12 months?* | | | | AKATIIMBA KAKOZESEIBWE OMU KIRO? *Was the net hanging last night?* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EEGO *Yes* | INGAAHA *No* | TARIKUHAMYA *Unsure* | YAAHUNAMA *No response* | EEGO *Yes* | INGAAHA *No* | TARIKUHAMYA *Unsure* | YAAHUNAMA *No response* | EEGO *Yes* | INGAAHA *No* | TARIKUHAMYA *Unsure* | YAAHUNAMA *No response* |
| AKATIIMBA 1 Net 1 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| AKATIIMBA 2 Net 2 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| AKATIIMBA 3 Net 3 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| AKATIIMBA 4 Net 4 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| AKATIIMBA 5 Net 5 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

31. OINE AMAIZI G'OKUNAABA OMU NGARO HAIHI N'ENJU?
   - ☐ EEGO
   - ☐ INGAAHA
   - ☐ TARIKUKIHAMYA KURUNGI
   - ☐ YAAHUNAMA

*Are there hand washing facilities near the house?*
- ☐ *Yes*
- ☐ *No*
- ☐ *Unsure*
- ☐ *No response*

32. *KU ARARE YAAGIRA NGU EEGO OMU KIBUUZO 31,* HARIHO ESAABUNI AHA MWANYA OGUKOZIRWE KUNAABIRWAMU ENGARO?
- ☐ EEGO
- ☐ INGAAHA
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

*If yes to question 31, Is there soap at the washing facility near the house?*
- ☐ *Yes*
- ☐ *No*
- ☐ *Unsure*
- ☐ *No response*

*33.* AMAIZI G'OKUNYWA AHA BW'ABANTU OMU KA EGI NIMUKIRA KUGAIHA/KUGATAHA NKAHI? *ORI KUBUUZA EBIBUUZO: OTASHOMA EBIGARUKWAMU EBI. KURUGIRIRA AHARI EBYO EBI YAAGAMBA, TOORANA ENSHONGA EISHATU OMU BUKURU BWAZO HAZA OZIHANDIIKYE; OTI: HANDIIKA "1" OMWANY A OMUKURU OGURI KWIHWAMU AMAIZI G'OKUNYWA, "2" OMWANYA OGURI KUGARUKA AHA GW'OKUBANZA, "3" OMWANYA GW'AKASHATU GUBE OGWO OGURI KUKOZESEBWA EMYANYA ENKURU YAABA ETARIHO. KOZESA EBY'OKUREEBERAHO BYABA NIBYETAAGISA.*
- ☐ TAAPU AHEERU Y'ENJU
- ☐ PAIPU/TAAPU YA BOONA
- ☐ NAYIKONDO
- ☐ EIZIBA ERIREEBERIRWE
- ☐ EIZIBA ERITAREEBERIRWE
- ☐ OMUDUMO/OMURINDI OGUREEBERIRWE
- ☐ OMUDUMO/OMURINDI OGUTAREEBERIRWE
- ☐ KUTANGISIRIZA AMAIZI G'ENJURA
- ☐ OMUGYERA/ENYANJA/OMURINDI
- ☐ AMAIZI G'OMU CUPA
- ☐ EBINDI, SHOBORORA: ___________________________
- ☐ TARIKUKIHAMYA KURUNGI *[GYENDA AHA KIBUUZO 36]*
- ☐ YAAHUNAMA *[GYENDA AHA KIBUUZO 36]*

What are the main sources of drinking water for members of your household?
*Interviewer: **Do not** read out options. Based on participant answers, select up to three sources, using numbers to rank importance.*
- ☐ Private standpipe or outdoor tap,
- ☐ Public standpipe or tap
- ☐ Tube well or borehole
- ☐ Dug well (protected)
- ☐ Dug well (unprotected)
- ☐ Water from protected spring
- ☐ Water from unprotected spring,
- ☐ Rainwater harvesting or cistern
- ☐ Surface water (river, lake, stream)
- ☐ Bottled water,
- ☐ Other (specify): ____
- ☐ Unsure *[Skip to Q36]*
- ☐ No response *[Skip to Q36]*

34. HOW WOULD YOU RATE THE OVERALL QUALITY OF THE WATER FROM THESE SOURCES? *NOTE: PLEASE COMMENT ON THE WATER QUALITY **BEFORE** IT IS TREATED OR BOILED.*
- ☐ OMUTIINDO GURI AHANSI MUNONGA
- ☐ MUBI
- ☐ HAKIRI
- ☐ NI MURUNGI
- ☐ NI MURUNGI MUNONGA
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

How would you rate the overall quality of the water from these sources? *Note: please comment on the water quality **before** it is treated or boiled.*
- ☐ Very poor
- ☐ Poor
- ☐ Fair
- ☐ Good
- ☐ Very good
- ☐ Unsure
- ☐ No response

35. NOOSHEMEZA OTA AMAIZI G'OKUNYWA? *TOORANA BYONA EBIRI KUKWATWAHO.*
- ☐ TINDI KUSHEMEZA MAIZI NA KAKYE
- ☐ NINGATEEKA
- ☐ NINGAGYEGYENA
- ☐ AMAANI G'EIZOOBA N'OMUSHANA
- ☐ NINKOZESA OMUBAZI NKA "WATER GUARD"
- ☐ NINGURA AMAIZI AG'OMU CUPA
- ☐ EBINDI, SHOBORORA: ___________________________
- ☐ TARIKUKIHAMYA KURUNGI
- ☐ YAAHUNAMA

Do you treat your drinking water? *Select all that apply.*
- ☐ Do not treat the water
- ☐ Boiling
- ☐ Filtering
- ☐ Ultraviolet irradiation (i.e. sunlight)
- ☐ Chemical treatments (e.g. "Water Guard" Tablets)
- ☐ Purchase purified water
- ☐ Other (specify): ____
- ☐ Unsure
- ☐ No response

36. EKA YAAWE EINE KIGO KI?
*ORI KUBUUZA EBIBUUZO: OTASHOMA EBIGARUKWAMU EBI. KYABA NIKYETENGESA, YONGYERA OBUUZE OTI: HARIHO EMYANYA ENDIIJO? KOZESA EBY'OKUREEBERAHO.*
- ☐ EKIHORONI, KYOMBOKIRWE
- ☐ EKIHORONI, KITOMBEKIRWE
- ☐ EKISHAKA
- ☐ EBINDI, SHOBORORA: ________________________
- ☐ TARIKUKIHAMYA
- ☐ YAAHUNAMA

What kind of toilet facilities does your household use?
*Interviewer: Do not read options. Select the first **3** options mentioned. If necessary, prompt by asking, "Are there any other toilet facilities used?" You can use examples as prompts if needed.*
- ☐ Pit latrine (covered)
- ☐ Pit latrine (uncovered)
- ☐ No facilities/ bush/ field
- ☐ Other (specify): ____
- ☐ Unsure
- ☐ No response

37. EKIHORONI/EKIGO N'EKYAWE N'EKA YAAWE MWENKA NINGA NIMUKIKOZESA NA BANDI BANTU?
- ☐ EKA YANGYE TWENKA
- ☐ NITUKIKOZESA N'AMAKA MAKYE AGANDI
- ☐ EKYARO KYOONA
- ☐ TARIKUKIHAMYA
- ☐ YAAHUNAMA

Are the toilet facilities you use private, semi-private, or communal?
- ☐ Private
- ☐ Semi-private (shared with a few other households only)
- ☐ Communal
- ☐ Unsure
- ☐ No response

38. NITWENDA KUMANYA AB'OMUKA YAAWE BAABA NIBEEJUMBA OMU MIRIMO ERI KURUGA AHA MIRUNDI ESHATU OMU SAANDE N'OKUKIRAHO? *TOORANA BYONA EBIRI KUKWATWAHO.*

We are interested in whether any members of your household participate in the following activities 3 or more times a week, and for what purpose? *Select all that apply.*

| | TIBARI KWEJUMBAMU<br>*Do not participate in this activity* | KURONDA EBY'OKURYA<br>*To provide food for my family* | KURONDA EKY'OKUTUNDAMU SENTE<br>*To sell for income* | KURONDA EKY'OKUHANISAMU EBINTU EBI NTAINE KURUGA OMU BANDI<br>*To give as gifts or non-monetary trading with family or friends* | KURONDAMU EMIBAZI Y'OKURAGURA<br>*For spiritual or medicinal purposes* | EBINDI, SHOBORORA<br>*Other (specify):* | TARIKUKIHAMYA<br>*Unsure* | YAAHUNAMA<br>*No response* |
|---|---|---|---|---|---|---|---|---|
| KUSHOHA EBY'ENYANJA<br>Fishing | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | ☐ |
| KUHINGA<br>Tending ***someone else's*** crops | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | ☐ |
| KURIISA<br>Tending animals | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | ☐ |
| KUKORA OMU MISIRI<br>Tending ***own*** crops | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | ☐ |
| KUHIGA<br>Hunting | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | ☐ |
| KUCWA EMIBAZI<br>Collection of medicinal plants | ☐ | ☐ | ☐ | ☐ | ☐ | | ☐ | ☐ |

***EKYI NIKYO KIBUUZO KYAHA MUHERU*** ***That was my last question***

*39.* OINE EKINDI KIBUUZO EKI ORIKWENDA KUMBUUZA NINGA EKINDI KINTU EKI ORI KWENDA KUNSHOBORE RAHO? *ORI KUBUUZA EBIBUUZO? HANDIIKA EBYO BYONKA EBI EBIRI KUKWATA AHA NSHONGA EZI.*

Do you have any other questions or comments? *Interviewer: write any additional comments the respondent has said that are relevant*

SHOBORORA:

Comments:

______________________________________________________________________________

______________________________________________________________________________

__________________________________________________________________

***YEBARE MUNONGA. EBIGARUKWAMU EBI WAAHAYO NIBAIJA KUTEERANWA N'EBYA BANDI BANTU ABAABUZIBWA OMU KUCOONDOOZA OKU. BWANYIMA HARUGYEMU AMAKURU AHA MAGARA GA BANTU OMU KICWEKA EKI. EBYO EBIRAYEGWE AHA MAGARA GA BANTU, NIBIIJA KUGUMA BIRI EBYEKIHAMA KANDI TIHARIHO EIZIINA RY'OMUNTU N'OMWE ERIRAMANYWE ABANDI BANTU NINGA GAVUMENTI. YEBARA MUNONGA KUKWATANISA NAITWE.***

**Thank you very much for your participation. The answers you provided will be combined with all other participants to give us information about the health of people throughout the community. The information you provided is strictly confidential and no names will be released to the community or government.**