

## Rural Livelihoods and Community Local Knowledge of Risk of Malaria Transmission in the Okavango Delta, Botswana

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### Abstract

The Okavango Delta in north-western Botswana is a malaria endemic area. Most livelihood activities in this area are seasonal, usually coinciding with malaria season (November-April). The objective of this paper is to assess community perceptions of the relationship between rural livelihood sources and risk to malaria transmission in Shakawe and Ngarange villages of the Okavango River Panhandle in north-western Botswana. Primary data were collected through participatory rural appraisal methods using tools such as seasonal calendars and livelihood rankings. Key informants interviews were also conducted and secondary data were sourced from both published and unpublished materials. Qualitative data were thematically analysed, while simple descriptive statistics were used to analyse quantitative data. The results show that fishing is perceived to increase the risk of malaria transmission more than other livelihood activities. Fishing activities take place at particular times which vary, with social groups. People's exposure to mosquito bites depends on their proximity to the river and potential mosquito breeding sites. Communities that depend on water-based livelihood activities face diverse and distinct risks resulting from ecological conditions, which are largely driven by climate variability and change. An integrated approach would improve malaria prevention and control strategies and take cognisance of malaria transmission routes which often have to do with livelihood activities.

**Keywords:** Rural livelihoods, malaria, Okavango Delta, risk, vector borne disease, local knowledge

### Introduction

Malaria is a public health problem in more than 100 countries worldwide (Shiff, Thuma, Sullivan, & Mharakurwa 2011; World Health Organisation(WHO), 2014). This disease had 214 million cases and 438 000 deaths in 2015 (WHO 2015). Due to, warm and humid tropical climate, African countries are the most affected and accounted for 88% of all malaria cases in 2015. Notwithstanding successful control programmes unlike the rest of the African continent, malaria is still a health problem in southern African region (Mabaso, Sharp & Lengeler 2004). This region alone had 29 234 malaria cases in 2014 (WHO 2015). In relative terms, malaria is no longer a major public health problem in Botswana, with 1346 confirmed malaria cases in 2014 (WHO 2015). However, the north-western district of the country, where the freshwater inland Okavango Delta is located, experiences high malaria transmission (Chihanga *et al.* 2013).

Due to the suitable climate conditions for mosquito breeding and survival in Ngamiland in north-western Botswana, the Okavango Delta region is malaria-endemic with frequent outbreaks of malaria (with 96 cases in 2015). The region has been one of the significant malaria hotspots nation-wide for several consecutive years (WHO 2015). From 2009 to 2012 the Okavango sub-district accounted

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for 22% of total national malaria cases reported in Botswana during the transmission season (Chihanga *et al.* 2013). Between January and March 2014, a 60% increase in malaria cases was reported in the Okavango sub-district (Chihanga *et al.* 2016). Chimbari and Magole (2009) reported that the malaria control programme in the Okavango district was functional, access to health facilities is limited during the rainy season and in times of high floods.

The interplay of factors, including those of climate variability, socio-cultural and institutional seriously impedes malaria elimination efforts in Botswana (Ministry of Health 2010). The disease remains a developmental problem which challenges livelihoods sustainability and the effectiveness of health systems (Mboera *et al.* 2013).

Most livelihood sources in the Okavango Delta are dependent on water-based resources (Murray 2005). A livelihood source comprise of assets (natural, physical, human, financial and social), the activities, and access to these (mediated by institutions and social relations) that determine the living gained by an individual or household (Kgathi & Motsholapheko 2011). Livelihood activities are strategies in which a household generate their livelihood (Kgathi & Motsholapheko 2011).

Fishing, which has been reported to promote outdoor exposure of individuals to malaria vectors in India (Barai *et al.* 1982) and Brazil (Sá *et al.* 2005), is one of the major livelihood activities in the perennial Okavango Delta. In the seasonal flood plains, time spent late in the day and outdoor whilst engaged in flood recession farming (*molapo* farming) activities exposes communities to malaria transmission (Chirebvu *et al.* 2014; Molefe *et al.* 2014; Motsumi *et al.* 2012). However, a significant part of the Delta is dry or occasionally flooded, thus allowing land based activities, including livestock and rain fed arable agriculture. Variations in the hydro-periods of Okavango Delta (Mendelsohn *et al.* 2010) enables a diverse natural resource based livelihoods but may also make communities vulnerable to malaria epidemics over extended periods.

In rural communities, particularly those in wetlands such as the Okavango Delta, malaria transmission and endemicity may be closely linked to livelihood systems mainly by co-dependence (Adger *et al.* 2004). Therefore understanding the dynamics within a livelihood may improve our understanding of household vulnerability to malaria. Shayo *et al.* (2015) posit that rural livelihood activities are some of the important determinants of malaria transmission and control. Livelihood activities have been observed to overlap with malaria risk in terms of specific daily tasks, responsibilities and leisure time, particularly those undertaken outdoors at dawn and/or dusk (Dunn *et al.* 2011; Le Mare *et al.* 2014).

Malaria risk behaviours depend on wider aspects of local livelihoods, socio-cultural beliefs and practices which interplay with the use and non-use of the stipulated interventions (Dunn *et al.* 2011). The term risk implies the possibility of adverse health consequences due to possible exposure to certain events (Covello & Merkhoher 1993). In this case, risk associated with exposure to malaria mosquito bites may be morbidity or mortality due to malaria infection. The level of risk depends on the vulnerability of the individual. Vulnerability generally refers to the capacity of a system, population or individual to be harmed by a threat (Adger *et al.* 2004), associated with environmental and other changes due to the lack of capacity to adapt (Adger, Hallie Eakin & Winkels 2009; Tompkins & Neil Adger 2005). For example, the natural environment of the Kilombero Valley in south eastern Tanzania has been observed to increase people's vulnerability to health risks (Hetzl *et al.* 2007) just like in the Okavango Delta, where inhabitants are prone to water and vector-borne diseases including malaria. In Botswana, there is a knowledge gap with regard to the linkages between water-related livelihood activities and malaria risk among different socio-economic groups. This study assesses perceptions of the relationship between rural livelihood sources and risk to malaria transmission in two communities in the Okavango Delta panhandle. The objectives were to (a) analyse the community's perceptions of

malaria exposure in relation to livelihood sources; (b) analyse the community's perception of malaria exposure by different social groups; and (c) assess the community's perception on the link between climate variability and malaria exposure.

## Materials and Methods

### *Study area*

This study was conducted in the Okavango Delta panhandle in north-western Botswana. This Delta is a perennial wetland in a semi-arid environment. It is the habitat of many aquatic and terrestrial species and a vital source of livelihoods for the human population in the region (Kgathi, Ngwenya & Wilk 2007). Consequently, the population is clustered in a band of settlements around the Delta. The area experiences very high temperatures (32° C average daily maximum) and receives rainfall averaging 500mm per annum (Department of Meteorological Services (DMS) 2015). These conditions favour reproduction of the malaria vector *Anopheles arabiensis*. The annual floods in the Okavango Delta also provide habitats for the malaria vector, thus exposing the communities in the area to malaria transmission.

Two study sites were Shakawe and Ngarange villages (Figure 1), located in the area labelled as endemic for experiencing perennial malaria transmission. The sites were selected based on the number of malaria cases recorded, proximity to the perennial surface water and access to health facilities. Communities in this area are vulnerable to contracting malaria during flood periods. In this region maximum flood levels are reached between July-September, and minimum: October to March, which also coincides with high incidence of malaria in November to May with a peak in February to April. Shakawe is the largest fishing village in Botswana and fishing is linked to outdoor exposure to malaria transmission (Mmopelwa *et al.* 2005) This village is located in the upper northwest corner of Botswana on the northern banks of the Okavango River (Figure 1). Shakawe has a population of 6 693 people (Central Statistics Office (CSO) 2011) and the village is growing fast; it has a shopping centre, government offices, Non-Governmental Organisations (NGOs) and several private safari lodges. On the other hand, Ngarange village is on the eastern part of the panhandle along the Okavango River (Figure1). It has a population of 988 people (CSO 2011). Livelihood sources in both villages include but not limited to fishing, gathering of wild and aquatic fruits, pastoral and arable *molapo* farming. The main ethnic groups in these villages are the HamBukushu, BaHerero, BaYei, BaSarwa and BaTawana. The livelihoods of these ethnic groups particularly the HamBukushu and BaYei are traditionally dependent on water resources such as fishing and *molapo* farming, hence the possibility of being exposed to malaria transmission.

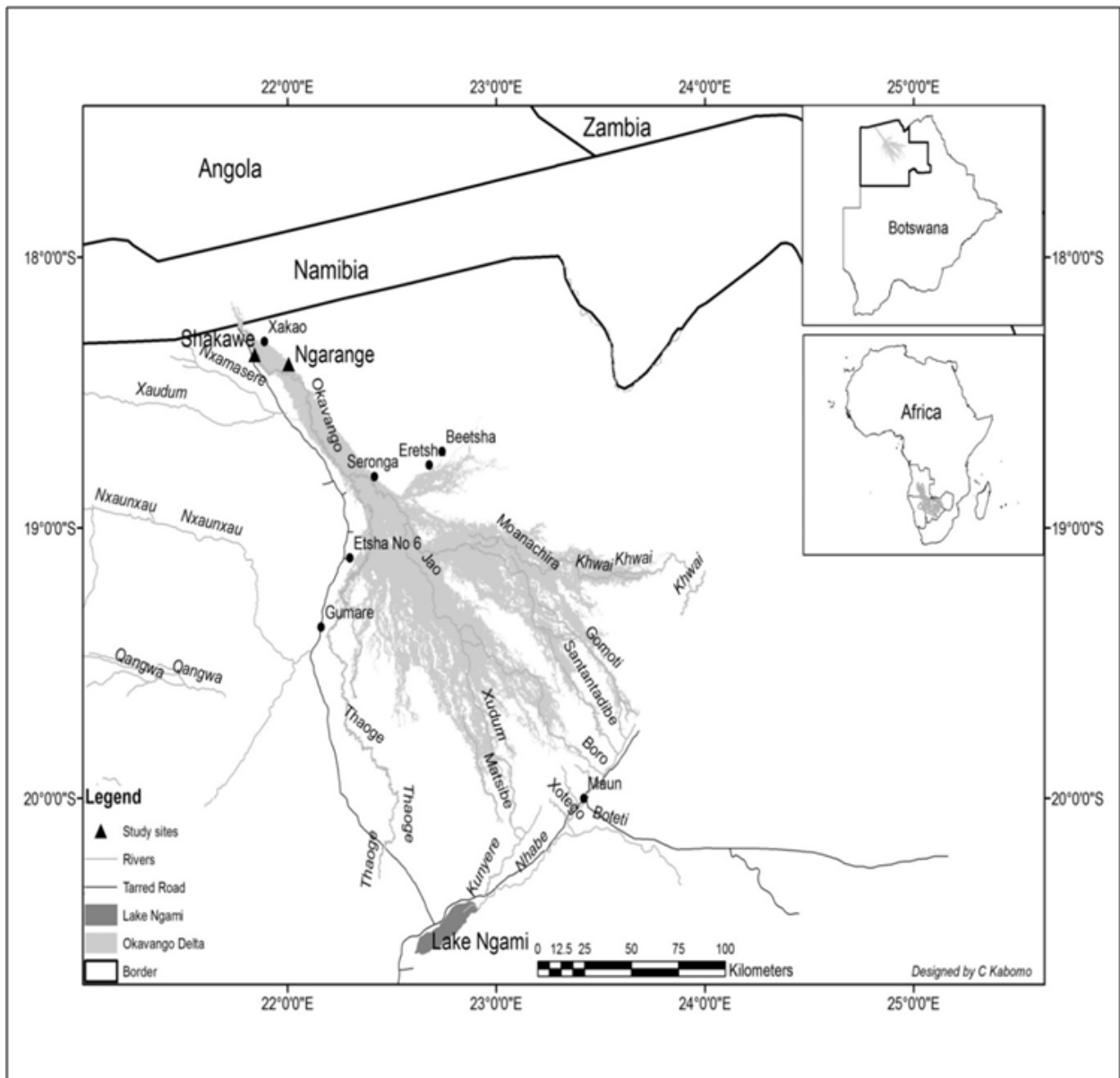
The results presented in this paper are a product of a larger project entitled "Social, environment and climate change impacts of vector-borne diseases in arid areas of southern Africa". The study covers three countries; Botswana, South Africa and Zimbabwe and is commonly referred to as Malaria and Bilharzia in southern Africa (MABISA) study. The project adopts an ecosystem approach to human health, emphasising trans-disciplinarily community participation, as well as gender and social equity (Charron 2012; Dakubo 2010).

### *Data collection*

Data were collected through a Participatory Rural appraisal (PRA) workshop. One of the strengths of PRA is that the analysis and interpretation of findings is carried out during the appraisal providing opportunities for cross-checking (Townsend 1996). The overall objective of the PRA was to gather and package knowledge from the community about their livelihoods in general and how these relate to the social, environmental and climate change/variability impacts of malaria and/or bilharzia.

The PRA was held in Shakawe village from 25th – 27th June 2014. This period was selected to optimize participation since it is a low activity period in terms of community livelihood activities and in the hydrological cycle of the Okavango River flood pulse. A total of 34 participants from Shakawe and Ngarange villages were selected purposively based on diversity of socio-economic backgrounds in terms of profession, knowledge and influence of health issues. The participants comprised of 10 females and 7 males from Ngarange village, and 7 females and 10 males from Shakawe village, thus 17 participants from each village. The participants included village elders, youths, women and men from diverse occupational backgrounds including farmers, social workers, chiefs, teachers, nurses, traditional and spiritual healers. Their position in society gives them access to information sought by our research (Marshall 1996). The PRA participants were divided into three gender-mixed focus groups of 11-12 individuals through random numbering. Each group was assigned specific tasks with instructions, and was led by a scribe and a facilitator.

Figure 1: Map of the study area showing the study villages of Shakawe and Ngarange



Participatory Rural Appraisal tools used to collect data included, livelihood analysis (free listing, ranking, gender profiling and spatial situating) and disease calendar, as well as impact of climate variability on disease and vector dynamics. These tools provided data on malaria exposure in relation to livelihood activities, different social groups and climate variability. Afterwards one participant from each group made a presentation to all participants for the purpose of validation of the information by other villagers and researchers.

As indicated earlier, livelihood analysis was carried out by listing and ranking of the livelihoods activities. This was followed by perceived malaria exposure in relation to livelihood source connoted (-, T, TT, TTT), where: ‘-’ represents no risk; T denotes low risk; TT denotes medium risk; and TTT denotes high risk. Livelihood sources were then ranked relative to the exposure to malaria, to establish the extent to which they are perceived as likely to expose people to malaria. Each participant was given five (5) stones to cast per given livelihood source, where one stone denoted ‘very low risk’ and all five denoted ‘very high risks’ depending on individual perception of the level of risk to malaria exposure each livelihood activity presented. The summation of stones collected from all individuals gave the total scores for each livelihood source, and this was used to rank each livelihood source.

A seasonal analysis of livelihood sources was done to demonstrate perceived linkages between climate variability and malaria exposure. For meaningful analysis, livelihood sources, vector abundance and disease patterns were then mapped against the climate variables of flood and rainfall to produce a ‘livelihood-malaria seasonal calendar’ (Mukherjee, 1997). Participants also did an analysis of disease exposure within social groups to indicate age and gender vulnerability (men, women, girl, boy symbols (♂ ♀ 😊 😞 respectively) (Table 3).

Key informants were interviewed in the two study sites in May 2014 (prior to the PRA activity), using a semi-structured interview guide with both close and open ended questions. Overall, 40 key informants were interviewed. Criterion-based purposive sampling (to identify and select all cases that satisfy a pre-set criterion of importance) (Palinkas *et al.* 2013) was used to identify the 40 key informants. The criteria for selection included women and men above the age of 18 years, adults who have lived in the locality for a minimum of 10 years, who are knowledgeable on vector-borne diseases transmission, prevention and treatment, risk and adaptation strategies. The respondents comprised of tribal/community leaders; medical and traditional health practitioner/personnel, government officers and non-governmental organisation representatives. The key informants were selected because of their personal skills, position in the society, ability to provide more information and a deeper insight into the dynamics and events around them. Of the 40 key informants sampled, 25 (63%) from Shakawe and 15 (38%) from Ngarange, 13 (32%) were female and 27 (68%) were male. The processing and analysis of key informant interviews, involved data coding, categorization and allocation of numerical codes of the responses. The data were then analysed through descriptive statistics such as frequencies, percentages and graphs.

## Results and Discussion

### *Livelihoods sources, local knowledge and vulnerability to malaria transmission*

Water dependent livelihood activities taking place near or at the river present higher exposure to malaria compared to other activities. This phenomenon was observed in the development of irrigated rice production systems in the Ruzizi plains of Burundi, where malaria transmission was clearly demonstrated (WHO 1996). Such activities in the study area include fishing, gathering of water lily (*Tswii* in Setswana) (*Nymphaea nouchali*) and other aquatic plants, hunting in the river in summer, gathering of wild fruits by the river in summer and *molapo* (flood recession) farming.

The focus group discussants ranked fishing and hunting at the river first and second respectively in terms of malaria risk, followed by *molapo* farming depending on season and time of day related activities. According to the community the lowest risk to malaria transmission is associated with gathering of thatching grass in the wild, which is commonly done during the day (Table 1). Fishing was ranked highest because fishers spend most of their time from morning to dusk or at night in the water and or in fishing camps (depending on the type of fishing and season). Fishing activities are primarily carried out in the early morning and evening when exposure to the mosquito vector of malaria is highest, especially for commercial fishers. In line with community perception malaria has been recorded in other studies including one of the occupational diseases in fisheries (Ukoroije & Abowei 2012). Participants ranked gathering of thatching grass in the wild as a livelihood activity least likely to expose participants to mosquito bites because the harvesters work far away from the river (which is the potential mosquito breeding site (Table 1).

**Table 1:** Ranking of perceived risk to malaria livelihood sources

Rank	Livelihood source N=11	Score/55
1	Fishing	40
1	Hunting at the river	39
2	Molapo pastoral farming	38
2	Water reed, and grass harvesting in the river	37
3	Gathering of water lily and other plants	36
4	Molapo arable farming	33
5	Gathering of wild fruits (summer)	30
5	Gathering of fruits by the river (winter)	29
6	Gathering of fruits by the river (summer)	26
7	Dry land arable farming	23
7	Dry land pastoral farming	23
7	Gathering of wild fruits (winter)	23
8	Hunting in the wild (winter)	22
8	Irrigation farming	22
9	Gathering of thatching grass in the wild	18

Hydrological conditions in the Okavango Delta are determined by the local rains and the magnitude of the annual flood from the Okavango River catchment (Murray-Hudson 2009). Rainfall usually starts from September to April (8 months). Normally the rainy season over much of southern Africa spans from October to March and coincides with the high incidence malaria season (Davis 2011). Time series malaria and climate data analysed over the last century worldwide has shown that a change in rainfall amount (excess rainfall or occasional drought) is correlated with malaria incidences variability (Thomson *et al.* 2005). Rainfall is associated with an increase in mosquito breeding habitats hence the mosquito population and malaria transmission intensity (Wandiga *et al.* 2010).

The 1<sup>st</sup> flood inflow (October-December) and the 2<sup>nd</sup> flood inflow (March-April), the peak rainfall season (December- April) overlapping malaria transmission season (October-April), throughout the year with fishing activities (prior to 2008 fishing regulations, which permits fishing from 1<sup>st</sup> March to 31<sup>st</sup> December ). Differences in colour intensity of the same colour code in Table 2 suggest difference live-

lihood activity or disease peaks. However, some post 2008 fishing regulation activities fall within the malaria transmission period, thus rendering groups of fishers at risk of malaria transmission.

**Table 2:** Livelihood sources, flood/rainfall and malaria calendar. (The darker the colour coding the more intense the activity or disease exposure situation)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Malaria cases				end						start		
Floods	low	low	2 <sup>nd</sup> inflow start	end						1 <sup>st</sup> inflow start		end
Rainfall				end					start			
Mosquito abundance			end					start				
Fishing	Pre-2008	Pre-2008										end
Hunting in the river					start			end				
<i>Molapo</i> pastoral farming								start				end
Water reed & grass harvesting in the river							start				end	
Gathering of water lily and other plants		start										end
<i>Molapo</i> arable farming								start				end

Hunting for aquatic mammals in the river occurs from May to August when the water level has receded. The temperatures during this period are suitable for prolonged storage of meat. *Molapo* pastoral farming is usually carried out from August to December (5 months) when the water level is low enough for this activity. Other livelihood sources such as reed and thatching grass harvesting between July and November (5 months) are relatively low malaria risk, especially in Shakawe where they start later in August. Although gathering of water lily (*N. nouchali*) and other aquatic plants appear to run throughout the year (February to December), Table 1 suggests that these were considered to be moderate to low risk because harvesters may practice these during low risk season (May-August) when it is either cold (winter – June-July) or hot (August/September) and thus avoid or minimise risk of malaria transmission.

In addition to livelihood sources, exposure to malaria transmission differentially impact on social groups of women, men and children because of their social status and division of labour. PRA participants inferred the level of risk and vulnerability to malaria transmission within each livelihood source and analysed disease exposure by social group based on a gendered division of labour. Table 3 below shows that gathering of water lily (*N. nouchali*), fishing, and harvesting wild fruits by the river in summer, *molapo* (flood recession), pastoral and arable farming predisposes people to increased risk of malaria transmission. All members of the household participating in fishing, harvesting wild fruits and arable *molapo* farming were considered at high risk. Women were regarded as being at higher risk when harvesting aquatic plants including water lily (*N. nouchali*). Adult men and boys engaged in pastoral *molapo* farming and hunting in the river in summer, were considered as having increased risk of transmission. With regards to arable *molapo* farming, all members of the household were considered at risk. Nonetheless, the participants reasoned that all genders are vulnerable to diseases exposure. Of all social groups, boys were regarded having increased risk of malaria transmission. This can be attributed to their high participation in many of the livelihood activities (they work with both their mothers and fathers). Men were considered the second most exposed to risk of disease (after boys), followed by women. While girls are the least exposed to the disease, due to their limited participation in the activities (they usually work with their mothers only). It has been observed that although some parts of the country experience sporadic transmission, the northern districts particularly Chobe and Okavango experience perennial transmission (WHO 2007). This maybe attributed to the perennial surface water found in these districts. Therefore fishers, grass and reed harvesters and participants in other water based livelihood activities are likely to be exposed due to the perennial transmission of malaria in this district.

Fisheries are important for majority of livelihoods in African countries for river dwelling communities such as those found in Tanzania, hence malaria is an occupational hazard for such communities (Mboera *et al.* 2013; Njaya & Howard 2006). Commercial fishers are perceived as being at high risk of malaria transmission due to the techniques, duration and time of the day of occurrence of their activity. According to Mosepele *et al.* (2007), commercial fishers in the Okavango set nets before dawn (when the malaria mosquito is much likely to bite) around 0400hours and lift them shortly after, at times the nets are set in the evening around 1900hours and 2100hours for overnight fishing. Furthermore there is evidence that most fishing communities are poor and tend to be exposed to numerous health risks including malaria (Njaya & Howard 2006).

These results are consistent with the conclusion by (Esan *et al.* 2014) that the difference in exposure to malaria mosquito bites due to labour division by gender may be the cause for the severe and prevalent malaria infection in males compared to females. In most cases men engage in outdoor activities such as in the fields and forests where mosquitoes are most likely to bite them (Reuben 1993). Another explanation for this could be that males expose their bodies more especially during hot weathers making them more vulnerable to mosquito bites. Contrary to the males, females tend to stay covered up, reducing chances of mosquito bites (Akanbi *et al.* 2010). However, doing chores before dawn may expose women to malaria transmission (Reuben 1993). It is noteworthy that given equal exposure, both genders stand the same chance of malaria transmission, with the exception of pregnant women whose immunity is biologically compromised especially in malaria endemic areas (Reuben 1993). Figure 2 below shows that key informants rated pregnant women as the third most vulnerable social group at 52.5%. In Africa, of the 50 million women in malaria-endemic areas who become pregnant each year, 10,000 women and 200 000 new born babies die each year due to malaria (Chedruai, Daily & Wylie 2016).



Key informants were also asked to rate livelihood sources and risk of malaria transmission. Figure 2 below shows the top five livelihood sources ranked in relation to perceived malaria transmission risk as the following: commercial fishing (62.5%), grass harvesting (50%), reed harvesting (47.5%), livestock herding (45%) and arable farming (42.5%). There is no literature linking reed and grass harvesting to malaria transmission, but from this study it has been observed that these activities take place from July to November, thus overlapping for two months with the malaria season which is October to April.

According to Sogoba *et al.* (2007) fishing settlements have more adult mosquitoes and larval habitats during the dry season which extend into nearby areas at the beginning of the rainy season. Areas in proximity to mosquito breeding sites have highest human biting rate immediately after mosquito densities peak, which is when adult mosquitoes have contact with humans (Mboera *et al.* 2013). Therefore it is reasonable that fishing was perceived as the riskiest activity in Shakawe and Ngarange and these communities rely heavily on fishing for their livelihoods.

**Table 3:** Livelihood source and exposure extent (T) by gender (♂men ♀women, girl 😊☹️ boy) and age

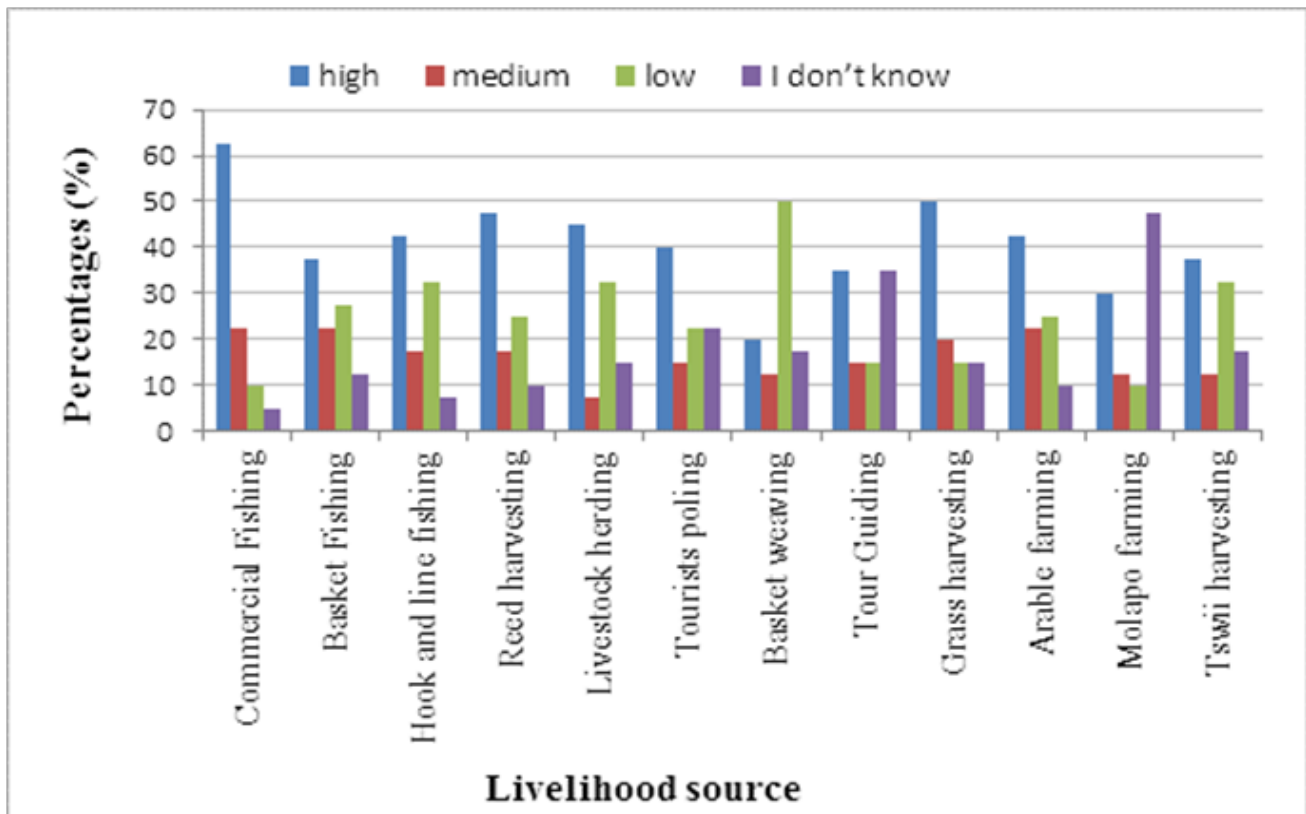
Livehood activity	Malaria	Exposure
1. Gathering of water lily and other plants etc.	TTT	♀
2. Fishing	TTT	♀ 😊 ☹️
3. Gathering of fruits by the river (winter)	TT	♀♂ 😊 ☹️
4. Gathering of fruits by the river (summer)	TTT	♀♂ 😊 ☹️
5. Gathering of wild fruits (winter)	T	♀♂ 😊 ☹️
6. Gathering of wild fruits (summer)	TT	♀♂ 😊 ☹️
7. Water reed, grass and harvesting in the river	TT	♀ 😊
8. Harvesting grass in the wild	T	♀ 😊
9. <i>Molapo</i> arable farming	TTT	♀♂ 😊 ☹️
10. Dry land arable farming	T	♀♂ 😊 ☹️
11. Irrigation farming (summer)	TT	♀♂ 😊 ☹️
12. Irrigation farming (winter)	T	♀♂ 😊 ☹️
13. <i>Molapo</i> pastoral farming	TTT	♂ ☹️
14. Dry land pastoral farming	TT	♂ ☹️
15. Hunting in the wild	T	♂ ☹️
16. Hunting at the river (winter)	T	♂
17. Hunting at the river (summer)	TTT	♂ ☹️

Having livestock kraals nearby diverts and reduces the mosquito population density away from human dwellings (Yakubu & Singh 2008). However, livestock kraals could also attract more mosquitoes to nearby houses (Saul 2003). Proximity of enclosed livestock supplements the source of blood meal for mosquito reproduction, and breeding habitats. Such incidences have been observed in Ethiopia and Pakistan where an increase in the density of malaria vector was linked to livestock (Hewitt *et al.* 1994; Tirados *et al.* 2011). Given that *Anopheles arabiensis* is exophilic, that is, the species rests outdoors (Durnez & Coosemans 2013), it is possible that outdoor biting rates and risk are higher for households with livestock (Tirados *et al.* 2011). Livestock farming in the study area involves herding cattle and driving them from the grazing areas into the kraals in the evening, when mosquitoes are likely to bite, especially for the *molapo* pastoral farmers where, cattle graze on the flood plains and islands, thereby increasing the chances of malaria transmission for these herders.

The findings from this study also show that respondents link arable farming with exposure to

malaria transmission. Crop cultivation has been reported among the livelihood activities that increase mosquito productivity, biting exposure and consequent malaria transmission intensity (Mboera *et al.* 2013). Other studies have observed that, on average all malaria indices are higher near cultivated swamps, due to exposure to mosquito bites in the process of tending for crops (Lindblade *et al.* 2000). Flood recession (*molapo*) farming is practised in the seasonally flooded plains (Magole & Thapelo 2005). As soon as the flood recedes in the Okavango Delta around August, ploughing starts hence tending the crops and harvesting time will coincide with transmission season in November.

Figure 2: Livelihood sources and malaria exposure by key informants.



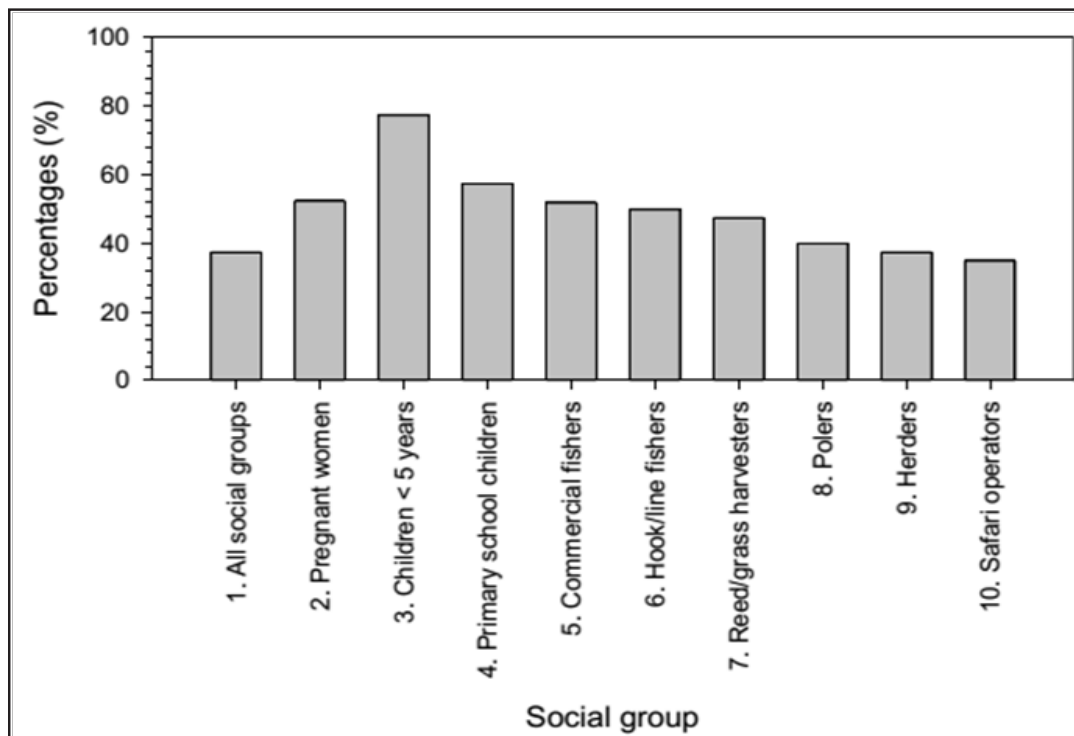
*Social vulnerability to malaria*

Key informants were asked to indicate social groups they perceived as vulnerable to impacts of malaria transmission. Children under 5 years and primary school children were found to be the most vulnerable to malaria transmission by 77.5% and 57.5% (N=40) of the respondents respectively; followed by pregnant women, commercial fishers and hook and line fishers as indicated in Figure 3. Figure 4 shows national malaria data from the Ministry of Health indicating that children under 5 years of age (0-4 years) had 14 cases of malaria in 2015 and children of 5-10 years of age (who are likely to be in primary school) have the highest number (30) of malaria cases in all age groups. Chirebvu *et al.* (2016) found out that age group of less than 5 years in Tubu (another village along the Delta fringes) had the highest cases of clinical malaria. Figure 3 also suggests that males in almost all age groups had more cases of malaria compared to females, particularly in the age groups between 16 to 40 years old. Commercial and hook and line fishers, as alluded to by key informants, are normally male and are therefore more likely to be exposed to mosquito bites.

The responses from this study align with the WHO statistics which show that children under 5

years of age are among the most vulnerable groups affected by malaria. There were an estimated 438 000 malaria deaths worldwide in 2015, of which approximately 69% were of children under 5 years of age ( WHO 2016). Of the >500 million school-age children worldwide at risk of malaria infection, 200 million of them live in Sub-Saharan Africa (Gething *et al.* 2011).

**Figure 3:** Social group and malaria exposure. Source: Compiled by author from the Key informant interviews results.



*Climate variability and malaria exposure (floods, rainfall and temperature)*

The PRA participants were asked to establish the direction of the impact (that is, which factor/s increased or decreased the risk of exposure to malaria vector) and the extent (either positive + or negative -) on malaria transmission in relation to host abundance, + or - represents the direction of impact. The climate variables considered were: drought, high flood, low flood, heavy rain, low rain, wet spells, dry spells, cold spells and hot spells (Table 4). Drought (low rain), heavy rains, cold spells, dry spells and the shift of seasons, from summer to winter, were negatively associated with malaria transmission; these variables were perceived as unfavourable for survival of the vector. This is in contrast with a survey of wetlands in the United States of America where mosquito density increased intensely in natural drought conditions (Chase & Knight 2003). Participants in this study attested that floods (high and low), low rainfall, wet spells and hot spells increased mosquito abundance. Climate variables which increase mosquito abundance consequently increase malaria cases, and vice versa. From the key informant interviews, climate variables such as drought, floods, rainfall and temperature are recognised as having an impact on malaria incidence patterns. In summary, Table 5 shows that most respondents link temperature, floods and rainfall with increased incidences of malaria (65.0%; 77.5% and 67.5% respectively).

Malaria epidemics have been linked to temperature variability before and during the rainy season. Higher temperatures shorten the development time of the larvae and parasites in the mosquitoes (Thomson *et al.* 2005) hence the likelihood of an increase in number of vectors and malaria transmission

incidence. *Anopheles arabiensis* has been recorded to exhibit great production at extremely high water temperatures; hence this species dominates the hottest months (Kirby & Lindsay 2009). This is in consensus with this study, participants attest that hot spells result in high mosquito abundance and consequently increase malaria cases. The minimum and maximum monthly temperatures averages recorded from 2001 to 2013 in Shakawe were 13-15°C and 30-32°C respectively (CSO 2015). This may explain the seasonal malaria outbreak in the hottest months (November to May) in Botswana

Figure 4: Notified malaria cases by age group and sex. Source: Ministry of Health (2015)

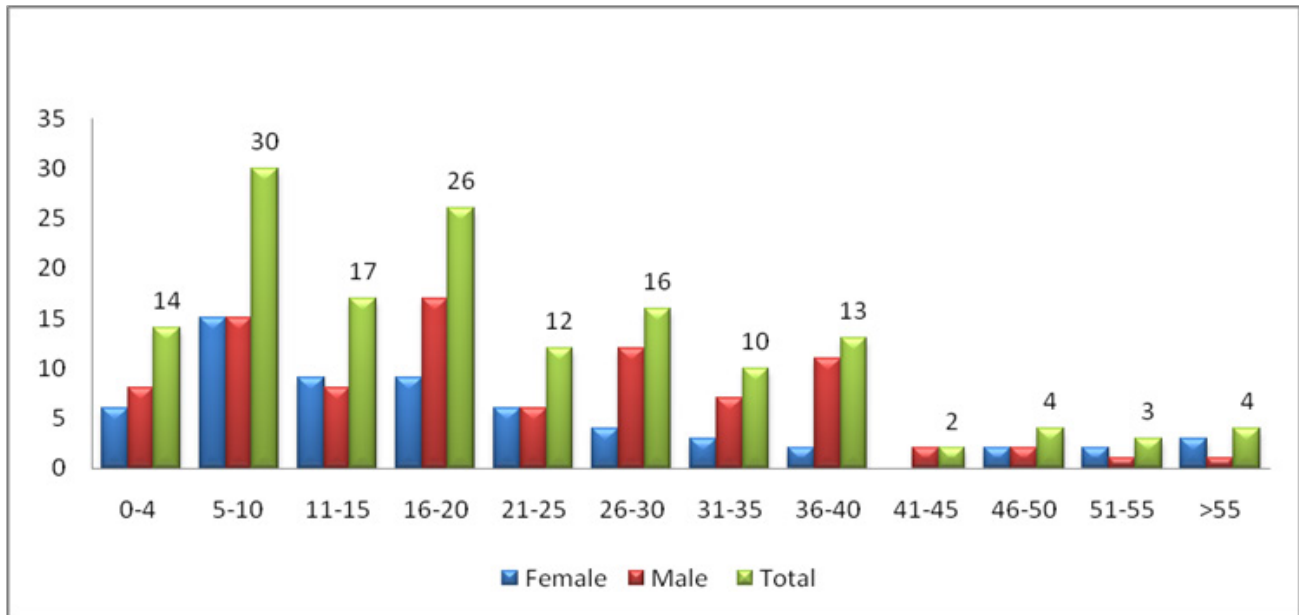


Table 4: Influence of perceived climate variability on mosquito abundance and malaria

Disease/ Vector	Climate variable									
	Drought	High Flood	Low Flood	Heavy Rain	Low Rain	Wet Spell	Dry Spell	Cold Spell	Hot Spell	Shifting Seasons
Mosquito	- high	+high	+medium	- medium	+high	+high	- high	- high	+high	+ medium (winter-summer) - medium (summer-winter)
Malaria	- high	+high	+medium	- medium	+high	+high	- high	- high	+high	+ medium (winter-summer) - medium (summer-winter)

**Table 5:** Climate variability and malaria incidences

Climate variable	<b>Malaria % (N =40)</b>			
	They are not linked	Increased Incidences	Reduced incidences	Don't know
Drought	27.5	20	5	47.5
Floods	5	67.5	0	27.5
Rainfall	5	77.5	0	17.5
Temperature	7.5	65.0	0	27.5

Even though floods may initially wipe out mosquito breeding habitats, they are recreated as the waters recede resulting in malaria outbreak within an interval of 6-8 weeks. Heavy rainfalls or river overflows may leave stagnant water behind, providing breeding sites for mosquitoes, and exposing affected populations to malarial infections (WHO 2016). In developing countries, members of poor fishing communities are found in the floods prone areas and in proximity to the shore, hence they are susceptible to post disaster problems including malaria (Njaya & Howard 2006). Shakawe and Ngarange populations are in the poorest district in Botswana with a poverty head count rate of 46.2 % (CSO 2014). The human populations in these villages are also vulnerable to floods as they are located along the banks of the Okavango Delta.

According to Thomson *et al.* (2005) more than two-thirds of the malaria variability incidences from January to May in Botswana can be attributed to rainfall that occurs from December to February. The livelihood disease calendar compiled from the focus group discussion also shows an overlap between the flood season (March-April), malaria mosquitoes and malaria incidences. This period (between March and April) has been observed as the high flow (five times higher than the lowest volumes of water: between September and November) season into the Delta through the panhandle (Mendelsohn *et al.* 2010).

### Conclusion

This study has demonstrated that community-level exposure to malaria is linked to the livelihood activities of community members. This exposure is also differentiated by social group (by gender and age). The study has further illustrated that the community possess useful local knowledge of environmental conditions, including seasonal and climate variations, which enhance and/or inhibit mosquito breeding resulting in various levels of malaria transmission. Exposure to mosquito bites and hence malaria transmission also varies with activity, water-dependent activities present higher exposure to malaria as compared to other activities. Fishing in general exposes community members to malaria transmission more than other occupations. Natural resource-dependent sources of livelihoods, such as farming, fishing, herding and hunting face diverse and distinct climate change-related risks induced by heavy rains, high winds, drought, fires and invasive species. Climatic variability risks are perceived to increase mosquito abundance consequently, increasing malaria cases and transmission intensity and vice versa. From the findings of this study we suggest that there is need for integrative re-thinking to improve malaria prevention and control strategies, and to pay more attention to the potential contribution of certain livelihood activities and practices to malaria transmission.

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