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Indigenous environmental indicators for malaria: A district study in Zimbabwe

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ABSTRACT

This paper discusses indigenous environmental indicators for the occurrence of malaria in ward 11, 15 and 18 of Gwanda district, Zimbabwe. The study was inspired by the successes of use of indigenous knowledge systems in community based early warning systems for natural disasters. To our knowledge, no study has examined the relationship between malaria epidemics and climatic factors in Gwanda district. The aim of the study was to determine the environmental indicators for the occurrence of malaria. Twenty eight key informants from the 3 wards were studied. Questionnaires, focus group discussions and PRA sessions were used to collect data. Content analysis was used to analyse the data. The local name for malaria was 'uqhuqho' literally meaning a fever. The disease is also called, "umkhuhlane wemiyane" and is derived from the association between malaria and mosquitoes. The findings of our study reveal that trends in malaria incidence are perceived to positively correlate with variations in both temperature and rainfall, although factors other than climate seem to play an important role too. Plant phenology and insects are the commonly used indicators in malaria prediction in the study villages. Other indicators for malaria prediction included the perceived noise emanating from mountains, referred to as "roaring of mountains" and certain behaviours exhibited by ostriches. The results of the present study highlight the importance of using climatic information in the analysis of malaria surveillance data, and this knowledge can be integrated into the conventional health system to develop a community based malaria forecasting system.

1. Introduction

Early warning systems provide communities with relevant, topical information on environmental conditions so that they can assess levels of risk and make informed decisions to protect their safety (Centre for international studies and Cooperation, 2011). Most early warning systems are self-monitored by villagers and this empowerment indicates that the community is a key stakeholder in the early warning strategy (Centre for international studies and Cooperation, 2011).

A malaria early warning system is a series of approaches that refine the understanding of geographical variation of malaria risk in a dynamic environment and usually comprises forecasting, early warning and early detection. In this context, forecasting refers to seasonal climate forecasts; early warning refers to the monitoring of meteorological conditions and early detection is case surveillance (Hay et al., 2003; Cox and Abeku, 2007). The same authors argued that much research on malaria early warning systems has focused on methodological or scientific issues and that it is probably the practical aspect of implementation that has been a barrier to their uptake.

Malaria early warning attempts to predict epidemics before unusual transmission activity begins usually by using weather variables that predict vector abundance and efficiency and therefore transmission potential (Thomson and Connor, 2001; Thompson et al., 2005). Seasonal climate forecasts accurately predict the average season's weather, increases in mosquito density and survival including mosquito and parasite development rates (Thomson and Connor, 2001). The same authors postulate that vector and parasite dynamics will accurately predict increases in the entomological inoculation rate which will be directly related to the number of malaria cases. Rainfall anomalies are widely regarded to be a major

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driver of inter-annual variability of malaria incidence in semi-arid areas of Africa (Thompson et al., 2005).

A model to analyse the spatial temporal role of climate in inter-annual variation of malaria incidence in Zimbabwe for the period 1988–1999 showed that high annual malaria incidence coincided with high rainfall and relatively warm conditions while low incidence years coincided only with low rainfall (Mabaso et al., 2006). The study demonstrated that mean values of temperature, rainfall and vapour pressure are strong predictors of increased malaria incidence.

Since the occurrence of malaria is determined by variations in climatic factors epidemics may be predicted using these factors. Indigenous knowledge systems have been used by local populations to develop mitigation and adaptation strategies to reduce their vulnerability to climate variability (Nyong et al., 2007; Jiri et al., 2016; Orlove et al., 2010; Anandaraja et al., 2008; Pareek and Trived, 2011). Even though indigenous knowledge is the basis for local level decision making in many rural communities, it has value not only for the culture in which it evolves but also for scientists and planners working to improve the lives of rural communities (Soropa et al., 2015). This knowledge is however rarely taken into consideration in the design and implementation of modern mitigation and adaptation strategies. Indigenous cultures have warning systems for various hydro- meteorological events that have proven effective for generations in warning local populations about impending threats (Glantz, 2009; Soropa et al., 2015). Communities in hazard prone areas have generated a vast body of knowledge on disaster prevention, mitigation, early warning, preparedness and response and post disaster recovery (Pareek and Trived, 2011; Armatas et al., 2016). People in malaria prone areas therefore have potential to develop malaria early warning systems using indigenous knowledge systems to reduce their vulnerability to malaria outbreaks. Indigenous knowledge is one of the tools of early warning apart from Geographic information system (GIS), remote sensing and forecast warning terminology (Glantz, 2009). Scientific forecasts tend to be applicable to relatively large areas and lack specificity. The information is usually disseminated late and in unfriendly languages with technical jargon that limits the uptake of such warning information (Mapfumo et al., 2015).

Indigenous knowledge is a body of knowledge, skills and technology, which belongs to a particular geographical community (Ndangwa, 2007). It is based on practical experiences and can be preserved and harnessed for the benefit of both present and future generations, which live in these communities (Mapira and Mazambara, 2013). Indigenous knowledge refers to practices that evolved through trial and error and proved flexible enough to cope with change (Eyong, 2007). Integration of indigenous knowledge and scientific warning systems seems to be a key possible thrust to reduce vulnerability, enhance resilience and increase the adaptive capacity of rural communities (Jiri et al., 2016). In order to integrate indigenous knowledge into conventional health systems there is need to acknowledge that indigenous knowledge has provided people with the capability of dealing with past and present vulnerabilities. Several studies have shown how indigenous knowledge is utilised in forecasting climatic variations in agriculture (Jiri et al., 2016; Armatas et al., 2016; Mapfumo et al., 2015; Byg and Salick, 2009; Nethononda et al., 2013; Kalanda-Joshua et al., 2011; Chang'a et al., 2010; Kihupi et al., 2002; Mhita, 2006; Ayal et al., 2015; Mahoo et al., 2015; Gukurume, 2014).

Local communities in different parts of the world have continued to rely on indigenous knowledge to conserve the environment and deal with natural disasters and this knowledge is still intact in many parts of Africa and other regions of the world (Kijazi et al., 2012). Indigenous knowledge on rainfall prediction in Zimbabwe was demonstrated in several studies (Soropa et al., 2015; Risiro et al., 2012; Shoko and Shoko, 2013; Mudzengi et al., 2013; Makwara, 2013). Local communities in Zimbabwe have been coping with droughts through the integration of scientific and indigenous weather forecasting methods (Shumba, 1999). The same methods can be utilised for the prediction of malaria.

In response to the need to develop malaria early warning systems in Africa, the World Health Organisation published a framework proposing the generic concepts and potential early warning and detection indicators for use in Malaria early warning systems (Thomson and Connor, 2001). The framework has seasonal climate forecasting and environmental monitoring as some of its components and is mainly directed for utilisation by the health systems.

Communities are capable of forecasting rainfall using various environmental and astronomical indicators as well as plant phenology, behaviour and movement of birds, animals and insects as demonstrated in studies discussed earlier. If the community's ability to relate rainfall to the occurrence of malaria is established, their ability to predict malaria can also be enhanced. The studies done in Zimbabwe have focused on rainfall prediction for agricultural purposes. The utilisation of indigenous knowledge systems for the prediction of malaria in Zimbabwe and specifically in Gwanda district has not been demonstrated. We assessed the perception of local communities on the environmental indicators for the occurrence of rainfall as a precursor to the occurrence of malaria in ward 11, 15 and 18 of Gwanda district in Matabeleland South, Zimbabwe. Community perceptions of malaria as a disease and the factors that they perceive as affecting its occurrence were also assessed.

2. Methodology

2.1. Study area

The study was conducted in wards 11, 15 and 18 of Gwanda District in Zimbabwe. Fig. 1 shows the position of Gwanda District in Matabeleland South, Province and the location of the province in Zimbabwe.

Zimbabwe has seasonal and geographic variation in malaria transmission that corresponds closely with the country's rainfall pattern (Mabaso et al., 2005). Malaria transmission mainly occurs during the rainy season between November and April, with average temperatures ranging from 18 and 30 ° Celsius. The peak transmission season for malaria is between February and April. The annual rainfall in Gwanda district is less than 700 mm (President's Malaria Initiative, 2016). The low rainfall received in the area has necessitated the construction of dams and setting up of irrigation schemes. People in the District mainly survive through subsistence farming, cattle ranching, brick moulding, irrigation farming, gold panning, fishing, vending and cross border trading.

A ward is an administrative area under a district that consists of an average of 10 villages and each village consists of an average of 100 households. Wards 11, 15–18 and 20–24 in the southern part of Gwanda experience unstable malaria. There are 12 146 households and an overall population of 50434 people in these wards (Zimbabwe National Statistics Authority, 2013). Gwanda has recorded the second highest mortality due to malaria in Matabeleland South Province in the period 2009–2013 as shown in Fig. 2. The highest mortality was in Beitbridge district with 29 deaths followed by Gwanda district with 11 deaths (District Health Information, 2016).

The district also recorded the second highest incidence of malaria during the same period as shown in Fig. 3. Malaria control is mainly through indoor residual spraying, the use of insecticide-treated nets (ITN) and larvaciding. Communities are not directly involved in the planning of these control measures but are usually informed when decisions have been made at the district level.

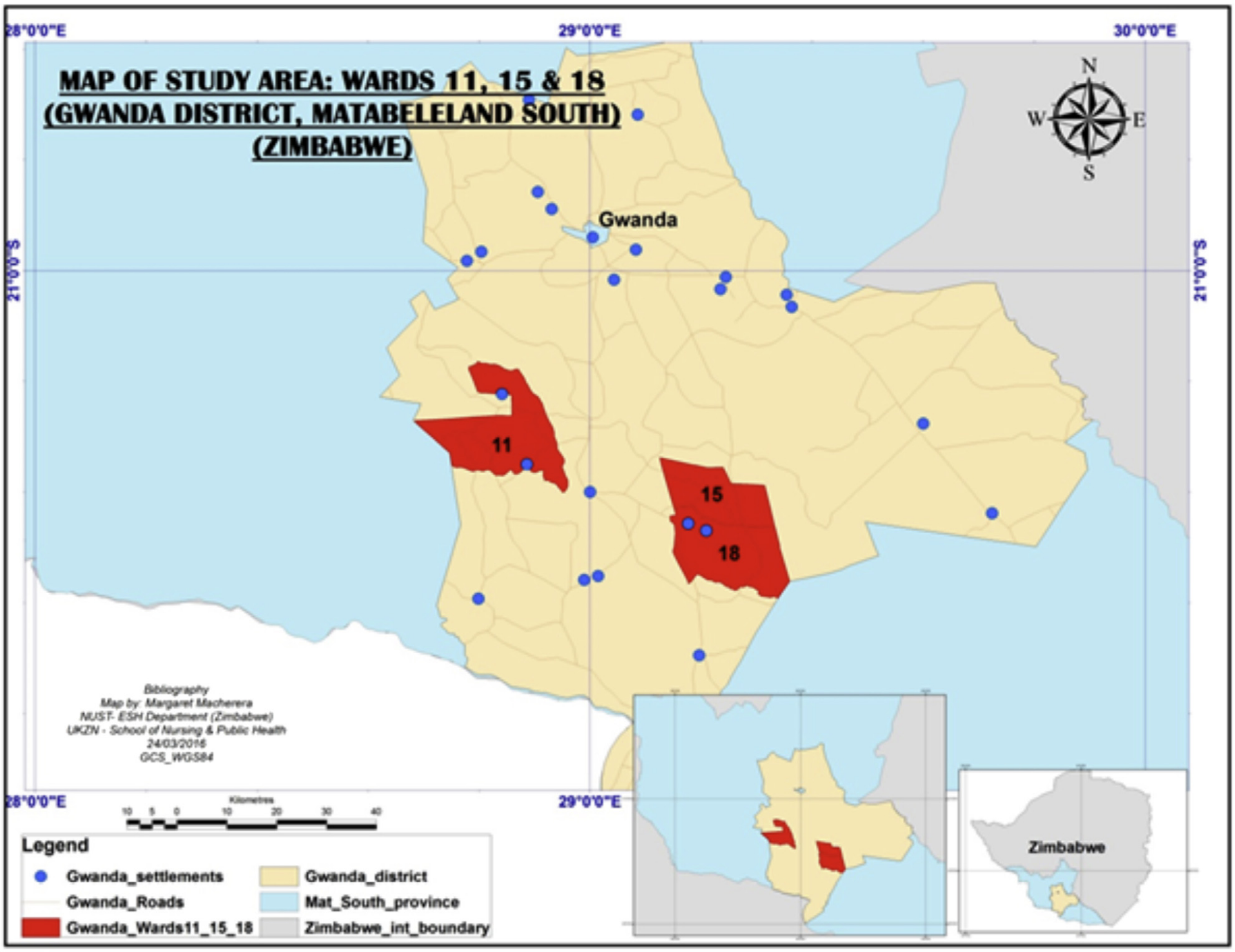

Fig. 1. Map showing the position of Gwanda district in Matabeleland South Province and the position of the province in Zimbabwe.

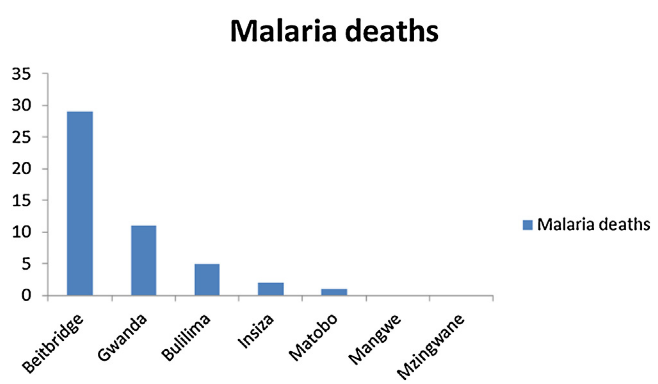

Fig. 2. Malaria deaths per district in Matabeleland south Province (2009–2013) (District Health Information, 2016).

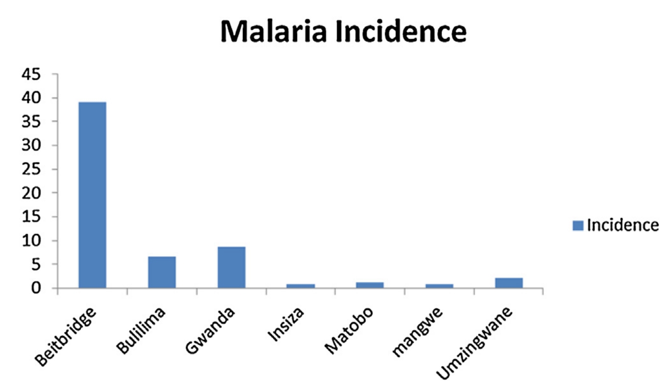

Fig. 3. Malaria incidence per district in Matabeleland south province (2009–2013) (District Health Information, 2016).

According to the principal environmental health officer in Matabeleland South Province, there is no formal malaria early warning system (EWS) in the district and province in general. The district depends on weekly surveillance for early detection of outbreaks but because the data is centrally (at the province level) analysed the response to malaria outbreaks is delayed. There is limited capacity within the district to capture weather patterns in order to predict outbreaks. A malaria pre-elimination capacity assessment study conducted in Matabeleland South Province in 2011 showed that malaria positivity rates for Gwanda were around 8% and the district had the second highest density of *Anopheles* larvae scoop of 4 after Bulilima district, in the same province, which had 10 (Ministry of Health and child welfare Zimbabwe, 2011).

2.2. Operational approach

The selection of the wards to be studied was based on the prevalence of malaria. The wards with the highest prevalence of malaria in the district were selected. Clinical cases recorded in ward 11, 15 and 18 between 2005 and 2014 were 1045, 811 and 1233 respectively (District Health Information, 2016). Pretested key informant interview guides and focus group discussion guides were used to collect the data. The data collection tools solicited for information on the local name for malaria, the perceived signs and symptoms and the causes of malaria. Questions were also asked on the season of occurrence for malaria and how the occurrence of malaria is predicted in the community during the season of occurrence. The interviewer probed on the different categories of indicators such as plant phenology, insects, animals and astronomical and meteorological indicators for rainfall as a precursor to the occurrence of malaria. Three focus group discussions (FGDs) were conducted in the three study wards. The participants of the groups were identified through the ward councillors, who provided a list of elderly men and women in each ward and their age groups.

The elderly men and women were ranked according to age and assembled into groups starting with the eldest until 12 participants were obtained ensuring equal representation in terms of gender. The discussions were conducted at the ward centres during times convenient to the participants. Key informant interviews were conducted with, traditional leaders, traditional healers and faith healers who were purposively sampled. The number of key informants interviewed in each ward depended on the number of leaders and healers in each ward. Where the leaders or healers were not available, the elderly aged 50 years and above who were not included in the focus group discussions were interviewed. A total of 28 key informants across the three wards were interviewed.

Two participatory rural appraisal (PRA) sessions were conducted; one in ward 15 and another in ward 11, to assess the community perception on the impact of variability of weather patterns on the occurrence of malaria. The sessions were attended by 67 participants in ward 11 and 71 participants in ward 15. The participants were divided into groups and asked to construct ward disease calendars. After that exercise they were asked to construct tables showing the impact of the various weather patterns on the presence of mosquitoes and malaria.

3. Results

3.1. Perception on malaria

In all the wards studied, the term malaria was commonly used. The main vernacular names used for malaria were 'uqhuqho'or 'inyongo' and the name 'umkhuhlane wemiyane' was mentioned in one of the focus group discussions in ward 11. However the name malaria was commonly used in all the wards. The name 'uqhuqho' literally means shivering. After probing to find out the origin of the name the study participants said that the person with malaria shivers and sometimes feels hot so the name describes the shivering. Twenty one out of the 28 key informants interviewed referred to malaria as 'uqhuqho' while 6 out of the 28 (21%) key informants called it 'inyongo' the reason being that a person with malaria shivers and vomits bile. One of the respondents said

> 'uqhuqho lubizwa njalo ngoba yikho okwananzelelwayo kakhulu emuntwini ogulalumkhuhlane.'

This statement means that the disease derives its name from the shivering symptoms experience by a patient. One of the respondents, a traditional healer, referred to malaria as a disease of the mind because the person gets confused. The other names mentioned included jaundice and 'umvimbano' which means difficulty in breathing.

3.2. Community perception on the causes of malaria and the season of occurrence

All key informants expressed that malaria was transmitted by mosquito bites. Nine of them (32%) said that the mosquitoes emerge from dirty water around the homes and in marshy areas. Some of the participatory rural appraisal participants also related the occurrence of malaria with poor hygiene, and eating sweet food. However, many of them associated the disease with the presence of rain and pools of water where the mosquitoes breed. This concurred with the findings from the FGDs where malaria was said to be transmitted by mosquito bites. Two FGDs, one in ward 18 and the other one in ward 15, however, related the occurrence of malaria with the presence of new fruits and the budding of new leaves during the rainy season. Participants of the focus groups in ward 11 indicated that malaria occurs during the months of March and April. This concurred with the group in ward 15 that agreed that malaria occurs during the period November to April. The group in ward 11 mentioned the peak of the malaria season, while participants in ward 15 talked about the whole malaria season. The PRA groups in ward 15 conducted an analysis of the impact of climate variability on the occurrence of malaria and also the occurrence of mosquitoes. The PRA participants constructed tables showing that during times of drought and during cold spells there were few mosquitoes and also a few cases of malaria. The occurrence of malaria was perceived to be high when there was heavy rain and wet spells and low when there was low rainfall. The participants expressed that the important factor in the occurrence of malaria was the availability of pools of water for mosquitoes to breed. When asked how malaria can be present when there is low rainfall, they said that when pools of water are formed they can provide breeding places for the mosquitoes that cause malaria. The occurrence of mosquitoes and malaria was also related to hot temperatures. Contrary to the consensus reached in ward 15, the ward 11 group said there was low malaria and fewer mosquitoes during wet spells and when there was little rain. The disease livelihoods calendar drawn by the community during the PRAs showed that the malaria season occurred during the rainy season. This was the season perceived to have high temperatures and also the season during which many mosquitoes were observed. The malaria season was perceived as starting in October and ending in March, while the rain season started in October and ended in April. Mosquitoes were observed from the month of September up to May. High temperatures were experienced from September to April.

3.3. Predictions

Participants of the FGDs agreed that it was possible to predict malaria using rainfall because of the relationship between occurrence of malaria and rainfall. Twenty one (78%) of the key informants also said that it was possible to predict the occurrence of malaria using rainfall predictions. Plant phenology was found to be the most used indicator in predicting the occurrence of malaria in all the wards. The participants indicated that the flowering and leafing of plants and the abundance of fruits in trees were mostly used as predictors for rainfall as well as signs for the occurrence of malaria as shown in Table 4. This could probably be because the trees are easier to observe than the other indicators. Other indicators mentioned include behaviours and movement of birds, insects and animals. A beetle called "inkunkwane,"*cleoptera: tenebrionidae* was said to be the most accurate insect in the prediction of rainfall in all the wards. The occurrence of these indicators was also used to determine the intensity of malaria for the season. The findings revealed that most of the indicators the communities used for the prediction of malaria were those occurring in the period from September to November. No indicators were mentioned for time periods before September. The communities expressed that although these indicators worked for them, sometimes they would miss them because there was no formal way of observing the indicators with most of the observations made on an individual basis. The knowledge, however, was communicated to the younger gen-

Table 1
Demographic characteristics of the key informants.

Characteristic	Frequency
Gender	
Male	18
Female	10
Level of Education	
Primary	13
Secondary	15
Age groups	
Between 50 and 60 years	11
60 years and above	17

erations at community meetings called 'inkundla'. Some of the indicators mentioned by the communities were associated with ancestral spirits symbolized by lions and elephants passing by the homestead. This was perceived as an indicator of a good rainy season but a season with high incidence of malaria as was also the roaring sounds heard from the mountains and spontaneous fires on top of sacred mountains. A good rainy season signified high incidence of malaria. Meteorological indicators including wind patterns, direction and variation were mentioned as monitoring indicators for rainfall. As mentioned earlier, less rainfall meant that there would be less malaria while more rainfall meant more disease. When asked about the reliability of the indicators, 82% of the key informants said the indicators were reliable. The remainder said that they did not know or they did not observe the indicators. The focus group discussion participants indicated that it would be possible to integrate indigenous knowledge systems (IKS) into the health system through existing structures such as the ward health teams and the traditional leadership. This concurred with the responses from 64% of the key informants. Tables 1–3 provide details of the local indicators used for the prediction of malaria in the three wards and how they are used. Although one of the wards under study was under different traditional leadership, all the wards concurred in terms of the indicators that they use for the prediction of malaria.

It was observed that even though the communities were aware of the indicators the observation was on individual basis and not integrated into the conventional health system.

The documentation of the different categories of indicators used to predict the occurrence of malaria is shown in Tables 1–7 .

3.4. Month-wise malaria incidence for gwanda district 2011–2016

Data collected from the District Health information 2 (Ministry of Health and child Care, 2016) showed that Gwanda district peak months for malaria were between February and May of every year. Fig. 4 shows that 2011 recorded the highest number of cases followed by 2014 then 2015 and 2012. The indigenous environmental indicators are observed between September and November which makes it possible for the communities to predict whether there will be high or low incidence of malaria between February and May of the following year.

3.5. Observed implications of climate change on indicators from focus group discussions

Focus group discussions were conducted in each ward studied. The discussions revealed that there were similarities in the changes observed by the communities in the 3 wards. They all indicated that there was a shift in the seasons in all the three wards. For instance rain was now erratic and its distribution pattern had changed. They also indicated that the winters had become warmer but longer. The

Table 2
Documented Insect indicators and their application in rainfall forecast Indicators.

Local name	English name	Signs commonly related with malaria incidence
Amagenga	Termite	Appearance of many termites indicate onset of rainfall. When they carry grass and make rapid movements that signifies imminent rainfall. However, these observations do not indicate the intensity of the rain and do not show the level of malaria incidence although they indicate the imminence of the malaria season.
Inkunkwane or Gugwana	Beetle (*cleoptera: tenebrionidae)*	The beetle hits the ground with its tail as a sign of good rain in that year. This usually happens around September and October. This shows that there is likely to be a high incidence of malaria
Amavevane amhlophe	White butterflies	White butterflies generally fly from west to east in large numbers signifying that much rain was expected. If the butterflies are observed in October, it indicates that the season is likely to be a good one in terms of rain abundance but implies that there would be high malaria incidence.

Table 3
Birds indicators and their application in rainfall forecasting.

Local Name	English name	Signs commonly related with malaria incidence
Ithendele	Guinea fowl	Laying of many eggs by guinea fowls is a sign of a good rainy season and that also implies high malaria incidence would be observed.
Intshe	Ostrich	When ostriches run with their wings flapping their bodies making noise that sounds like that from drums that signifies a good rainy season ahead. This usually occurs during the months of October and November and is associated with high incidence of malaria.
Inkonjani	Swallow	Large numbers of swallows observed flying in the sky signify the coming of rain and if that happens in November that means the onset of rains will be imminent. However, this observation does not provide information on the nature of the malaria season to be expected. It only shows that the malaria season is imminent.
Amahundundu	Ground hornbill	Ground hornbill makes noise around September to November if there is going to be good rain during that season and that signifies a high incidence of malaria.
	Migratory birds	Presence of large numbers of migratory birds signifies approaching of the rainy season and that indicates the beginning of the malaria season.

Table 4
Animal indicators for the prediction of rainfall.

Local name	English name	Signs commonly related with malaria incidence
Inyamazanazeganga	Wild animals	Wild animals bearing much offspring is an indicator of a good rainy season and high malaria incidence.
Inkomo	Cattle	Cattle run around with their tails up they indicate imminence of rain on that particular day. That does not signify the status of the season nor does it give an idea of the incidence of malaria.
Izilwane	Lions	Lions pass by the homesteads but do not attack livestock or people around September and October as a sign of a good rainy season ahead. This shows that there is going to be high incidence of malaria.

Table 5
Plants phenology documented indicators and their application in rainfall forecast.

Scientific name	Local name	Signs commonly related with malaria incidence
Lanchocarpus capassa Rolfe	ichithamuzi	If this tree produces flowers around October and November, that may mean that there would be much rain in the following rainy season and that malaria incidence would be expected to be high.
Boscia albitrunca (Burch.) Gilg & Benedict	Umthopi.	If this tree flowers early and produces many fruits by November, much rain will fall during that season. The incidence of malaria will be high.
Acacia karroo Hayne	Isinga	When this tree bears many fruits around October and November, there will be low rainfall in that season and the incidence of malaria will be expected to be low in that season.
Colophospermum mopane (Benth.) Leonard	Iphane	When this tree flowers and bears fruit before the rain falls, there will be low rainfall during that season and there malaria incidence will be expected to be low.
Cassia abbreviata Oliv	Isihaqa	When *Cassia abbreviata* produces new leaves during October and November that rainy season will be expected to be good and much malaria would be expected.
Ximenia caffra Sond	Umthunduluka	If these trees flower early around October, that rainy season will be expected to be good and there would be high malaria incidence When poor rains fall, the trees flower after the first rains and the incidence of malaria will be expected to be low.
Sclerocary abirrea (A Rich.) Hochst	Umganu	Flowering of this tree around October signifies a good rainy season and high incidence of malaria. If it flowers later than October less rain will be expected and the same for malaria incidence.
Jasminum stenolobum Rolfe	Umkhuwi/idolonkonyana	Early flowering of the tree signifies good rains for the year and high incidence of malaria.
Afzelia quanzensis Welw	Mukamba	If this tree produces new leaves early around September and October, there is going to be a good rainy season that year and high malaria incidence.
Acasia nigrescens Oliv	Isinanga	If the tree bears a lot of fruits it means that little rain is expected. If there Is drought the old leaves do not fall so the tree delays producing new Leaves. Malaria incidence will be expected to be low.

Table 6
Astronomical and meteorological indicators.

Local Name	English name	Signs commonly related with malaria incidence
Isiziba	Ring around the moon	When there is a good rain season the moon is surrounded by a ring. The bigger the ring, the more rains expected. A bigger ring signifies high incidence of malaria in that season.
Amayezi	Clouds	Clouds that show a good rainy season and high malaria incidence are those thinly spread in the sky. Clouds along the horizon mean much rain that year and a high incidence of malaria.
Ukutshisa	Increasedtemperatures	When temperatures are very high but alternating with windy conditions, a good rainy season is indicated for that year. High temperatures in October and November signify onset of rainfall and the prospect of a good rainy season. Malaria incidence is predicted to be high.
Umoya	Wind	When the wind blows from the east to the west and then from the west to the east there will be much rain in that year and high malaria incidence. If the wind continually blows from the east to the west, there will not be any rain and low malaria incidence. Frequent occurrences of whirlwinds during September and October show that there is going to much rain that year and high malaria incidence.
Umkhathi	Air and sky	When the air is hazy or misty around the months of September and October, there will be much rain during the coming rainy season and high malaria incidence.

rain was said to fall in patches and not covering the whole ward. Cyclones were said to have become more common. The change in the timing of maturation, greening and fruiting of some plants was also observed as due to climate change. The focus group discussion participants however maintained that the indicators are still viable despite the advent of climate change. The participants used a combination of indicators to curb the inaccuracy of those indicators that may have been affected by climate change. Climate change

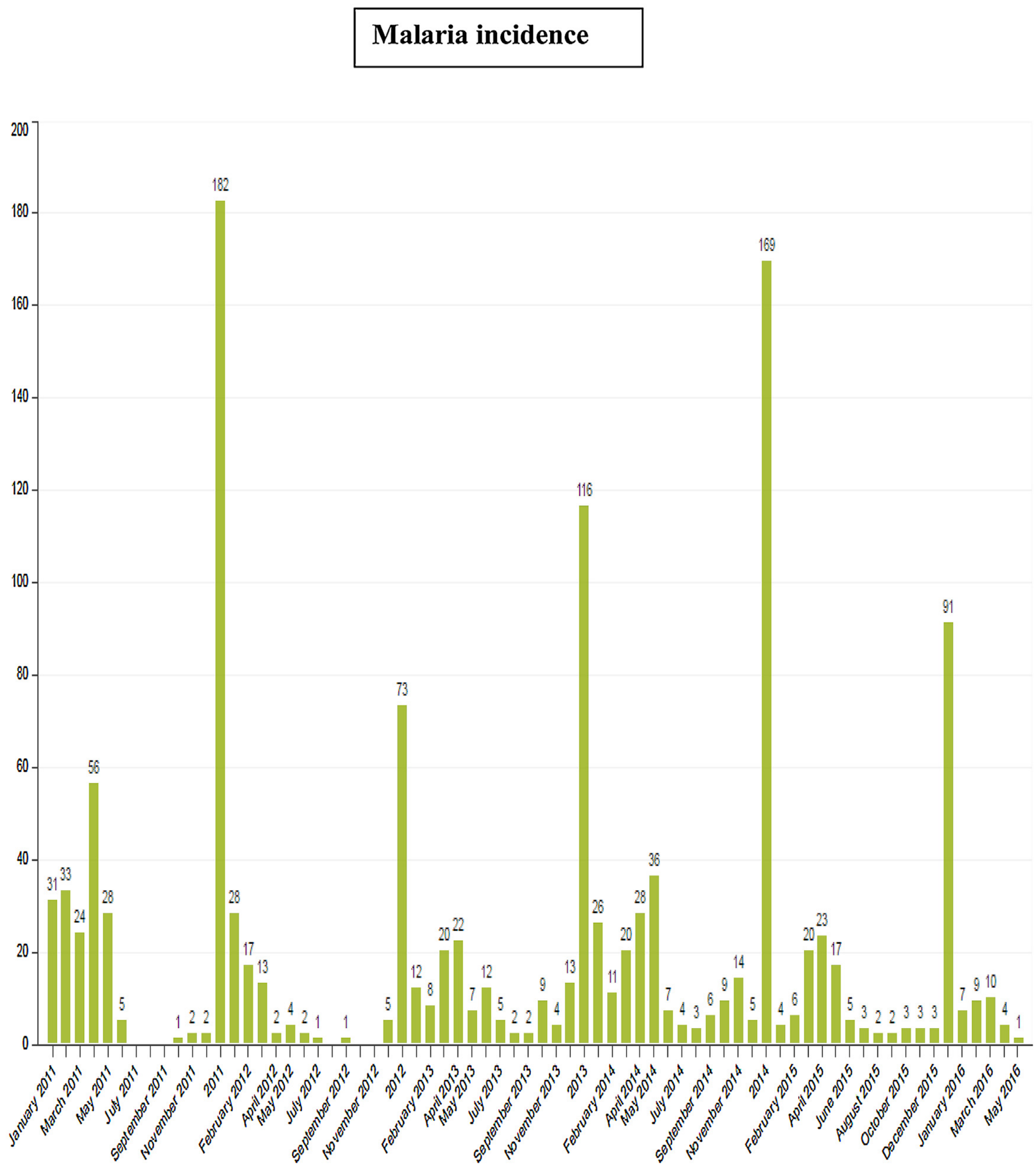

Fig. 4. Gwanda District Monthly confirmed malaria cases: 2011to 2016 (Ministry of Health and child Care, 2016).

Table 7
Other indicators.

Local Name	English name	Signs commonly related with malaria incidence
Amaxoxo	Frogs	When big frogs croak around September and October, there will be good rain that year and a high incidence of malaria.
Intaba	Mountains	When a roaring sound is heard from the mountains and there is fire breaks upon top of the mountains good rains will be expected that year Malaria incidence will also be expected to be high.

was said to have been caused by technology and mobility of people resulting in dilution of cultures. The participants also said that people no longer performed some cultural rituals like the rain making ceremonies. This has resulted in the observed changes in weather patterns (Table 7).

4. Discussion

The communities in wards 11, 15, and 18 of Gwanda district view malaria as a fever as deduced from the local name given to the disease. The vernacular names for the disease demonstrated the community's knowledge of the causes and signs and symptoms as derived from the literal meanings of these vernacular names. Even though the vernacular names existed the term malaria was commonly used in the study area. Other studies have shown that local terminology for malaria was derived from biomedical nomenclature with no vernacular names identified (Espino et al., 1997; Minja et al., 2001; Laar et al., 2013). The work reported in this study mainly involved elderly men and women who still had knowledge of the indigenous knowledge systems on malaria in the study area and hence it was possible to obtain vernacular nomenclature.

The reference to malaria as "umkhuhlane wemiyane" demonstrated that the community associated the occurrence of malaria with mosquitoes because it literally means a disease caused by the mosquito. A similar observation was also made in Tubu village in Botswana and other endemic countries such as India, Ghana and Ethiopia (Chirebvu et al., 2013; Vijayakumar et al., 2009; Ahorlu et al., 1997; Karunahmoorthi and Kumera, 2010; Jimma et al., 2005). The high knowledge levels could be due to the health education campaigns carried out by the Ministry of Health and Child Care during every malaria season and also during the implementation of the indoor residual spraying programme. The relationship between the occurrence of malaria and the advent of new leaves and eating of water melons can be explained by the fact that malaria season coincides with the availability of such foods. This may mean that people have observed that during the time of the year (February to April) when such foods are found in the fields many people suffer from malaria. The misconception on certain food types causing malaria was also noted in Myanmar (Kyawt-Kyawt-Swe Pearson, 2004). Several knowledge, attitudes and practices studies on malaria indicate that misconceptions concerning malaria are still present in different communities (Kyawt-Kyawt-Swe Pearson, 2004). Even though the community related the presence of mosquitoes to the presence of breeding places, there was a misconception on the breeding places for the anopheles mosquitoes. They said that the mosquitoes that cause malaria emerge from dirty water around the homes and in marshy areas. The community seemed not to know the difference between the vector mosquito and other species that do not transmit malaria. The other misconception was the association of malaria with poor hygiene; this could be because health promotion workers often talked about the removal of empty cans and the clearing of grass around the home as a way of preventing malaria. Similar environment-related misconceptions were also found to be common in other studies carried out in Southern Africa (Legesse et al., 2007; Okeke and Okafor, 2008; Maia and Moore, 2011). These misconceptions may be attributed to the way malaria health education campaigns are conducted which may result in misinterpretations (Legesse et al., 2007).

The respondents agreed that it was possible to predict the occurrence of malaria using the indicators for rainfall. Other studies conducted in the Okavango delta, India, Tanzania and Ethiopia have shown that local farmers have the ability to forecast weather events in their immediate environment using indigenous knowledge indicators (Anandaraja et al., 2008; Mahoo et al., 2015; Kolawole et al., 2014; Ayal et al., 2015). A study conducted in Kenya that investigated the relationship between malaria and weather conditions concluded that rainfall has the most predictive pattern to malaria transmission in the endemic study area (Sewe et al., 2016) thus confirming the possibility to predict the occurrence of malaria using rainfall prediction.

The current study participants described the malaria season in the study area. According to the study participants the malaria season was from October to April. This observation concurs with the documented malaria season for Zimbabwe (Mabaso et al., 2006; Mabaso et al., 2005 President's Malaria Initiative, 2016). The rain season in Zimbabwe normally runs from mid-November to March (Kanyangarara et al., 2016) this coincides with malaria transmission which usually occurs during the same period and peaks between February and May as a result of the preceding rains (Thomson et al., 2006). There is therefore a relationship between the rain season and the malaria season as pointed out by the study participants. This relationship between the rain season and malaria enabled the communities to come up with indicators for the occurrence of malaria. The use of indigenous based forecasting in agriculture has been extensively studied (Jiri et al., 2016; Mahoo et al., 2015; Soropa et al., 2015; Kolawole et al., 2014; Ayal et al., 2015). Despite the fact that the same indicators could be used to predict malaria through the prediction of rainfall not much work has been done in the use of indigenous knowledge to predict malaria. The importance of incorporating seasonal forecasts into the decision making in malaria control has been shown (Sewe et al., 2016; Thomson et al., 2006; Mabaso et al., 2005). In a study of indigenous weather forecast practices in a district in Tamil Nadu, India, farmers were reported to be using weather forecasting indicators to predict animal diseases (Mapira and Mazambara, 2013). This practice supports the possibility of utilising indigenous indicators in the prediction of malaria. Local indicators that are used by local communities in malaria prediction in the three wards studied were documented. It was observed that most of the indigenous knowledge indicators for rain and malaria were observed during the months of September, October and November. The same observation was also made in the South- western Highland of Tanzania (Chang'a et al., 2010). The Tanzanian study however focused on the prediction of rain. It has been found that plant phenology is the mostly used indicators in rainfall prediction in all the wards. The communities studied the timing of plant life cycle stages. The life cycles observed by the communities in plant life included leafing, flowering and the amount of fruit produce. The utilisation of plants for prediction of the occurrence of rain and hence malaria was commonly used. This could be due to the extinction of the animals and also the accessibility of the plants. The use of plant phenology in weather forecasting is widely practiced in Southern Africa and other parts of the world (Jiri et al., 2016; Soropa et al., 2015; Mahoo et al., 2015; Kolawole et al., 2014; Ayal et al., 2015).

The roaring noise emanating from mountains and spontaneous fires on the mountains during the months of September and October as a sign of a good rainy season could signify thunderstorms and not the status of the season or the incidence of malaria (Svotwa et al., 2007). The presence of smoke from spontaneous fires adds impurities to the air around which condensation can take place, which may explain how spontaneous fires may be related to rainfall. The behaviour of ostriches and the observation of migratory birds were also mentioned as good indicators used in rainfall and malaria prediction. A number of studies have been done that also identified the use of birds as indicators for rain (Chang'a et al., 2010; Kolawole et al., 2014; Svotwa et al., 2007; Manyatsi, 2011). The respondents said that swarms of butterflies flying from the west to the east during the month of October signify a good rain season and therefore a high incidence of malaria. The same observation was made in Tanzania to indicate a good rain season (Chang'a et al., 2010). The Tanzanian study found that the occurrence of large swarms of butterflies is indicative of imminent rainfall onset and the community there said that it is also a sign of a good season ahead. According to the current study a good rain season means high malaria incidence.

Amphibians like lizards and frogs were also used to predict rain in Gwanda. A good rain season and a season of high incidence of malaria is anticipated when big frogs croak around the months of September and October. The croaking of frogs during the summer season from September to March in Swaziland signifies approaching rainfall (Manyatsi, 2011). In the South western highland of Tanzania when frogs croak much it means that rainfall onset is near (Chang'a et al., 2010). When the noise intensifies, it means that there could be more rainfall in the coming season.

High temperatures during the months of October and November were interpreted as a sign of a good rain season in Tanzania (Chang'a et al., 2010) and the same interpretation was also made in the Gwanda study. The similarities in the interpretation of the indigenous indicators in the different countries could mean that the indicators may be accurate in the prediction of rain in those countries. Another indicator mentioned by the respondents in Gwanda was that wild animals bear many offspring as a sign of a good season ahead. A study in the Manicaland Province of Zimbabwe reported similar findings (Svotwa et al., 2007). This means that in a year when animals bear a lot of offspring there will also be a high incidence of malaria. The abundance of rain in a year when animals bear many offspring can be explained using the fact that tropical animals become fertile when day length is short so that they bear offspring in summer when there is plenty food (Svotwa et al., 2007). A study conducted in Murehwa, Tsholotsho and chiredzi districts of Zimbabwe (Soropa et al., 2015) showed that weather forecasting indicators used by communities differ due to differences in available natural resources and cultural and traditional backgrounds. This explains why some plants, insects and animal behaviours described in the current study may not be used in other areas. However, some indicators such as the wind, clouds, moon and sun are common in most studies on indigenous weather forecasting (Jiri et al., 2016; Orlove et al., 2010; Pareek and Trived, 2011; Soropa et al., 2015; Mahoo et al., 2015; Ayal et al., 2015).

4.1. *Perceived causes of climate change and its effects on the indicators*

The causes of climate change mentioned by the communities in Gwanda district have been highlighted in other studies conducted in other parts of Zimbabwe (Pareek and Trived, 2011; Mubaya et al., 2010). The current study participants did not mention scientific causes such as the depletion of the ozone layer and technological advancement as highlighted by a study done among small holder farmers in three districts of Zimbabwe (Soropa et al., 2015). This could be because the study population was mainly the elderly who may not know about the scientific causes of climate change. The changes in climate recorded by recent studies done in Zimbabwe include unpredictable rain patterns, rain seasons becoming shorter, increased temperatures and warmer winters (Mubaya et al., 2010; Muzari et al., 2014). These concur with the changes observed in the current study. The participants in the current study acknowledged that the indicators may be affected by climate change but they also had coping mechanisms to improve on the accuracy of the indicators. They used a combination of indicators to come up with a prediction. The same coping mechanism was reported among small holder farmers in 3 districts of Zimbabwe where the researchers reported that farmers could be using many indicators to minimise risk (Soropa et al., 2015).

5. Conclusion

The present study reveals the understanding of the relationship between rainfall and malaria that exists within the communities in the three wards in Gwanda district. It also shows that the community in these wards could relate temperature to the occurrence of mosquitoes and hence the potential occurrence of malaria. The study has shown various categories of the environmental indicators used by the community in Gwanda district to predict the incidence of malaria. Light has been shed on the possibility of the utilisation of indigenous environmental indicators in malaria control.

Author contributions

Margaret Macherera, Moses John Chimbari and Samson Mukaratirwa conceived and designed the study. Margaret Macherera performed fieldwork and data collection. Margaret Macherera analysed the data with the guidance of Moses John Chimbari and Samson Mukaratirwa. Margaret Macherera wrote and compiled the manuscript. All authors read and approved the final version of the manuscript.

Conflicts of interest

The authors declare that they have "no" competing interest.

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