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MEDIA & COMMUNICATION STUDIES | REVIEW ARTICLE

Climate risk communication of navigation safety and climate conditions over Lake Victoria basin: Exploring perceptions and knowledge of indigenous communities

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Abstract: Governmental and non-governmental organizations have increasingly developed climate services and products to improve safety on Lake Victoria, Africa's largest and the world's second largest freshwater lake. Despite these efforts and other interests in efficient exploitation of natural resources, Lake Victoria is one of the most dangerous waterways in the world. Each year, around 5,000 people lose their lives on the lake due to navigation accidents. The purpose of this study is to analyze the perceptions of the stakeholders about climate change, meteorological services, causes of accidents, and cultural, social, and economic barriers that lead to lack of safety of navigation on Lake Victoria. The study uses anecdotal interviews with a convenience sample of five participants and surveys research with a convenience sample of 316 respondents from Burundi, Kenya, Rwanda, Tanzania, and Uganda. The study makes a significant contribution to the understanding of the multilayered ecological, socioeconomic, environmental, technological, and health-related factors that influence the safety of navigation on the lake by harnessing the



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ABOUT THE AUTHORS

James Kiwanuka-Tondo, the first author of the current research paper, is Associate Professor and Director of Graduate Programs in the Department of Communication, North Carolina State University, Raleigh, North Carolina, USA. He was an investigator and played a major role in designing the study and data collection on the research project that was funded by the East African Community to strengthen meteorological services on Lake Victoria to enhance safety of navigation and efficient exploitation of natural resources.

Fredrick Semazzi, the second author of the current research paper, is Professor Emeritus of Meteorology, North Carolina State University, Raleigh, North Carolina, USA. He was the principal investigator initiated the grant proposal for the research project.

Keon Pettitway, the third author of the current research paper, was a PhD. student at North Carolina State University, Raleigh, North Carolina, USA when we conducted the research. He played a role in conducting a literature review, analyzing the data and write up of the project report.

PUBLIC INTEREST STATEMENT

Governmental and non-governmental organizations have increasingly developed climate services and products to improve safety on Lake Victoria, Africa's largest and the world's second largest freshwater lake. Despite these efforts, Lake Victoria is one of the most dangerous waterways in the world. Each year, around 5,000 people lose their lives on the lake due to navigation accidents. The study uses interviews and surveys to analyze the perceptions of the stakeholders about climate change, meteorological services, causes of accidents, cultural, social, and economic barriers that lead to lack of safety of navigation on Lake Victoria. The study makes a significant contribution to the understanding of the socioeconomic, environmental, technological, and health-related factors that influence the safety of navigation on the lake by harnessing the indigenous knowledge of the stakeholders about their concerns and experiences. The authors reaffirm the importance of integrating indigenous to enhance climate services and make technological products culturally relevant.

indigenous knowledge of the stakeholders about their concerns and experiences. The authors assert and reaffirm the importance of integrating indigenous and scientific climate knowledge, offering strategies to enhance climate services and make technological products culturally relevant.

Subjects: Social Sciences; Urban Studies; Communication Studies

Keywords: Lake Victoria; indigenous knowledge; participatory communication; climate risk; perceptions

1. Introduction

Lake Victoria is Africa's largest and the world's second largest freshwater lake with an area of 69,000 square kilometers spanning Tanzania, Uganda and Kenya. It is also a key resource for the people of East Africa. It has the largest freshwater fisheries producing 700,000 to 800,000 metric tons of fish annually, worth USD 350–400 million at the landing points and USD 250 million in export. Moreover, Lake Victoria Basin (LVB) is the commercial and social-economic “nerve center” of East Africa. Approximately 30 million people live along its shores and the fish industry sustained by the Lake currently provides employment for millions of people (Njiru, Kazungu, Ngugi, Gichuki, & Muhoozi, 2008). While other industries operating in the catchment area of Lake Victoria include paper and textile mills, breweries, and pulperies, there is potential to expand eco-tourism (Awange & Obiero, 2006).

Despite interest in efficient exploitation of the natural resources, Lake Victoria is one of the most dangerous waterways in the world. For instance, overexploitation resulting in increased fishers and fishing boats (Matsuishi et al., 2006) impact safety and navigation. In the 1970s, around 50,000 fishermen and 12,000 fishing vessels were operating around the lake (Butcher & Colaris, 1975). In 2012, over 205,000 fishers and 71,000 fishing crafts, including foot fishers and rafts dominated maritime activities from more than 1400 landing sites or beaches around the entire lake (LVFO, 2012). This increase is particularly significant given that each year 4,000–5,000 people lose their lives on the lake due to navigation accidents (CNN, 2013; EAC, 2011). Consequently, each death impacts eight dependents—affecting over 40,000 people's wellbeing annually (WMO, 2014).

Governmental and non-governmental services and products have been created to improve safety on the lake, including education and training, search and rescue services, personal flotation devices, early warning systems, water transport laws (LVFO, 2017a; Mecrow & Suvanprakorn, 2014; Rocha, 2013). In 2016, the Lake Victoria Basin Commission (LVBC) received funding to further improve safety and fishing activity on the lake, as well as establish a network for maritime communication. These efforts, however, are challenged by compounded ecological, socio-economic, environmental, technological, and health risk factors (Atieno, Onyango, Joyce, Onyisi, & Omondi, 2017; Eggert, Greaker, & Kidane, 2015; LVFO 2017b; Nunan, 2014; Olago et al., 2007).

While translations of risks and uncertainty associated with weather extremes, climate variability and change might be consumed through journalistic media and scientific communication (Boykoff, 2008; Stevenson, Peterson, Bondell, Moore, & Carrier, 2014), some researchers have investigated how perceptions of climate change impact how people use knowledge for coping strategies (Orlove & Kabugo, 2005; Peterson et al., 2011). Participatory frameworks have been particularly useful to account for perceptions and attitudes of end users alongside modern scientific knowledge systems of climate change (Roncoli, 2006; Spark, 2007). In addition to studies focused on perceptions of climate systems and services, researchers have particularly focused on the significance of integrating indigenous and scientific climate knowledge (Kalanda-Joshua, Ngongondo, Chipeta, Mpembeka, 2011), as well as ways in which indigenous climate knowledge connects with climate science (Orlove, Roncoli, Kabugo, & Majugu, 2010). Such studies indicate that local indigenous knowledge is critical to dealing with the uncertainty of climate change (Ogalleh, Vogel, Eitzinger, & Hauser, 2012) and improving wellbeing

(Opio, Muyonga, & Mulumba, 2013; Tushemereirwe, Tuhebwe, Cooper, & D'ujanga, 2017). In the context of Africa, recent studies have reported on the significance of indigenous knowledge, experiences, and perceptions of climate change for understanding climate change variability, mitigation, and adaptation (Codjoe, Owusu, & Burkett, 2014; .Mapfumo, Mtambanengwe, & Chikowo, 2016; Nyong, Adesina, & Elasha, 2007; Speranza, Kiteme, Ambenje, Wiesmann, & Makali, 2010).

The purpose of the current research is to analyze the perceptions of the stakeholders—fishermen, fish traders, boat owners and operators, farmers and other stakeholders—about the weather conditions and navigation hazards over the Lake Victoria and the cultural, social, economic, and political factors, that affect communication so as to enhance safety of navigation and efficient exploitation of natural resources on the lake. The authors assert and reaffirm that integrating indigenous and scientific climate knowledge systems through participatory strategies is critical to effectively enhance climate services and make technological products culturally relevant. In this study, indigenous knowledge is defined as “knowledge and know-how that have been accumulated across generations and which guide human societies in their innumerable interactions with their surrounding environment” (Nakashima, Rubis, & Krupnik, 2018, p. 3). The researchers define participatory research as a means that gives stakeholders the opportunity to share their ideas about the survey research, and their indigenous knowledge is used to drive the research agenda. Thus, the study uses anecdotal interviews with a convenience sample of five participants and survey research with a convenience sample of 316 respondents from Burundi, Kenya, Rwanda, Tanzania, and Uganda.

By researching perceptions in this way, the study is guided by the premise that participatory research focused on “hearing local people’s voices and priorities” is central to address climate changes issues (Moser & Stein, 2011, p. 464). Conceptually, this approach is based upon a culturally responsive indigenous paradigm that decolonizes knowledge about climate change. Methodologically, the study uses unstructured interviews that embody a storytelling approach in order to center the lived realities of people who may be commonly marginalized in climate science based upon Western ways of knowing. As Mutua and Swadener (2004) suggest, storytelling is the “central genre of contemporary decolonizing writing” (p. 13). As a counter-narrative, such approaches can make known and confront “prevailing structures and relationships of power and inequity” (p. 16). The present research makes a significant contribution to the area and methodological approach to addressing issues of climate, weather, and navigation. Additionally, the study makes a significant contribution to the understanding of the multilayered ecological, socioeconomic, environmental, technological, and health-related factors that influence the safety of navigation on the lake by harnessing the indigenous knowledge of the stakeholders about their concerns and experiences.

2. Background

Lake Victoria in the East Africa sub-region has high occurrence of severe and hazardous weather (Thiery et al., 2016). This is associated with the local circulation patterns due to the differential heating between land and water surfaces and their interactions with the large-scale (synoptic) circulation patterns. Accidents involving transport and fishing boats occur frequently over the lake (CNN, 2013; EAC, 2011). For instance, in May 1996, a passenger ferry, the MV Bukoba, capsized while on its way to Mwanza in Tanzania killing about 800 people. Furthermore, the MV Kabelega sank on 8 May 2005 and though losing no lives, lost consumer produce to the tune of about 800 tons. On the other hand, the grounding of the MV Thor at Ghana Island on 24 March 2006 lost 300,000 liters of petroleum products. Moreover, on 21 April 2006, the MV Nyamageni capsized and sank, resulting in 28 deaths. In addition, on 22 July 2010, a passenger boat capsized on the Ugandan side of the lake, losing 50 people. Survivors tell of strong waves hitting the vessel, shattering it into pieces. Therefore, understanding geophysical mechanisms, meteorological services and products, and the significance of local indigenous knowledge is essential to improve the safety of navigation in the lake.

2.1. Geophysical modeling systems

The East African rain seasons are primarily determined by the passage of the inter-tropical convergence zone (ITCZ) of the northeast (NE) and southeast (SE) monsoons and they follow the inter-hemispheric

migration of the overhead position of the Sun (Leroux, 2001). The Long Rains (March to May) account for the largest proportion of the annual rainfall (Camberlin & Philippon, 2002). The Short Rains (October to December), although not as wet, are also essential for crop development and other major regional social-economic sectors. Areas over the northern and southern extremes of the region experience unimodal rainfall climate regimes. This simple background climatology is significantly modified by sub-regional factors including the complex orography, vegetation-land-ocean contrasts, and large inland lakes and in particular, Lake Victoria. The Long Rains have exhibited persistent multi-decadal decline since the 1980s (Lyon, 2014; Lyon & DeWitt, 2012; Semazzi et al., 2015). To reconcile the declining trend of the Long Rains and the IPCC projected wetter conditions (IPCC, 2007 & 2013), the notion of East Africa (Monsoon) Climate Change Paradox' has been conceived (Dave Rowell UKMO, personal communication, and HyVic, 2015).

It is evident that although numerous meteorological studies of Lake Victoria have been carried out, the most significant comprehensive investigations focus on the geophysical aspects (HyVic, 2016). Previous studies have shown that Lake Victoria plays an important role in the modulation of the regional climate (Anyah, Semazzi, & Xie, 2006). Therefore, a regional coupled model (*RegCM3-POM*) was developed to understand the two-way interactions between the regional meteorology of Eastern Africa and Lake Victoria. The atmospheric component of the model is the standard ICTP regional climate model (*RegCM*). The lake component of the model is the Princeton Ocean Model (*POM*) based on the full primitive equation formulation thus replacing the one-dimensional lake module (Hostetler, Bates, & Giorgi, 5045-5057) in the standard version of *RegCM3*. The numerical simulations show that the south western region of the lake is an important source of warm water because it is relatively shallower, and the water column is heated up much more quickly during the day than the rest of the lake. The results confirm that by adopting the traditional modeling approach in which the lake hydrodynamics are neglected, and the formulation is entirely based on thermodynamics alone is not entirely satisfactory for the Lake Victoria basin.

2.2. Severe weather prediction systems

Major advances have been made to develop methods that can skillfully predict severe weather associated with a large percentage of navigation accidents over Lake Victoria. Thiery et al. (2017) have complemented ongoing early warning efforts based on numerical weather prediction, by developing a new satellite data-driven storm prediction system, the prototype Lake Victoria Intense storm Early Warning System (*VIEWES*). *VIEWES* derives predictability from the correlation between afternoon land storm activity and nighttime storm intensity on Lake Victoria and relies on logistic regression techniques to forecast extreme thunderstorms from satellite observations. Evaluation of the statistical model reveals that predictive power is high and independent of the type of input dataset. Thiery et al.'s study results suggest that regression-based models that are motivated through process understanding have the potential to reduce the vulnerability of local fishing communities around Lake Victoria. The experimental prediction system is publicly available under the MIT license at github.com/wthiery/VIEWES.

Several other related initiatives have been undertaken to improve safety and well-being for stakeholders operating on Lake Victoria. As part of the global WMO Severe Weather Forecasting Demonstration Project (*SWFDP*) framework to improve warnings of hazardous weather conditions and weather-related hazards, the Eastern Africa *SWFDP* project monitors, analyzes and predicts the various severe weather events.

2.3. Mobile early warning alert systems

A number of other initiatives utilize mobile technologies. The Working Group on Nowcasting Research (*WGNR*) of the World Weather Research Programme (*WWRP*) provides scientific guidance to the Mobile Weather Alert Project (*WAP*) among other initiatives. Similarly, the Uganda National Meteorological Authority (*UNMA*), Ericsson, the MTN Group, the National Lake Rescue Institute, and the WMO piloted a Short Message Service (*SMS*) in July 2011 called "Mobile Weather Alert." The project uses mobile technology as a sustainable warning service to reduce casualty tolls and the

vulnerability of communities in the Lake Victoria Region to weather hazards. Despite these mobile phone-based advancements, one significant area that challenges the effectiveness of communicating climate risk is integrating the production of local indigenous and scientific knowledge (Boykoff, 2008; Peterson, Broad, Orlove, Roncoli, Taddei, & Velez, 2010; Stevenson et al., 2014).

Recent meteorological services such as the Mobile Phone Weather Alert Program provide a delivery mechanism to increase safety, but Lake Victoria still lacks effective rescue, and early warning systems to protect those who depend on the Lake and the waterway for their livelihood. Given these efforts underway to produce such a system and address problems of safety and exploitation of resources, it is important to understand the perceptions and local/indigenous climate knowledge of stakeholder operating around the Lake Victoria Basin.

2.4. Indigenous climate knowledge systems

It is reasonable to assume that the appreciation of meteorological warnings to the Lake Victoria transport sector from UNMA would be better appreciated by the local population if it is conveyed in the context of or built upon indigenous knowledge of the threats posed by meteorological extremes and variability. Several studies have focused on indigenous climate knowledge systems related to Lake Victoria. For instance, Gabrielsson, Brogaard, and Jerneck (2013) used a variety of focus groups, interviews, and mapping of seasonal calendars in order to understand local indigenous knowledge of Kenyan and Tanzanian farmers who operate in Lake Victoria Basin, particularly their perceptions of climate-induced stressors and vulnerability. Another study used interviews and semi-structured questionnaires as a “people-centered” approach for designing and implementing early warning systems for safety on Lake Victoria (Tushemereirwe et al., 2017). Such studies illustrate that qualitative methods can be integrated as a participatory conceptual framework.

To understand the issue of climate change and how it impacts livelihoods of stakeholders—fishermen, fish sellers, boat owners and operators—operating in the Lake Victoria Basin the following research questions were posited:

RQ1: What are stakeholders’ weather-related concerns and appreciation of climate issues and exploitation in the LVB?

RQ 2: What are the major perceptions of the stakeholders—fishermen, fish sellers, boat owners and operators—about the meteorological services in the LVB?

RQ 3: What are the perceptions of the stakeholders about the causes of accidents and hazards on Lake Victoria?

RQ 4: What are the cultural, social, and economic barriers to effective communication of climate and weather conditions on Lake Victoria to the stakeholders?

3. Methods

3.1. Data collection

The present research used triangulation of 2 research methods—*anecdotal interviews* and *survey research*. The purpose was to use the *anecdotal interviews* to inform the researchers in their formulation of the *survey research* questions. In conducting the study, the research used a *participatory approach* in the data collection phase. This means that stakeholders were given an opportunity to share their ideas about the *survey research* and their *indigenous knowledge* was used to drive the research project.

Anecdotal interviews are similar to *in-depth interviews* in that they offer rich *in-depth data* about the feelings, perceptions, and attitudes of the respondents. However, unlike *in-depth*

interviews participants give their responses in an informal way as if they are telling a story. Furthermore, the analysis does not use a structured format as is with in-depth interviews. This method offers spontaneity for the researchers as well as the respondents.

The survey instrument included demographic items aimed at understanding the social, economic, cultural, and educational level differences of these end users. The instrument also included Likert scale items to examine the attitudes, beliefs, and perceptions of these end users about meteorological services, marine safety, exploitation of natural resources, and health-related issues of the lake. In addition, there were a few open-ended questions.

3.2. Sample population

Anecdotal interviews were conducted with a convenience sample of five veteran fishermen by the second author. The interviews were conducted on the same day at the Ggaba landing site near Kampala, Uganda, on the shores of Lake Victoria. All the fishermen had previously operated from both coastal and Island landings in their work. They had extensive indigenous knowledge of meteorological conditions over Lake Victoria that they believe is important for their industry.

The survey was administered to a convenience sample of 316 fishermen and boat owners and operators in the five countries of East Africa. The respondents were selected by the district meteorology officers on the shores of Lake Victoria from each country to make up the sample. The break down by country was as follows: Uganda 34% (108), Kenya 33.2% (105), Tanzania 32% (101), Rwanda 0.6% (2). Unfortunately, while survey questionnaires were administered to fishermen and commercial ship operators from Burundi, their responses could not be analyzed because the data was in French and the available resources were not adequate to translate them. On the other hand, we received only two responses from Rwanda because the country does not share the Lake Victoria shore although it is part of the Lake Victoria Basin and East African Community. In hind sight we should not have involved it in the survey. We received more responses from Kenya, Tanzania, and Uganda since they share the Lake Victoria shore, and it was easier to interview the stakeholders who live on these shores. The sample sizes for each country were determined after consultations with the meteorological, marine, and harbor departments in each country.

3.3. Procedures

Before data collection, we applied and received IRB approval from North Carolina State University where the first and second author were faculty members at the time of the research study. The data collection was conducted in two phases. First, the second author conducted anecdotal interviews with five fishermen at Ggaba fishing boats landing site near Kampala, Uganda. The interviews were conducted in the Luganda language, which is the main means of communication over the Lake basin sector in Uganda. The major purpose of these interviews was to gather preliminary information about fishermen weather-related concerns and appreciation of weather hazards to marine navigation, as well as social, cultural, and economic variables that affect their perceptions of the meteorological services on the lake. The data from these interviews was analyzed using thematic analysis, which yielded two major themes as we shall describe in the results. The data gathered from these interviews was used in formulating the survey questionnaire and informing the other components of the research project.

Second, the first author designed the draft questionnaire and consulted the directors and senior meteorologists at the headquarters of all the five countries of East Africa. During the consultations, the draft questionnaire was discussed to make sure that the questions were tailored appropriately to each local situation in each country. Second, a workshop was held in Kisumu, Kenya, in which several stakeholders attended including fishermen, boat owners, fisheries and meteorological officers from the five countries. During the workshop, the survey instrument was discussed to make sure that the questions were understandable by the intended respondents. The stakeholders who attended were given an opportunity to give feedback on all questions. In addition, all stakeholders were trained in survey data collection and management. This process was critical

in ensuring that all stakeholders envisaged the research project as their own. Therefore, they felt that they had a stake in the success of the research project.

Meteorological officers from the five EAC partner states recruited participants and administered the survey questionnaires. The meteorological officers received training in survey research administration during the workshop in Kisumu, Kenya. One of the key reasons to do the training at the workshop was to ensure that the officers got to know each other so that they would be able to collaborate and help each other in case of unforeseen difficulties during the administration of the survey research. The participants of the workshop received an overview of the sampling procedures, the role of the interviewer, and interview procedures. Training was concluded with role-playing to practice the administration of the survey and to review the data collection and management process. Before administering the instrument all survey respondents signed consent forms. The data was entered and analyzed using SPSS at North Carolina State University.

4. Results

A total of 316 participants responded to our survey in five countries ($N = 316$). Of the 316 respondents, 19.7% ($n = 62$) were women and 80.0% ($n = 254$) were men. Regarding age the highest percentage of the respondents were 25–34 years with 35.2% ($n = 111$), followed by 34–44 years with 31.6% ($n = 100$), 45–54 years with 14.6% ($n = 46$), 19–24 years with 11.7% ($n = 37$), 55 and above with 4.5% ($n = 14$), 15–18 years with 1.5% ($n = 5$), and below 15 years with 0.3% ($n = 1$). The rest did not indicate their age. Regarding marital status, a majority of the respondents, 71.2% ($n = 225$) indicated that they were married while 18.7% ($n = 59$) were single, 5.0% ($n = 16$) were divorced, 3.5% ($n = 11$) were widowed, and only 0.3% ($n = 1$) was dating. The break of country residence was as follows: Uganda had the highest percentage of respondents at 34.2% ($n = 108$) followed by Kenya at 33.2% ($n = 105$), and Tanzania at 32.0% ($n = 101$). Rwanda had only 0.6% ($n = 2$) while the data from Burundi could not be analyzed and was excluded from the results. Regarding employment status, the majority of the respondents, 59.5% ($n = 188$) indicated that they were self-employed, while 30.7% ($n = 97$) were employed by others, and only 7.3% ($n = 23$) were unemployed. The monthly income break down of the respondents was as follows from lowest earning group to highest: \$0–99 made up 75.3% ($n = 238$), \$100–199 made up 13.6% ($n = 43$), \$200–299 made up 2.9% ($n = 9$), \$300–399 made up 3.2% ($n = 10$), while \$400–499 made up 1.9% ($n = 6$), and \$500 and above made up only 0.6% ($n = 2$). Finally, we wanted to find out the highest level of education that they attained. Of the 316 respondents 59.5% ($n = 188$) indicated that they had attained primary education, 21.2% ($n = 67$) had attained high school education, 7.6% ($n = 24$) had attained some college education, 5.1% ($n = 16$) had attained postgraduate education, while 6.3% ($n = 20$) had not attained any formal education.

4.1. Navigation and weather-related safety

The results of the anecdotal interviews revealed two major themes as concerns of the fishermen that were interviewed—navigation safety and weather-related safety. The first of the concern that manually powered fishing boats have no scale to keep track of weight limits. Moreover, they felt that smaller boats are more prone to overloading. Second, they indicated that the structural integrity of boats declines with age and that newer boats are made of asbestos but they are much fewer in number than wooden boats. Third, they mentioned major accidents often occur due to hippo and crocodile attacks on the lake which is a major safety hazard. Fourth, the fishermen felt that fatigue and exhaustion often cause accidents, particularly during stormy weather.

The first weather-related concern raised by the fishermen was that underwater currents drift both fishing boats and nets to dangerous distances for navigation. The second major concern was the occurrence of Tornado-like weather (locally known as Nsoke). They described conditions when dark clouds descend in the form of a “tail” and touches the water surface which causes water to rise and gives the appearance of the cloud touching the water surface. They explained that these systems cause paths of total destruction as they move from water to land regions. Thirdly, the fishermen gave an account of seasonal strong winds in the season surrounding the month of July. These winds result in increased levels of accidents. Fourth, the fishermen gave vivid accounts of the dependence of fish

population on Lake Surface Temperatures (LST). During the season around April, the deeper waters in the interior of Lake Victoria are warmer than other seasons. However, fish prefer cooler water and therefore escape to the near coastal waters where the temperatures are cooler. This creates favorable fishing conditions within a 5-mile near-coastal ring around the lake. This is not only safer for the fishermen but also cheaper because of reduced fuel consumption.

4.2. Meteorological services

When asked whether the stakeholders knew where the meteorological/weather station is located in their region, the majority of respondents (59.8%) indicated that they did not know (See Figure 1). Only 38.3% indicated that they knew. A cross-tabulation analysis was conducted which showed that only 33.3% of the fishermen, only 31.9% of the fish traders, and only 18.2% of the fish transporters knew where the meteorology/weather station is located in their region.

When asked whether they knew about the services provided by meteorology/weather station in the region, only 31.6% of the respondents indicated that they knew while the rest either did not know or were missing data. When asked how much they knew about the services provided by the meteorology/weather station in the region only 31.6% indicated that they had any knowledge about these services—about 7% knew a lot or quite a lot or little while about 24% knew very little or fairly little. (See Figure 2). The rest were missing or not sure.

When asked how much they knew about weather changes on Lake Victoria from the meteorology/weather station in their region only 29.4% indicated having any knowledge—23.4 know a little or very little while 6% new quite a lot or a lot. (See Figure 3). The rest were missing or not sure. Furthermore, when asked how much they knew about storms on Lake Victoria from the meteorology/weather station in their region only 26.6% knew a lot or quite a lot or little or very little. The rest were missing or not sure. In addition, when asked how much they knew about safety on Lake Victoria from the meteorology/weathers station in their region only 26.3% knew a lot or quite a lot or little or very little (See Figure 4). The rest were missing or not sure.

When asked about their level of satisfaction with the information about weather changes that is provided by the meteorology/weather station in their region a majority of respondents—60.1%—were either very unsatisfied or unsatisfied. Furthermore, when asked about their level of satisfaction with the information about safety on Lake Victoria that is provided by the meteorology/weather station in their region a majority of respondents—62.0%— were also either very unsatisfied or unsatisfied. In addition, a cross-tabulation analysis showed that a majority across all categories of those involved in activities related to Lake Victoria—fishermen, fish traders, fish transporters, boat owners/commercial ship operators, and fish processors were either very unsatisfied or unsatisfied.

Figure 1. Stakeholders' knowledge about where the meteorology station is located.

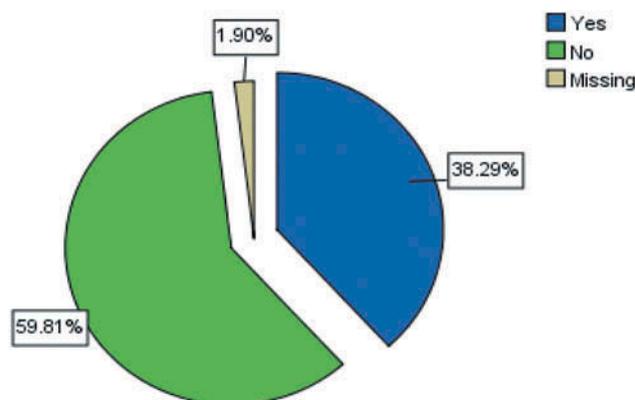


Figure 2. Stakeholders' knowledge about the services of the meteorology station in the region.

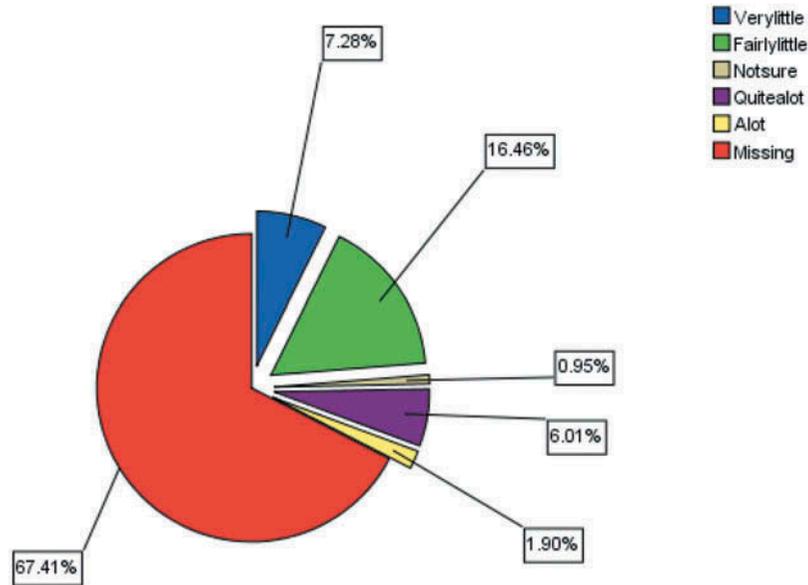


Figure 3. Stakeholders' knowledge about the weather changes on Lake Victoria from the meteorology station.

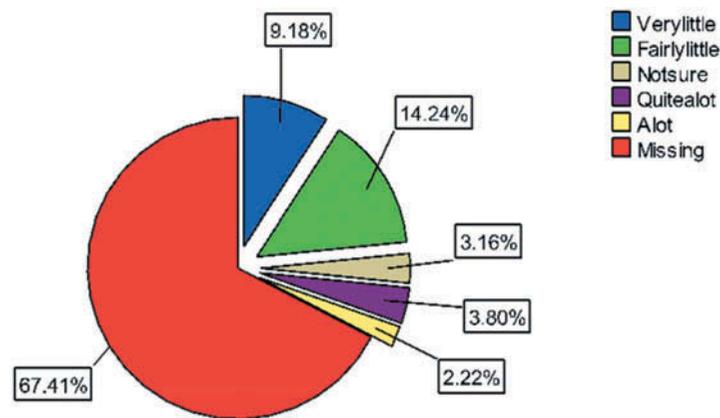
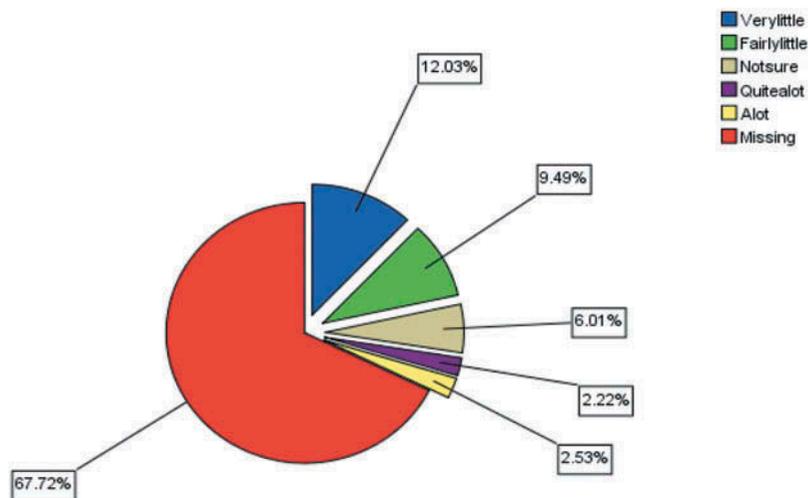


Figure 4. Stakeholders' knowledge about how much they knew about storms on Lake Victoria from the meteorology station.



4.3. Causes of accidents and hazards

First, we asked about the most important cause of accidents. The most important navigation hazards mentioned by the respondents were as follows: storms at 28.8%, strong winds at 14.9%, and strong waves at 13.3%. Second, the weather hazards mentioned by the respondents were as follows: strong winds at 43.0%, followed by storms at 32.6%. Third, the specific weather hazards experienced in the past three months mentioned by the respondents were as follows: winds at 32.3%, followed by storms at 18.4%.

When asked about which season they experience severe storms on Lake Victoria the respondents indicated the following seasons: June–August 55.0%, March–May 24.7%, December–February 9.5%, and September–November 6.96% while 3.8% were missing (See Figure 5).

When asked whether they knew anyone who died or whose boat capsized in the past three months a majority of respondents, 61.7%, indicated that they did. This is critical information regarding the number of people who die on the Lake every year.

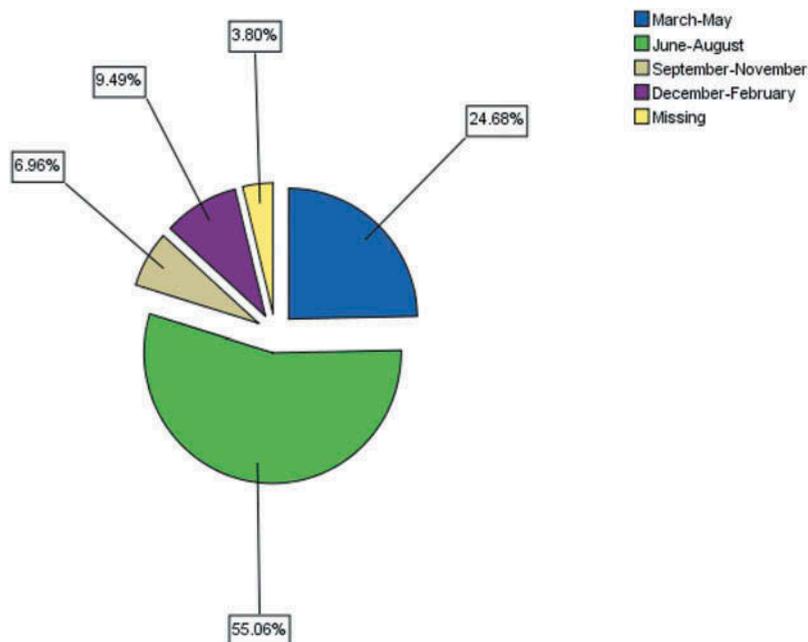
4.4. Cultural, social, and economic barriers

The respondents indicated that they speak a multitude of languages. The major languages are Kiswahili at 23.1% (n = 72), Luganda at 23.1% (n = 72), and Kiswahili/English at 12.0% (n = 41). The rest of the respondents indicated so many other languages which are too numerous to mention. The results further show that the second major barrier is socioeconomic status. This factor has two specific variables. The first variable is education level. As mentioned earlier of the 316 respondents 59.5% indicated that they had attained primary education, 21.2% had attained high school education, and only 7.6% had attained some college education. The second variable is income. As mentioned earlier over 75% of the respondents earn less than \$100 a month.

5. Discussion

Overall, this study confirmed the fact that the climate information provider community should play a larger role in improving the safety of navigation in the Lake Victoria Basin as a matter of urgency. Earlier EAC Lake Victoria maritime safety studies focused on Search and Rescue (SAR). Furthermore, the LVBC has commissioned several studies in the past to investigate the prospects

Figure 5. Stakeholders' answer about which season they experience severe storms on Lake Victoria.



for the application of Maritime Communications for commercial and safety purposes on Lake Victoria and to define viable Public Private Partnership (PPP) implementation approaches. These activities have mainly focused on rescue needs and have concluded that there is vast potential to improve the safety and well-being of thousands of people around Lake Victoria. The mobile telecommunications industry has therefore been mobilized to take responsibility for the connectivity component. The results, however, also indicate several significant weather and non-weather related challenges for consuming meteorological resources for use in the Lake Victoria Basin beyond a “technology-adoption’ paradigm” (Roncoli, 2006, p. 94).

First, one of the most significant finding indicated by participants concerns the seasons when they experience severe weather. This participatory study has unveiled important phenomenon regarding the seasonal dependency of navigation accidents over Lake Victoria, which exhibit maximum occurrence around the month of July which is associated with near minimum rainfall occurrence during the annual cycle. This is counter-intuitive and in contradiction with the expectation that the worst navigation accidents should be expected during the rainy seasons of March-April-May (long rains) and October-November-December (short rains) when the inter-tropical convergence zone (ITCZ) winds have maximum convergence over East Africa and the most severe thunderstorm activity occurs. During July, which is considered by the fishermen as the time of the year associated with maximum navigation risk, is a dry season and thunderstorm activity is not as intense as is the case during the rainy season. However, during this time the cross-lake (i.e. cross equatorial) low-level wind flow is climatologically at its peak. Therefore, this study has contributed to providing new insight regarding the physical mechanisms that climate scientists must consider in formulating metrics for the EWS for the fishermen over Lake Victoria. Based on the results we postulate that in addition to the importance of thunderstorm associated with the land breeze phenomenon, and which obviously occur throughout the year, it is critical to take into account the role of the near-surface wind flow.

Indigenous appreciation of actionable meteorological information over Lake Victoria is important for the performance of the fisheries sector and maritime navigation safety in general. This includes information about severe thunderstorm activity, underwater currents which drift both fishing boats and nets to dangerous distances for navigation, tornado-like weather (locally known as Nsoke), strong seasonal winds centered on the month of July, and the dependence of fish population on Lake Surface Temperatures (LST). During the season around April, the deeper waters in the interior of Lake Victoria are warmer than other seasons. However, fish prefer cooler water and therefore escape to the near coastal waters where the temperatures are cooler. This creates favorable fishing conditions within 5 miles from the lakeshore. This is not only safer for the fishermen but also cheaper because of reduced fuel consumption.

Second, providers of meteorology services (including early warning) in the Lake Victoria Basin need to improve in informing the public how relevant meteorological information may be accessed. This is critical in cases of emergencies and demand for other specific weather information by the public. Additionally, there is a need to raise general public awareness about the full range of available meteorological services. This requires a major public awareness campaign plan (Okaka & Apil, 2013). This lack of awareness, as the study shows, demonstrates that there is room for improved meteorology/weather climate services to improve the safety of navigation for the public. This is further confirmation of the fact that the meteorological information providers also need to strengthen the meteorology/weather monitoring network and accuracy of forecast models in the basin so that they can provide reliable early warnings about weather and safety in the basin.

Third, a number of non-weather related variables affect effective climate risk communication. For instance, economic variables indicate that participants may not be able to afford televisions sets, newspapers, or magazines, which are key outlets for early warning information. In addition, most cannot afford special apps even though over 82% have cell phones. While mass media is

a significant factor in communicating weather and climate information in Lake Victoria (Okaka & Apil, 2013) end users utilize different types of knowledge networks and media for information. This presents a major challenge of finding the most efficient and effective communication channel to disseminate climate and weather information to the stakeholders. We suggest that meteorology officers use opinion leaders to communicate this information to end users who do not have cell phones or radios. Results of education levels also imply that a majority of the stakeholders do not fully comprehend the complex climate and weather information products. Therefore, it should be disseminated in simple terms and in layman's language. This presents a huge challenge for meteorologists and journalists in packaging the warnings in a form that gives optimal outcomes.

As mentioned earlier, the results show that stakeholders of the shores of Lake Victoria speak a multitude of languages. This is another major barrier to effective communication of climate and weather conditions on Lake Victoria. Apparently, climate and weather information has to be translated in multiple languages in order for the stakeholders to understand this complex information. According to some scholars, language is not simply important for communicating information but also affects people's perception of reality in different cultures (Hojjer, 1976). Moreover, Dodd (1978) argues that language is one of the basic elements of culture (Dodd, 1998). Hence, the issue of cultural differences has to be given a lot of thought if climate science information is to be effectively communicated to local communities.

Lastly, using interview and survey data as a mixed participatory approach, this study indicates that integrating indigenous knowledge with scientific knowledge is beneficial for livelihood, safety, and wellbeing for broad range of stakeholders operating in Lake Victoria. Researchers can further develop and improve upon a multitude of similar conceptual frameworks such as multisectoral analysis (Kiwanuka-Tondo & Pettway, 2016). Additionally, while this study focused on safety and communication barriers, participatory indigenous knowledge research must also encompass both climate/weather-induced stressors and human-induced issues.

The unique patterns of severe weather which continuously threaten air and marine navigation over the lake and its basin also promote poverty among other negative effects, and meteorological-induced health stressors (Wandiga et al., 2006; Yanda, Kangalawe, & Sigalla, 2005). For instance, rainy seasons lead to stagnant water paddles, which are breeding grounds for mosquitoes. Consequently, the stakeholders on the Lake Victoria shores suffer from persistent malaria leading to less productivity and poverty. Furthermore, due to the high population growth rate, increased farming and fishing activities over the lake basin, human-induced water pollution is also a problem (Hecky, Mugidde, Ramlal, Talbot, & Kling, 2010; Seto, Güneralp, & Hutya, 2012). As such, there is a need for pollution monitoring to assess and advise relevant authorities on the pollution risks from upcoming industries, increased population and the increasing intensive farming. Moreover, language and education level must be taken into account in packaging outreach information for disseminating early warning information. Future surveys can be used to find out the technologies available to access early warning information.

6. Conclusion

This study has reaffirmed the high level of importance placed by the inhabitants of Lake Victoria Basin on the need and urgency to improve navigation safety over the lake because of the role it plays on their livelihoods. The analysis has identified a need for enhanced outreach by meteorological information providers to the stakeholders to overcome this major obstacle in the provision of weather/climate services. The study has reinforced the need for the climate information provider community to engage more effectively with the lakeside weather/climate information user community through mass media and other communication channels including mobile phones and radio. We also conclude that a number of non-weather related factors impact effective climate risk communication. They include affordability and access to outreach/communication technology, limitations due to educational background which indicates that information must be disseminated in simple terms and use of layman's language; this study indicates that integrating indigenous knowledge with scientific knowledge is

beneficial for livelihood, safety, and wellbeing for a number of stakeholders operating in Lake Victoria. Engaging indigenous knowledge and perceptions of climate risk communication, services, and products might provide principles for creating “community-centric early warning systems” (Baudoin, Henly-Shepard, Fernando, Sitati, & Zommers, 2016).

This participatory study has unveiled an important phenomenon regarding the seasonal dependency of navigation accidents over Lake Victoria, which exhibit maximum occurrence around the month of July. It has contributed in providing new insight regarding the potential physical mechanisms that climate scientists must include in formulating actionable user metrics for the EWS for the fishermen over Lake Victoria. Based on the results we postulate that in addition to the obvious importance of thunderstorm activity associated with the land breeze phenomenon, which occurs throughout the year, it is critical to take into account the role of near-surface wind flow. We envisage that recent technics which have exhibited high skills in predicting thunderstorm activity (Thiery et al. (2017), could be improved significantly by incorporating the contributions of wind flow as well as water currents and waves. Our participatory survey shows that the respondents in the study mentioned these as potential factors in explaining a large proportion of navigation hazards over Lake Victoria.

It is conventional wisdom that the best approach for establishing meteorological services involves co-designing and co-production by engaging all the key information producers and sectoral user stakeholders. For the navigation safety sector over LVB, we have identified multiple stakeholder communities including, LVB inhabitants, fishermen, policy-makers, NMHSs, LVBC, Search and Rescue (SAR), mobile telecommunications, and researchers. The co-production should, therefore, seek simultaneous, comprehensive and equal participation of these communities. It is apparent that previous co-production efforts lacked sufficient input of indigenous grass root stakeholders knowledge. This study has shown that this is a critical omission which can be eliminated through the approaches and methods adopted in this study.

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