WISER HIGHWAY:

Integrating Scientific Knowledge and Traditional Knowledge in Impact Weather Forecasting - Executive Summary

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EXECUTIVE SUMMARY

This report details the consolidated methodology employed within the WISER-funded HIGHWAY Research and Fellowship component (Output 3.4).

The overall aim of the HIGHWAY project is to develop academic and research capability in the region, facilitating the increase in uptake and use of weather warnings across target communities and users by making them more relevant and usable, integrating local knowledge and place-based terminology. The report outlines each of the steps in the methodology and a synthesis and analysis of the development and application of this methodology. It identifies specific recommendations for the potential improvement of the methodology and implications of research findings for strengthening the uptake and use of HIGHWAY impact forecasts amongst fishing communities in the Lake Victoria region.

The research design was co-developed with stakeholders in the start-up workshop. The research employed a combination of methodologies including: characterisation of the key social groups concerned with Lake Victoria's fishing sector to inform participation in research workshops and key information interviews (KIIs); a livelihood calendar with accompanying discussion on sources of weather and climate information used to inform fishing-related decisions; combining local knowledge indicators with scientific forecasts through the impact-based forecast risk matrix; information ecosystem mapping; and KIIs to compare workshop findings with inputs from a wider group.

A number of steps in the piloted methodology require review and sharpening. It will be important to ensure that the approach supports systematic collation of local indicators, including participants' perceptions of the accuracy and lead time of each indicator.

The research methodology piloted in Homa Bay in March and August 2020 has provided useful learning regarding the feasibility of bringing together local and scientific knowledge. While some local indicators are shared across sites, many are site-specific or, even if they are shared, are assessed as having different levels of accuracy between different locations

and stakeholders. Research findings to date suggest that in combining local indicators and scientific impact-based forecasts:

- When local indicators and scientific forecasts align, there is no difficulty.
- When local indicators and scientific forecasts do not align, participants prioritised some but not all local indicators perceived as having high levels of accuracy above scientific forecasts.
- In some cases, the local indicators can temper, rather than reverse, the scientific impact-based forecasts.
- In many cases local indicators and impact-based forecasts may not conflict as they may not be available at similar timeframes.
- In future development, particular attention needs to focus on discussion regarding local indicators that indicate good fishing conditions where the impact-based forecast assesses dangerous conditions, and vice versa, where the local indicators indicate dangerous fishing conditions where the impact-based forecast advises fishing. It would be good to try and identify if there are specific occasions where this conflict between forecast and local indicators have occurred. [1]

Research highlights that combining local indicators and impact-based forecasts needs to be undertaken at a local level to:

- Identify local indicators
- Engage local assessment of the levels of accuracy of different local indicators
- Enable participatory discussion and agreement on how impact-based forecasts may inform a range of decisions made with local indicators.

[1] This could possibly be completed as a further phase of research by the Regional Network; monitoring fisher folk decision making with both local knowledge and scientific knowledge.

While such a localised approach raises questions of how scaleable the approach may be, the methodology could be shared, and indeed form part of the training undertaken with those institutions identified as intermediaries to receive, communicate and support use of impact-based forecasts, such as representatives of the Beach Management Units (BMUs), for them to lead localisation of impact-based forecasts.

Overall, it is important to emphasise that the methodology (outlined here) to integrate local knowledge and weather forecasts from the National Met. Services should be seen as an on-going, dynamic process. As has been recognised in other settings, local knowledge often integrates other information through time. In this case it should be noted that, the relative importance given to different pieces of information (i.e. scientific weather forecasts vs local indicators) when combining them to decide an overall warning, varies as people discuss the forecasts e.g. integrating different knowledge products is a dynamic process. Furthermore, these relative weightings would be expected to vary with variations in the perceived accuracy of information over time. A key basis for the combination of scientific and local knowledge is the explicit acknowledgment that forecasts and indicators of future weather and impact from different knowledge bases all contain uncertainities. They should therefore be treated in a risk framing rather than in a deterministic way. In scientific forecasts the risk of impact is represented by probabilities and skill indices, while the acknowledgment of local indicators as a forecast of risk is often more implicit. Hence, ensuring it is understood that all forecast and indicator information contain uncertainties is an important starting point for integrating them.

Across all three sites the top three most preferred channels for sharing of forecasts were radio, TV and WhatsApp. However, when looking at the sites separately there are some notable differences, with varying preferences for SMS, BMU and providers of local knowledge as channels for information.

In the first Pilot, the research visit was held at 3 sites, while participants were not solely from these three beaches but also included individuals from up to 40 beaches surrounding them[2].

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[2] between 5 and 15 miles around the 3 research sites.

Lwanda Nyamasare, Kiumba and Koguna Beaches were 3 of the 10 experimental sites in Homa Bay which have had warning flags and notice boards installed, while these communication channels were lacking at other beaches. It is important to note that in most of these sites, close to a half of the participants had not been receiving the KMD impact-based forecast and rather relied on radio stations for weather alerts. As such, during the workshops the KMD representative registered chairmen to the KMD WhatsApp to start receiving impact-based forecasts in the future. The recipients of the forecast were spread across most of the beaches in Homa Bay County facing the open Lake. The problem is that some officials receive the forecast and share it, while others receive them but do not share. Officials need to have smartphones to receive KMD impact-based forecasts and have been trained to interpret the forecasts to then communicate them to the wider community through word of mouth. This research wanted to gain insights from different participants who may not have attended smart-phone training. Discussions revealed that participants want information about the impact-based forecast matrix in poster form.

Most crucially there is a need to investigate what led to the noticeable and sustained reduction in weather-related deaths in Homa Bay from 2016. More generally, research findings also highlighted the need to extend training on and access to impact-based forecasts.

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GLOSSARY OF KEY TERMS

Co-production: "The bringing together of different knowledge sources, experiences and working practices from across different disciplines, sectors and actors to jointly develop new and combined knowledge for addressing societal problems of shared concern and interest" (Visman et al., 2018: 3).

Local knowledge: refers to the knowledge possessed by any group living off the land (or sea) in a particular area for a long period of time (Dewalt, 1994). It is typically tacit knowledge. Local knowledge is often used as a more encompassing term compared to 'indigenous knowledge' (see below), which sometimes excludes peoples who may have lived in an area for a long period of time but are not the original inhabitants.

Indigenous knowledge: the body of knowledge built up over generations by a group or a community from a particular area, based on their environmental understanding, interacting with nature and experiences within their area. Typically understood to describe the distinct knowledge of indigenous peoples; the original inhabitants of an area.

Indigenous knowledge indicator: bio-physical variables that are used to predict the weather based on indigenous knowledge. These variables can be used to predict imminent weather events as well as long-term prediction on upcoming seasons.

Traditional knowledge: is the knowledge, as well as skills and practices, that is developed within a community, sustained and passed on through generations within the community. This knowledge often forms part of the community's cultural identity, in this sense traditional knowledge typically emphasises the conveyance of knowledge along a cultural continuity.

ACRONYMS

BMU	Beach Management Unit
EAC	East African Community
EWS	Early Warning System
HIGHWAY	HIGH impact Weather lAke sYstem
IK	Indigenous Knowledge
IBF	Impact-Based Forecast
KII	Key Informant Interview
KMD	Kenya Meteorological Department
LVBC	Lake Victoria Basin Commission
NMHS	National Meteorological and Hydrological Services
SK	Scientific Knowledge
WISER	Weather and Climate Information Services for Africa
UNMA	Uganda National Meteorological Authority

Overall plan for the work

The overall aim of the HIGHWAY project was to develop academic and research capability in the Lake Victoria region, to facilitate the increase in uptake and use of the project's impact-based weather warnings amongst fishing folk. It sought to assess if more relevant and useable forecasts can be developed through closer integration of local and scientific knowledge. The project aims to investigate the feasibility and value of incorporating indigenous knowledge (IK) and local terminology into weather information and warnings, comparing and testing the effectiveness of different methods to support this process.

The WISER HIGHWAY Research and Fellowship was coordinated by the University of Sussex and undertaken through a cross-disciplinary team, with in-country leadership from Maseno University. Other key partners included Kenya Meteorological Department, Ugandan National Meteorological Agency and private independent consultants. Within the HIGHWAY project, Kenya Meteorological Department (KMD) and Uganda National Meteorological Agency (UNMA) have been providing impact-based scientific forecasts since July 2019 on the Ugandan side of the lake and since April 2019 on the Kenyan side. The project sites were beaches where KMD and UNMA had been working with the fishing communities. The sites in Kenya were all located in Homabay County and the ones in Uganda were located in Kalangala District.

To contextualise its approach, the proposal for this research and fellowship included a literature review which provides a general context of the Lake and those who live and work there, and the climate services currently available for the region, the review collates current understanding regarding: differences and similarities between scientific and indigenous or local knowledge and IK-based weather indicators.This was followed by a start-up workshop where stakeholders co-developed a methodology. The research employed a combination of methodologies including: characterisation of the key social groups concerned with Lake Victoria's fishing sector to inform participation in research workshops and key information interviews (KIIs); a livelihood calendar with accompanying discussion on sources of weather and climate information used to inform fishing-related decisions; combining local knowledge indicators with scientific forecasts through the impact-based forecast risk matrix; information ecosystem mapping; and KIIs to compare workshop findings with inputs from a wider group. The methodology was piloted twice in March and August 2020.

Literature Review

Lake Victoria Basin

According to the Kenyan Fisheries Divisions (2008), the Lake Victoria water body has a surface area of 68, 800 km2 which is shared by three East African countries as follows: Kenya 6% (4,128 km2), Tanzania 51% (35,088 km2) and Uganda 43% (29,584 km2). The shoreline of the lake is approximately 3,450 km long; where by 17% (550 km) is in Kenya, 44% (1,150 km) is in Tanzania and 50% (1,750 km) is in Uganda. The livelihood of the riparian countries significantly depends on Lake Victoria. For instance, the lake provides income and direct employment to thousands of fishermen operating vessels and other people who are either employed formally or informally in fisheries-related activities (Fisheries Divisions, 2008).

The World Bank (2013) reports that the socio-economic activities of over 40 million people in Kenya, Tanzania and Uganda rely heavily on Lake Victoria. Further, the report indicates that Lake Victoria has the largest continental fishing activity in the world, supplying about 1 million tonnes of fish a year, with a local turnover of 600 million USD and 250 million USD for export.

Extreme weather events such as thunderstorms, lightning, floods, strong winds, fog and waterspouts on Lake Victoria can increase the vulnerability of those who are dependent on the lake for their livelihoods. Up to 5,000 fishermen and small boat operators die on the lake each year leaving behind approximately 40, 000 dependents (WMO, 2010; IFRC, 2014). Most of these deaths have been attributed to hazardous weather conditions and water currents in the lake (Song et al., 2014). According to Oloo (2019), these deaths are a result of lack of weather warning information, failure to receive severe weather early warning messages, ignoring weather warning messages, or unclear weather warning messages. Provision of local specific, reliable, timely and user-friendly modern weather information services that effectively addresses the needs of fisher folk communities on Lake Victoria are limited. The communities depend mainly on indigenous weather forecasting practices to inform their fishing activities and decisions making, yet this knowledge is not comprehensively documented.

Understanding, predicting and anticipating changes in weather and other climatic variables is very important for the fisher folk communities living on Lake Victoria, whose livelihoods rely directly on weather and climate conditions. Local communities across the world observe climatic changes taking place in their environment which affect their livelihood choices (Nyong et al., 2007). Indigenous societies observe bio-physical animate and inanimate entities to make predictions about future and current weather variables that cannot be directly observed by the human senses (Acharya, 2011).

Despite the availability of literature on weather variability and its effects on fisher folk communities on Lake Victoria, there is a big gap in the literature on how these communities predict weather variability, how this informs their decision making, and how fisher folk cope with the effects of weather variability.

Fisher folk communities on Lake Victoria

The entire management of Lake Victoria was solely in the hands of the three governments of the countries falling on the lake; Kenya, Tanzania and Uganda. The governments managed the lake through indirect regulations aimed at controlling the fish population and making sure the composition and size of the biomass of the lake was maintained (Fisheries report, 2019; Luombo, 2007). However, due to budgetary constraints and limited staff within the national ministries, this management was ineffective as fishing resources continued to decline. An alternative approach was sought that could improve the management of the lake through incorporating the community and the government with each having defined responsibilities. From this, in the late 1990s, a co-management structure was established in Lake Victoria, and with it came the transformation in management approach from command and control approaches to a community-based and empowering co-management, where fisheries communities work with the government in managing the resource base (Luombo, 2007).

The fisheries departments of Uganda, Kenya and Tanzania came together with the three national fisheries research institutes under the Lake Victoria Fisheries Organisation (LVFO) which was formed in 1994 under the LVFO Convention and came into being in 1997 (Nunan, 2010). The LVFO was formed to build cooperation among member states in the development and adoption of conservation and management measures of the fisheries of Lake Victoria. The Lake Victoria Basin Commission (LVBC) was established in 2003 under Article 33 of the East African Community's 'Protocol for Sustainable Development of the Lake Victoria Basin' which aimed to establish a body for sustainable development and management of the Lake Victoria Basin (EAC, 2003).

Beach Management Units (BMUs) were formed to be the core structures at which co-management could be operationalised (Nunan et al., 2015). The LVFO developed BMU guidelines to help govern the operations of these newly established institutions (Ogwang et al., 2009). Under the new reformation every stakeholder involved in the fisheries around a landing site are required, by law, to register with a BMU (Luombo, 2007). All registered members of a BMU form the BMU Assembly from which a committee, a group of nine to fifteen members, is elected (Nunan et al., 2015). Each BMU committee is responsible for ensuring sustainable fisheries. In 2015, President Museveni disbanded BMUs in Uganda. As such the Fisheries Protection Unit is now the structure used for management of the Ugandan proportion of the lake. The units focus on enforcing compliance, affording less power to community members (Karuhanga, 2018).

The Lake Victoria fishing community consists of individual fishermen, artisanal fish processors, boat owners, small-scale fish traders and industrial processors. Thus fisheries activities play a vital role in the lives of the communities in terms of employment and nutrition. Fishing has evolved from a traditional and subsistence status to an industrial level characterized by high-level commercialization of production and distribution (Luombo, 2007). Changes in fisheries on Lake Victoria together with increased weather and climate variability has impacted negatively on the livelihoods of fisher folk and the majority have opted to supplement their income by involving themselves in other occupational activities (Odhiambo, 2013). The main activities that are used to supplement incomes are farming, livestock keeping, bee keeping, petty businesses, quarrying and mining (Fisheries report, 2019). Groups of fisher folk work on a seasonal basis; engaging in fishing during certain seasons and are established agriculturalists during other seasons.(Odhiambo, 2013).

While the indigenous fisher folk communities on Lake Victoria share similar livelihoods, the ethnic composition of the communities is diverse. For instance, on Tanzania side there are Wahaya, Wakerewe, Wazinza, Wakara, Wajita, Waruri, Wakuria, Luo, Wazanaki and Suba (Kulindwa, 2006). On the Kenyan side fisher folk community include Luhya, Luo, Wakuria and Suba. In Uganda they include Luhya, Baganda and Basoga (Kulindwa, 2006). in addition to the indigenous fisher folk communities on the Lake Victoria, there are also settlers whose activities either directly or indirectly depend on the lake, including fishing activities. The settlers, who have moved into the Lake region mostly for commerce and employment, include people from the Middle East, South East and South Asia as well as other ethnic groupings from other parts of the region (Kulindwa, 2006). Settler communities are majorly found in the urban centres around the lake shores for example in Kisumu, Homa Bay and Mbita (in Kenya), Mwanza, Musoma and Mara (in Tanzania) and Jinja, Entebbe and Kampala (in Uganda).

The majority of fishermen operate from open wooden canoes approximately eight metres long, powered by paddles and sail. In Kenya, 80% of canoes are powered in this way according to the Chairman of the National Association of BMUs, the remaining 20% are powered by outboard motors (Powell, 2016). Therefore, where most canoes can travel, and at what speed, is dependent on the speed and direction of the wind as well as the height of the waves. The canoes have a low freeboard making them vulnerable to capsizing in high waves and adverse weather. About 5,000 people are officially reported to drown every year in Lake Victoria (WMO, 2010), however it is suggested that this is an underestimate as many deaths go unreported (Powell, 2016). Most of these deaths are caused by boats capsizing or sinking in bad weather conditions (Jallow et al., 1999). Adverse weather conditions include strong winds, high waves, storms, waterspouts, heavy rainfall and lightening. The safety of fishermen and their ability to navigate on the lake is therefore highly dependent on the weather.

Weather information on Lake Victoria

Until recently, fishing communities on Lake Victoria have solely used indicators based on local and indigenous knowledge to predict the weather. Previously, there were no forecasts made specifically for the fishing community, only national and regional forecasts that lacked information that was sufficiently relevant to the fishing context. Fisher folk therefore did not use scientific forecasts. They relied on their indigenous knowledge of weather indicators. Sources of indigenous weather information include indigenous knowledge experts, parents and elders, as well as personal observations and experience. Dixit and Goya (2011 cited in Bigirimana et al., 2016) highlighted the importance of knowledge from elders and parents to the community. They found that information on weather variability sourced from parents had been passed down through generations and was considered reliable by the community. The process of decision making based on weather prediction information has also been reported to take place within this familial context.

Only in recent years has there been an effort to create and communicate scientific forecasts that are relevant to fisher folk and their activities on the lake. In 2011 the Ugandan National Meteorological Agency (UNMA) set up a pilot system of daily weather forecasts, called 'Mobile Weather Alert', for fishermen (Powell, 2016). The UNMA issued a forecast and hazard warnings were delivered free by SMS (although the SMS were only free to individuals who have a phone from Mobile Telephone Network (MTN) – a partner of the project). The information received included wind speed, cloud cover and visibility (Powell, 2016). It also included advice regarding the potential hazards associated with the weather; the UNMA used a four-colour hazard warning system, where green means there is no alert, yellow means to be aware, orange indicates to the recipient to be prepared and red is an alert to take action and to get to a safe area. A similar project, named (Weather and Climate Services) WISER Western, was started in Kenya in 2016, coordinated by the Kenya Meteorological Department (KMD), CARE and the Met Office. KMD produced daily forecasts, along with a three-color traffic light system (green – no hazard warnings, amber – be prepared and red – take action). Forecasts included weather information of the wind speed and direction, rainfall volume and spatial distribution, visibility and hazard warnings. Daily forecasts were communicated via local radio and through the BMUs. Weather forecast information was sent via SMS, in the form of a bulletin, to various chairmen of BMUs (Powell, 2016).

In both Uganda and Kenya, the projects stopped mainly due to funding issues, which meant forecasts also stopped.

The marine weather information available in the Tanzanian section of the lake is limited. The Tanzania Meteorological Agency (TMA) produces daily national forecasts that are disseminated by television, radio and on the TMA website, however this does not include marine weather information. The TMA only produces marine forecasts for commercial shipping on the lake, this includes information on wind speed and direction, wave height, sky conditions (e.g. rainfall and thunderstorms) and visibility (Powell, 2018). They also include severe weather warnings if winds exceed 40 kph and/or waves are expected to be over 1.5 metres high.TMA forecasts are currently principally distributed, by email, to a small amount of port officers, shipping companies and ship's captains. Therefore, no marine weather information is available widely for fishermen on the Tanzania section of Lake Victoria.

Given that weather extremes heighten risks in the Lake region, access to practical and timely weather and climate information is critical for fisher folk making decisions on whether or not to go fishing. However, there is a disconnect, as meteorological agencies and climate scientists have, until more recently, tended to produce projects aimed at a technical community, whereas local fisher folk need information in simple, accessible language that they can apply to everyday decision making. Despite efforts to improve weather and climate services in East Africa, engagement with users of climate information is still relatively low due to a lack of reach, relevance, and accessibility.

Indigenous knowledge vs. Scientific knowledge

Indigenous knowledge (IK) is, broadly speaking, the unique knowledge of particular cultural groups used to make a living in a particular environment (Warren, 1991). Different terms that are also used to designate the concept include traditional environmental/ecological knowledge, rural knowledge, local knowledge and farmer's or fisher folk's knowledge. Indigenous knowledge can be defined as “a body of knowledge built up by a group of people through generations of living in close contact with nature” (Johnson, 1992, p.4). Generally speaking, such knowledge evolves in the local environment, so that it is specifically adapted to the requirements of local people and conditions. It is also creative and experimental, constantly incorporating outside influences and inside innovations to meet new conditions (Langill, 2004). People in a given community develop knowledge over time and continue to develop it is based on experience, often tested over centuries of use, adapted to local culture and environment and is also dynamic and changing.

Indigenous people are the original inhabitants of a particular geographic location, who have a culture and belief system distinct from the international system of knowledge (e.g. the Tribal, Native, First, or Aboriginal people of an area). Indigenous knowledge is therefore sometimes used to describe the knowledge of the original inhabitants of an area. Some feel that such a definition is too narrow, in that it excludes peoples who may have lived in an area for a long period of time but are not the original inhabitants. This has led to widespread use of the term "local knowledge", a broader concept which refers to the knowledge possessed by any group living off the land (or sea) in a particular area for a long period of time (Dewalt, 1994). Others believe indigenous knowledge is not confined to the original inhabitants of an area, but rather, any community possesses indigenous knowledge rural and urban, settled and nomadic, original inhabitants and migrants (Dewalt, 1994). As such many use the terms local knowledge and indigenous knowledge interchangeably. In this study we will use the term “Local Knowledge” because of its broader application.

Scientists now recognize that indigenous people have managed the environments in which they have lived for generations, often without significantly damaging local ecologies. Many feel that indigenous knowledge can thus provide a powerful basis from which alternative ways of managing resources can be developed. A critical assumption of indigenous knowledge approaches, for example, is that local people have a good understanding of the natural resource base because they have lived in the same, or similar, environment for many generations, and have accumulated and passed on knowledge of the natural conditions, soils, vegetation, food and medicinal plants (Agrawal, 1995), as well as fishing activities. In fact, most observers suggest that a combination of both local knowledge and science be used to solve development problems and weather or climatic related issues in order to capitalise on the strengths of each. Local or Indigenous Knowledge is often transmitted by word of mouth rather than in written form. Consequently, this makes it vulnerable to rapid change (Agrawal, 1995; IIRR, 1996).Integrating local knowledge into scientific research is key as local people can provide valuable input about the local environment and how to effectively manage its natural resources.

Local/Indigenous knowledge is often contrasted with "scientific," "western," "international" or "modern" knowledge - the knowledge developed by universities, research institutions and the private sector using a formal scientific approach. There are differences between indigenous and western scientific knowledge. Scientific knowledge uses analytical and reductionist methods, in contrast to indigenous knowledge which often takes a more holistic and intuitive approach (Agrawal, 1995). While indigenous knowledge is often seen to appreciate the local cultural-specific context, scientific knowledge, on the other hand, offers a broader understanding of context beyond the local level, in search of universal validity (Agrawal, 2014; Pierotti and Wildcat, 2000). Additionally, western science is objective and quantitative, whereas, indigenous knowledge is predominantly subjective and qualitative (Agrawal, 1995; Bohensky and Maru, 2011).

Indigenous knowledge-based weather indicators

Local communities often rely on bio-physical variables to predict the weather which guides their decision making process. For instance, fisher folk communities on Lake Victoria, through centuries-old experimental knowledge passed down the generations by word of mouth, have developed elaborate strategies for predicting weather and climate patterns from observable changes in the bio-physical variables in their environment.

The Afar community in Ethiopia use trees that bloom in expectation of upcoming rain such as *Acacia tortilitis, Acacia senegal*, and *Acacia melifera* (Balehegn et al., 2019). They also predict specific weather based on observation of changes in animal behaviour change in plumage of birds, reproductive and browsing behaviour of camels and the behaviour and movements of insects, foxes and other wildlife (Balehegn et al., 2019).

The behaviour of African fish eagles, known in Luo as '*Balakwasi*', in Suba as '*Rabala Kwasi' and more generally as 'Kwasi'*, is used to predict the weather (Powell, 2016). For example, if the *Kwasi* bird cries out continuously or if it suddenly flies up into the air in the middle of the lake it means there is going to be a sudden change in wind direction and strong wind, which is dangerous for fishing boats as they may capsize (Powell, 2016).

Observations of changes in the pattern and constellations of different celestial bodies including the sky, the sun, the moon and stars are also used to predict upcoming weather. (Shoko and Shoko 2013; Speranza et al. 2010; Redeny et al., 2019). Farmers in Maluga village, Tanzania, use the moon's colour and shape to predict rainfall, for instance, if the moon is red high rainfall is anticipated (Elia et al., 2014). Similarly, farmers in Uganda use phases and shapes of the moon to predict the upcoming weather, for example, it is believed that during the dark phase of the moon rain is more likely (Orlove et al., 2010).

The fisher folk on Lake Victoria observe the direction, strength, force and duration of winds that blow at different seasons and use these as sources of information for predicting weather. Different winds are described and characterised according to strength and the direction from which they come. For example, the fisher folk community on Kenyan side of Lake Victoria refer to a certain strong wind coming from the southwest as "*Ogingo*". This wind brings the danger of waterspouts which are locally known as "*Nyakoi*" (Powell, 2016). Locally "*Tarai*" is a strong wind from the east and "*Ombalo*" is a strong wind from the south (Powell, 2016). "*Kus*" is the name given to a strong wind which produces gusts that come suddenly from different directions (Powell, 2016).

Integrating indigenous and scientific knowledge

Both local and scientific knowledge around weather and weather forecasting systems have unique values, as such, various researchers (Armatas et al., 2016; Sanni et al., 2012; Jiri et al., 2016; Roncoli et al., 2011) have opted to come up with synergies that would enable the incorporation of the local and scientific knowledge on weather forecasting systems. However, there is limited research identifying practical approaches for the synergetic use of the two knowledge systems.

Coproduction can be defined as "the bringing together of different knowledge sources, experiences and working practices from across different disciplines, sectors and actors to jointly develop new and combined knowledge for addressing societal problems of shared concern and interest" (Visman et al., 2018). Others have highlighted the need for co-production to narrow the gap between knowledge production and use; allowing for increased usability and use of knowledge in decision-making (Lemos and Morehouse, 2005; Lemos et al., 2012). Co-production has been utilised to transform climate science into climate services; information products that can support decision making in society (Bremer, et al., 2019). As such, in this field co-production is commonly used to describe the "deliberate, collaborative product-development work between climate scientists, or producers of climate data, and practitioners, or users who require climate information, including potential or even 'imagined users'" (Bremer et al., 2019, p. 42, citing Porter and Dessai, 2017). There is emerging consensus about some of the key steps or building blocks in the process of co-producing climate services (Carter et al, 2019). Critics suggest that co-production's complexity combined with the lack of concrete framework and no widely accepted definition makes it too ambiguous in practice (Thompson et al., 2017). Other critics also question its achievability, arguing there is a lack of evaluation of impact in collaborative research (Catalani and Minkler, 2009).

Methodologies for integrating scientific and local weather and climate information

Climate information provided by national and regional climate services do not always meet local needs. ***Participatory Action Research*** in Western Kenya aimed to integrate indigenous knowledge, from the Nganyi community, with weather information produced by meteorologists to increase the use of climate information. Meteorological forecasts were compared to indigenous forecasts and a consensus forecast was formed through a facilitated discussion (Ogallo, 2010).

Similarly, in the Lushoto District in Tanzania, ***consensus forecasts*** have been produced that integrate indigenous knowledge from farming communities and scientific weather information from the TMA. (Ziervogel and Opere, 2010). Consensus forecast increased farmers' use of climate information (Plotz et al., 2017).

Indigenous knowledge of weather prediction can also be produced in formats appropriate for use in statistical analysis, enabling the subsequent data to be integrated into scientific forecasts. This approach aims to convert indigenous weather indicators into recordable or measurable data which can be formed into a database (Plotz et al. 2017). This data can then be transferred into the weather forecasting stations to help develop a prediction based on the combined data from modern stations and indigenous knowledge. The database can be directly developed by local communities; this can be done through ***community-based observing networks*** (CBONs) (Alessa et al., 2016). CBONs use a network of indigenous observers to provide data, through observations of environmental variables (Alessa et al., 2016).

Another approach that can help to increase uptake of weather information by local communities is ***knowledge timelines*** through the integration of scientific and local knowledge. This method strengthens the understanding between the providers and users of weather information by comparing various sources of community and scientific weather and climate information, as well as, the levels of confidence and certainty in this information (Kniveton, 2014a).

Participatory downscaling is another methodology that is used to develop an understanding of the uncertainties in climate and weather information. This approach focuses on the uncertainty present at different temporal and geographic scales through a comparison of the scientific information forecasts and observations with community members' direct experience of specific events (Kniveton, 2014b).

Blending is a method that is complementary to participatory downscaling. This approach was developed by Christian Aid and its partners to support small-scale farmers in drought-prone areas of Kenya and Tanzania (Ewbank, 2014). The blending approach aims to identify ways of integrating local and scientific sources of weather information to develop forecasts that can practically support specific livelihood decision-making (in this case for farmers) (Ewbank, 2014).

Participatory Scenario Planning (PSP), developed by CARE International, is an approach that engages multiple stakeholders in a dialogue to share and examine local and scientific sources of climate information and to coproduce and deliver climate services that are more relevant to user needs (Ambani et al., 2018).

Forum theatre is a type of participatory theatre which enables discussions between and across a range of actors, using fictional characters to address power relationships, cultural hierarchies and barriers. The African Monsoon Multi-disciplinary Analysis (AMMA)-2050 project utilised the tool to facilitate participation, dialogue and knowledge co-production between scientists, local communities and policy makers (Audia et al., 2019).

Fuzzy cognitive mapping (FCM) is a method of analysing and representing IK that can be used to address the challenge of the informal and holistic nature of indigenous knowledge

(Masinde et al., 2018). FCM allows the integration of knowledge, experiences and perceptions of a system from different groups and presents this information in a map that links concepts through weighted connections, representing the relationships between concepts and the strength of these relationships (Olazabal, 2018). Knowledge from different sources can be integrated by combining multiple fuzzy cognitive maps into one 'universal' fuzzy cognitive map where different perspectives can coexist (Bremer, 2018). Masinde et al. (2018) used FCM to represent causal relationships between indigenous knowledge of weather indicators and weather conditions in communities in Kenya, Mozambique and South Africa.

Workshop to Develop Methodology

Workshop dates -19th to 24th January 2020

Workshop venue - Wigot Gardens-Kisumu-Kenya

Objectives:

1. Share findings of the literature review on examples where Indigenous Knowledge(IK) and Scientific Knowledge(SK) have been combined with a specific focus on impact based forecasting
2. Discuss and revise the methodology developed for combining scientific and indigenous forecasts
3. Share experiences from relevant external partners
4. Pilot the methodology
5. Review project timelines

Workshop participants

Participants were drawn from the following:

- University of Sussex-UK
- Maseno University-Kisumu/Kenya
- University of Nairobi-Nairobi/Kenya
- Sokoine University of Agriculture/Tanzania
- Uganda, UNMA
- Kenya Meteorological Department (KMD)t.
- NECJOGHA
- County Director Fisheries, Homa Bay-Kenya
- County Director of Fisheries, Kisumu -Kenya

- County Chairman-Beach Management Unit (BMU) Kisumu/Kenya
- County Chairman, Beach Management Unit (BMU) Homa Bay /Kenya
- National Fisheries Resources Research Institute-Jinja/Uganda
- National Fisheries Research Institute –Mwanza /Tanzania
- KEMFRI-Kisumu/Kenya

Proposed Methodology developed at the workshop

Step-by-Step combining approach

Step 1-Livelihood calendar

Develop livelihood calendars for fisher folk and livelihoods dependent on fishing. Livelihood calendars map the decisions of different members of the fishing community and the sources of information they used to inform each of their decisions. This method provides a structured way of understanding the activities of fisher folk communities and how and when they use indigenous knowledge and scientific knowledge to make decisions. This process clarifies the range of decision-making processes that weather and climate information can potentially support, enabling focus on those that can be supported by impact-based forecasts.

Step 2-Ascertain fisher folk confidence in IK indicators identified in Step 1.

- Perceived accuracy on a scale of: 1 = Not or only slightly accurate, 2 = moderately accurate, 3 = very accurate
- Perceived lead time for local indicators.

Step 3-Introduce or re-familiarize fisher folk with flag based impact based forecasts from science.

These were produced using a matrix approach by the HIGHWAYS project, as shown below.

Explain the content, format and probabilistic nature of the KMD impact-based forecasts, and that both local indicators and scientific forecasts are not 100% certain

Likelihood	High ≥70%			
	Medium >30% but <70%			
	Low ≤30%			
		Low / Minor	Medium / Significant	High / Severe
		Impact		

Key to hazard warning colors

GREEN	No severe weather is expected. It should be safe for small boats to sail on Lake Victoria
AMBER	Potentially dangerous weather is expected. **Be prepared**.
RED	Dangerous and potentially life-threatening weather conditions are expected. **Take immediate action to ensure your safety.**

Figure 1:-KMD Impact Matrix for Lake Victoria

Step 4-Explore different combinations of IK and science-based forecasts by the following:

1. Have 6 different cards – two for 'go fishing', two for 'proceed with caution' and two for 'no fishing'
2. Look at the IK forecast indicators mentioned by participants in the earlier livelihood calendar exercise where they assessed their accuracy.
3. For those indicators that people considered accurate – write these on the cards. For example, if people mention that the kwasi bird crowing and flapping its wings is an accurate forecast indicator not to go fishing, write this on the 'no fishing card'. Also note, beside the indicator, how much in advance people think this indicator appears (again this information was already given in the earlier exercise). Go through all the indicators assessed as accurate dividing them amongst the 3 cards.
4. Then turn to the scientific forecasts and again divide the forecasts amongst the same three cards: go fishing, proceed with caution, no fishing, and again mark the lead times.
5. Ask participants to work in groups, taking one of the 3 IK combined forecasts (either go fishing, stay alert, don't go fishing) and one of the scientific forecasts. So, one group might select IK that indicates don't go fishing, with a scientific forecast that indicates go fishing. Another group might select IK that select go fishing, with a scientific forecast that indicates don't go fishing.
6. Ask people to consider and note down on a separate card what action they would take with each combination.
7. Get groups to consider for several minutes. Then everyone can put back their forecasts and you shuffle them and then take another random combination of IK and scientific forecasts.
8. Get groups to report back in plenary and discuss to develop a matrix of the different combinations with the three types of IK based warnings on one axis and the 3 science based forecasts on another. Initiate a discussion to assign different advices to different

combinations. You need to be prepared that people will change their mind as the discussion continues. But aim to reach consensus through the overall discussion on when the IK and scientific forecasts can and cannot support each other.

9. Use a matrix to formalize the combination of the forecasts and prepare to change the outcomes as the discussion develops.

Step 5-Mapping Information Ecosystem.

This method maps the channels through which people in the fishing community currently receive weather and climate information to identify where there are gaps and which channels are most accessible and trusted by the fishing community in the Lake Victoria region. Through is process, communication channels that are available and most trusted are established, which can be utilised in the future when communicating forecasts.

Method:

1. Participants together identify the channels through which they currently get weather information (mass media, social media, social network etc). The facilitator notes the channels and groups them into common categories as they are called out. E.g. All radio stations will be under one category of radio (but keep note of all the channels mentioned so that KMD can later check to ensure that forecasts are currently shared with the radio stations mentioned).
2. Ask the participants to rank the communication channels to identify the most frequently used/accessed channel.
3. Ask the group to rank those channels that are most trusted.
4. Then draw the categories on a new flip chart and ask the participants to identify and explain the linkages between the channels mentioned, to identify the linkages for

example between local radios, BMUs, individual fishermen – and how these linkages work? For example, by SMS, WhatsApp, word of mouth, BMU meetings?

5. Ask if there are currently any ways in which they can provide feedback to KMD on the forecasts? And, if these do not currently exist, ask participants to indicate what might be some of the ways in which they could provide feedback?

Step 6-Triangulate research with Key Informant Interviews:

Questions on the Key Informant Interview Schedule

1. What are the main ways you earn your living? *(Individual)*
2. How does the weather impact on your life and income generating activities?
3. What weather information do you currently have access to?
4. What is the source of this information?
5. How do you receive this? Through which channels?
6. Which sources of weather information do you consider most reliable? And why?
7. How do you use weather information? What decisions do you take that are informed by weather information?
8. How do you rate the accuracy/skill of KMD/UNMA's impact-based forecasts? Why do you give this score?
9. What proportion of people in the community do you think:
   a) regularly receive KMD/UNMA forecasts
   b) consider them accurate?
   c) make regular use KMD/UNMA forecasts in their decision making?

10. What do you think are the main reasons why people don’t use KMD/UNMA impact-based forecasts?

11. Are there any ways that you think weather information could better support your decision-making?

Revisions to the methodology implemented in the second Pilot

The second piloting followed a similar overall format and the same series of steps as those employed in the initial piloting. It was however revised to address several areas where it was identified that the research methodology on participatory impact-based forecasting could be strengthened. These included:

- Strengthened participation of marginalized groups, particularly women;
- Greater clarity on participants’ perceptions of the accuracy and lead time of each local indicator;
- Strengthening understanding of the probabilistic nature and skill of scientific forecasts;
- Clarifying potential for conflicting information between local indicators and scientific forecast and discussing how these could be addressed;
- Reviewing the information eco-system mapping to clarify areas for strengthening the KMD’s existing communication of impact based-forecasts and ensuring regular feedback;
- Gaining further understanding from participants on the reasons for the recent reduction in weather-related deaths amongst fishers.

Co-production of climate services

Why do we integrate information from different knowledge sources to co-produce climate services?

It is clear that fishing folk on Lake Victoria have extensive and strongly held trust in local knowledge about the weather and climate, together with specific localised terminologies for describing it. In developing weather and climate services for the fishing folk, there is a need to embrace this knowledge and involve the traditional custodians of it, and so avoid creating unhelpful (and in many cases artificial) divisions between local and scientific indicators of future weather and fishing conditions.

In considering this process in more detail, there are a range of reasons why climate information producers such as National Meteorological Services may engage with local knowledge. These include:

Strengthening communication of forecasts

- Engaging with existing accessible and trusted channels and networks to support sharing of forecasts; and
- Supporting understanding through using local terms, for example related to winds and water spouts.

Improving forecasts

- Developing relevant and contextualised impact-based forecasts requires understanding of localised impacts of extreme weather events;
- Improving the localisation of forecasts and scientific modelling, through engaging with fisher folks to monitor and collate observations; and
- Support participatory and localised evaluation of the performance of forecasts to assess the scientific validity of local forecast indicators.

Supporting uptake and use

- Considering how to integrate local impacts into impact-based forecasts;
- Supporting appropriate use of probabilistic forecasts. For this, decision-makers need to be aware of key climate concepts including, forecast probability and skill; and
- Demonstrating the tangible benefits of increased forecast use within fishing decision-making.

While the integration of local indicators and scientific forecasts can be supported for multiple aims, the Research and Fellowship project is particularly focused on how the process of integration may support the uptake of the project's impact-based forecasts. It takes as starting points that:

- Local indicators produced from indigenous, traditional and local knowledge have credibility and legitimacy for many fisher folk;
- Forecast and indicators from all knowledge sources refer to future risk rather than being definitive predictions of the future; and
- Integration of different forecast and local indicator information is a dynamic process that will change over time and with location.

Criteria for the selection of research sites

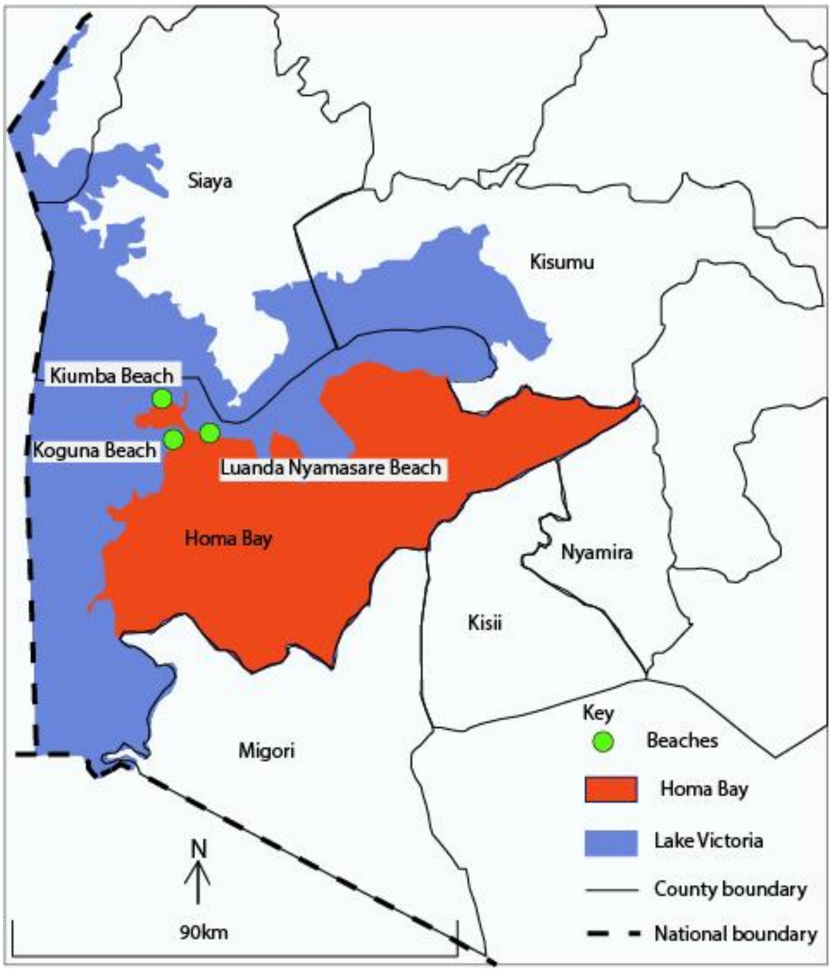

Figure 2-Sample sites

Criteria for the selection of sites for research in Kenya included:

- The sites face the open waters of Lake Victoria, which makes them at higher risk of severe weather events than the sheltered areas in the Gulf of Winam[3];

[3] This was also a recommendation given in Becky Venton's 2018 Report.

- The sites are impacted by large waves, strong winds, and other severe weather events;
- BMUs which have been receiving the HIGHWAY impact-based forecasts;
- Accessibility, enabling the research team to travel between sites and ensure coverage of three locations within the allocated research period of one working week.

Based on these criteria, three sites were selected to conduct a workshop/focus group discussion[4], namely Lwanda Nyamasare Beach (Site 1), Kiumba Beach (Site 2) and Koguna Beach (Site 3).

Composition of Research Team

The field research team implementing the workshops was made up of three facilitators who all spoke the local language. It also carried out key informant interviews in each of the sites. Data collection tools were developed jointly by the whole research team from University of Sussex, Maseno University, KMD, UNMA and private consultants.

Composition of the respondents

In the first pilot Lwanda Nyamasare Beach (Site 1) had 21 participants for the workshop, Kiumba Beach (Site 2) had 20 and Koguna Beach (Site 3) had 19 which totalled 60 participants. Boat owners and fishermen were 17,and the largest group followed by fishermen/fisherwomen (9 participants),fish trader(8) and boat owner(8). In the second piloting, 15 participants took part in the participatory impact-based forecasting in each site.

Differences in the composition of participants will result in differing levels of engagement, discussion and output in the participatory activities the research methodology employs.

[4] Note that although the focus groups took place at these three beaches, participants were not exclusively from these beaches but also from other beaches surrounding them.

The boats used for fishing were categorized into three sizes: small boats with a carrying capacity of between 1-4 people, medium-sized boats, able to carry 500kg or 6-10 people, and large sized-boats, carrying between 25-40 people or 5 tons. Boat type and size has implications for safety on the lake.

Table 1: Characterization of people who make fishing-related decisions

Fishermen	*Brief narrative of livelihoods*	*Day fishing (Setting of nets and hook fishing is done during the day)*	*Night Fishing (Omena is fished only at night but many fishermen go fishing at night)*	*Shoreline fishing (Certain fish species are found along the shores eg Ngege)*	Deep sea Fishing (Some fish are only found in the deep sea (eg Mbuta)
Boat owner who go out fishing on their own boat (only own one boat)	They fish using their own boats and sell fish to traders/middlemen/BMU. They are concerned about their safety and that of the boat				
Boat owner who go out fishing on their own boat and also lease out some of their boats (own many boats)	They fish using their own boats and sell fish to traders/middlemen/BMU. They are concerned about their safety and that of the boat. They rely on sale of fish and income from renting out boats				
Boat owner who do not go out fishing but lease out their boats (own at least one boat)	They are entrepreneurs. Income from renting boats could be one source amongst others. They are not exposed to danger on the lake. They are concerned about the safety of the boats.				
Fishermen who hire boats	They fish using hired boats and sell fish to traders/middlemen/BMU. They are more concerned about their safety than that of the boat. They are under more pressure because they must pay rents for the boat.				
Fishermen who work on the boats for pay	They are hired hands. The degree to which they are able to make fishing-related decisions is unclear. When they are not on the boat they are likely to engage in some other income generating activities.				
Captain or (Madhar)	These are fishermen who are leaders of their fellow crew tasked with decision-making on behalf the crews. These people use weather information to decide on fishing expeditions.				
Fishmongers	Those who buy and sell fish also depend on weather information to make decision on their business				
Fish agents or trade	They purchase fish from fishermen in				

	the lake and may consider weather information				
BMU officials	BMU officials or weather intermediaries who receive weather information and interpret it and pass it to fellow fishermen.				

STEP ONE-Livelihood Calendar

Based on the composition of the participants, the team identified two groups for developing fishing livelihood calendars:

a) Fishermen—those who go out to fish

b) Livelihoods on the beach that are related to fishing (e.g. Omena traders, hotel owners, etc)

All livelihoods listed (in column A) and placed in categories as shown below (in columns B,C &D)

Table 2:-Livelihoods of beach communities

A	***B***	***C***	***D***
Livelihood			
	Fishermen—(those who go out to fish)	*Livelihoods on the beach that are related to fishing*	*Livelihoods that are not related to fishing.*
Omena fisherman	x		
Mbuta fisherman	x		
Omena trader		x	
Hotel owner			x
Boat repairman		x	

Results from key informant interviews indicate the combination of livelihoods within the beaches. Respondents indicated that bad weather adversely affects the economy of the beach because the beach community depend on fishing (either directly or indirectly). When there is a lot of rain the water gets cold and the Omena catch is poor. When there is too much rain it interferes with Omena processing, as it requires sunlight to dry, leaving Omena spoilt and smelling bad.

KII Question 1: What are the main ways you earn your living?

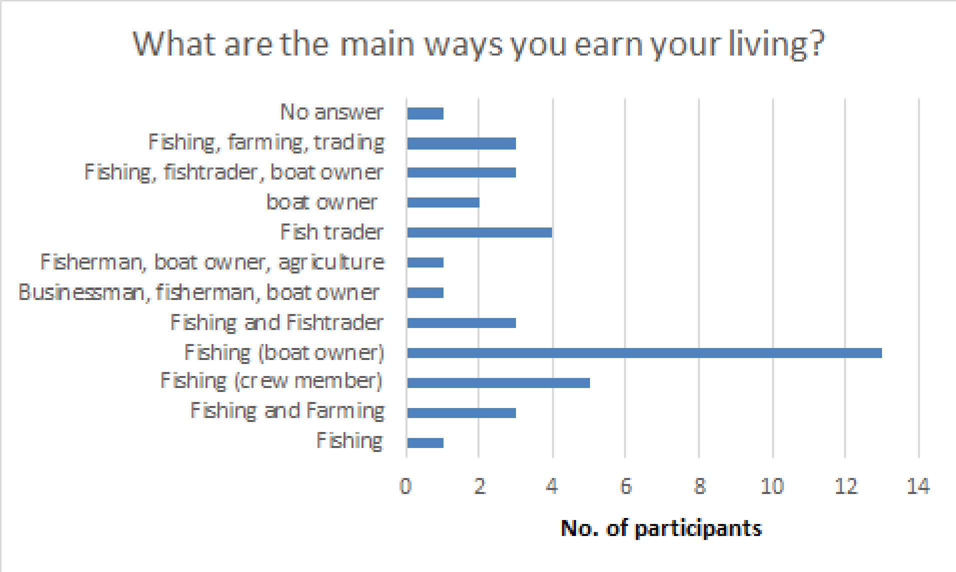

Figure 3:-*The main ways through which the community earn their living*

When do fishermen go out to sea to fish? *(Morning/afternoon/evening)*

Fisher men go fishing at different times depending on the type of fish they target to catch, the method of fishing they use and the location where they plan to fish.

Table 3:-When fisher men go out to fish

Fishing	***When they go out into the lake***	***When they come back***
Omena *(Type of fish)*	From 3-7 pm	After midnight to dawn
Mbuta (Nile perch) (toned-gillnet)	From 9 pm	6 am
Mbuta (Nile perch) Olow-long line hook	From 9 pm	
Long line hook fishers *(fishing method)*	0300-0600 (afternoon)	5-6 am morning
Gill nets *(fishing method)*	Day fishing 6am	6 pm
Tembea (Drift nets) *(fishing method)*	0500 (some also sleep on the lake)	
Rimba (Beach seines) *(fishing method)*	Both day and night	Both day and night

What determines the time they leave?

- The type of fish they plan to catch .
- The location where one wants to fish
- The prevailing winds
- The presence of rain
- Participants highlighted that those who engage in Omena fishing need a weather forecast at around 3pm to make a decision whether to go fishing or not, and they usually go out at 4-5pm.

What determines whether they go fishing or not go fishing? What information do they use to make this decision? Capture the information and categorize it as either local knowledge or SK.

Equipment such as;

- Paddles, anchor, sails life jackets etc

Elements of weather such as;

- Cloud formation, lightning and prevailing winds
- Calm weather (Yamo Okwee) an indicator that they can go fishing
- Rough weather (Yamo ywak matek) an indicator not to go fishing

Fishermen who go fishing in the morning observe weather between 2-4am in the morning. Those who go fishing in the afternoon observe the morning weather and those going fishing in the night observe the afternoon weather.

Winds are given names based on where they originate from. The same wind system may have different names in different places. Most fishermen use sail boats and are therefore dependent on the wind to sail out and sail back on shore. The fishermen understand the wind systems. They know when to expect each wind. They know the direction of the wind and can therefore determine which ones will help them sail out to sea and which ones will help them get back on land.

Table 4:-Seasonality of winds

Season	Wind patterns
(Chwiri)February to May-Long rains season. The main planting season	Winds are stronger and more unpredictable
(Yugni)Mist/Fog)—June to August	The weather is cold but not rainy Poor visibility/water temperature drop This is bad for fishing
(Oro)November/December/January Dry season	Nya Gwasi (wind) Disrupts fishing-Moves in the wrong direction

The fishermen in all the study sites use KMD forecasts to make decisions on whether to go fishing or not. The BMU chairmen receive the forecast from KMD and share it with members. Not all members can receive it because it is sent through WhatsApp and not all fishermen have access to phones that can use the application. The BMU assembly meets regularly (but not daily) and the secretary shares the forecast from KMD. A flag is placed on the beach daily to indicate recommended action. The colour of the flags is based on a warning advisory given in the KMD scientific forecasts, however, the BMU officials also observe the prevailing weather situation[5] and then decide on the flag colour to be raised. When the forecast indicates good weather conditions for fishing, the flag is GREEN. When it indicates bad weather for fishing, the flag is RED. When it indicates average conditions, the flag is AMBER and the fishermen go fishing with caution (Lwanda Nyamasare, Kiumba).

KII Question 9: Community access to, perceptions and use of KMD forecasts

Participants were asked: "What proportion of people in the community do you think: a) regularly receive KMD forecasts, b) consider them accurate, c) make regular use of KMD forecasts in their decision-making". A number of interviewees said they were unsure, while others indicated that the question was not applicable as they do not receive KMD forecasts or did not answer for other reasons.

[5] BMU chairmen are advised by the KMD that there are microscale events, such as waterspouts, that the KMD Numerical Weather Prediction Models cannot capture and as such BMU Chairs should observe current events to make decisions on what colour flag to raise.

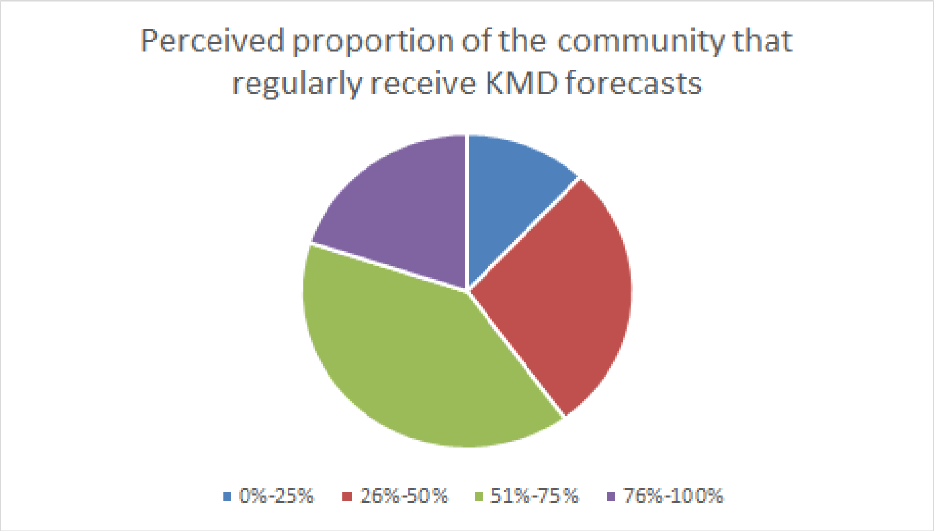

Figure 4:-Perceived proportion of the community that regularly receive KMD forecasts

Table 5:-Local indicators

1.	**Local indicators**	**Description**
2.	Genya (winds)	Genya is considered a dangerous wind blows from North West to South East. It is associated with big waves, and destructive storms. It is a high-risk wind which is most feared by fishers, and the most dangerous wind to Omena fishers. It destroys boats off shore and even onshore. It is a major cause of fishing accidents in the lake. When it is blowing nobody can go fishing. It often blows for a long period of time (all sites).
3.	Nyakisumo (wind)	Blows from North–East to South West, and usually blows from 1000-1100. It has a negative impact if it blows from 0400. When it blows in the morning it is bad for the fishermen because it stops them from going out to sea. When it blows in the afternoon it is good for the fishermen because it helps them come back on land. It reduces the water temperature which often leads to poor fish catch (Lwanda Nyamasare). Nyakisumo blows from the North East; a strong wind with strong currents and it makes water cold and it leads to poor fish catch (Koguna).
4.	Nyamaseno (wind)	Has a mild effect on fishing activities. (Kiumba). Nyamaseno blows from the North East, from Maseno direction. It is a gentle wind (Koguna).
5.	Ogingo (wind)	Common name used by most fishermen. It is a very dangerous wind, associated with a high fatality rate. It blows from south west to North East. It blows once in a while. (Lwanda Nyamasare). Implies go fishing with caution. It is a good wind that contributes to a better fish catch for Nile perch fishers. It changes the water current and makes them favorable for fishing. (Kiumba)

		Ogingo blows from the south–west. It is also accompanied by strong winds and waves. It is good for Nile perch fishing if it blows moderately. However, fishermen must take precautions because it is also associated with accidents in the lake. (Koguna).
6.	Nyandwara (wind)	A dangerous wind, associated with accidents in the lake.
7.	Nyarmanyala (wind)	Close to Genya and hinders fishing operations for both Omena and Mbuta fishers (Nile Perch)
8.	Nyolambwe (wind)	The winds that were classified as good for fishing included Nyolambwe which blows from the mainland to the lake. They like it in the morning because it helps them to sail to fishing grounds but when it blows in the afternoon it makes it difficult for them to come onshore (Lwanda Nyamasare). Nyalambwe winds blow from the South East. It is liked by fishermen and is associated with calmness of the lake, good current and good fish catch (Koguna)
9.	Sego (Wind)	Sego(wind) a gentle wind-(yamo ma nyap).Sego is another good wind that was praised by Lwanda Nyamasare fishermen. It blows from South East to North west.
10.	Komadhi/tarai (wind)	One of the best winds that promotes fishing on almost all beaches. When it blows the lake is calm, there is good current. They noted that it is only strong in the month of July. It is only a challenge for fishers using sails boats to return to shore safely when it blows until 1800. (Kiumba). Komadhi wind blows from East to West. It is one of the winds highly liked by fishermen. This wind often makes lake water hot and is associated with good fish catch (oketo pi maliet and rech kwayo) Koguna.
11.	Nyaosingo (wind)	Nyaosingo is another wind blowing from Southeast to Northwest, it is dangerous on the east part of the Rusinga island but to west is calm wind. The participants from the east of Rusinga noted that in the east the wind is stormy and they are unlikely to go fishing when it is blowing. The participants from western Rusinga observe that the lake is calm and it is good wind for them and they will go fishing when it blows.
12.	Nyagwasii (wind)	Nyagwasii is similar to Nyaosingo and those participants from Rusinga indicated it is good for fishing. Only a challenge for those who are using sailboats to return from fishing expeditions.
13.	Yandha (wind)	Yandha, min nam (mother of the lake), is considered a good wind. It starts blowing in the afternoon - around 1-2pm - and it is used by the boats for coming back to shore in the evening (Lwanda Nyamasare). In Lwanda Nyasare and Kiumba it is considered not good in the morning because it may prevent fishermen from going fishing as its direction is from the lake to shore. A wind praised by fishermen. It blows from the south west. It usually begins at around 1300-1400. It is good for fishermen with sail boats because it helps them to return safely to shore (Kiumba). Yandha winds blows from West to East. It is liked by fishermen as it leads to a good fish catch and an increase in water temperature (Koguna). Yandha is praised by all fishermen regardless of fishing types
14.	Cloud formations (boche polo)	They also observe cloud formation. They link cloud formation to winds. The wind is likely to blow from where there are heavy cloud formations (Lwanda Nyamasare).

		(Polo okwot)-pregnant clouds are a sign that a storm is brewing and there is likely to be rains and heavy wind (Koguna and Lwanda Nyamasare). Silver lined clouds (Polo shi nindo) - when silver lining occurs below clouds then it is an indication that wind will not blow (Polo odhi nindo). This depends on seasons. (Koguna)
15.	Lightning (*mil polo*) and thunder *(mor polo)*	*Polo mil*-(lightning)- An indicator of bad weather so they must be cautious (Lwanda Nyamasare). According to fishermen winds are likely to emerge from the direction where lightning is showing or cloud formations. Mbuta hides from lightning and thunder (Koguna). Thunder—associated with storms and strong winds and waves. (Lwanda Nyamasere) Fishermen believe that thunderstorms and lightning usually threaten fish and make them return to the deep in the lake. (Koguna)
16.	Nger (water currents)	Nger-these are water currents/movement of Hyacinth and indicator of water current movement/currents cause conflict because fishing nets entangle and fishermen disagree over fish.
17.	Kwasi (a bird)	Kwasi - the black and white eagle that feeds on fresh fish - crows and flaps its wings any time there is a change in direction of the wind. It only crows during daytime.
18.	Osou(a bird)	A bird that sits facing the direction from which the wind is about to blow and has a distinctive call.
19.	Opija (a bird)	A swallow that shows the direction of the wind (Koguna). They move in groups away from on-coming winds. They are seen to be heralding the coming of strong winds (Lwanda Nyamasare).
20.	Okok (a bird)	A white bird that is used to detect fishing ground for Omena fishermen.
21.	Adiel Mbusi(a bird)	A bird that indicates good fishing ground for Nile perch
22.	Ang’wayo (a bird)	Small birds that feed on silver fish and like light. It is used to detect the direction of wind particularly by Omena fishermen. It is also indicates a good catch of Omena.
23.	Okunga (a bird)	Indicates strong winds. It leaves water during strong winds.
24.	Sam (insects)	A type of fly that moves in large groups. They show that wind is coming and the direction.
25.	Nduklu	Small animals that swim and show where there is a good catch.
26.	Stars (sulwe	Bright stars indicate good weather. Omena fishers usually go fishing when stars are bright, but they do not go fishing when there is moonlight. Omena are attracted to the surface by light. When there is moonlight the Omena are everywhere and it is not easy to catch them. When there is no moonlight the fishermen go out to sea with lights which attract Omena to the boat in large numbers and allows them to be caught easily.
27.	Rain	Rain is not good for Omena fishing because it interferes with Omena processing
28.	Fog (ongweng’o)	Foggy conditions no fishing
29.	Waves (Apaka)	For waves, we observe waves heights and sound of waves. When water turns white (nam nyiero)

Table 6:-Cross site comparison of local indicators and their implications for fishing boat safety and potential

Local indicator	**Fishing boat safety**			**Fishing potential**		
	Lwanda Nyamasare	**Kiumba**	**Koguna**	**Lwanda Nyamasare**	**Kiumba**	**Koguna**
Genya (wind)	Dangerous	Risky or bad	Bad	Low fishing potential	Bad (no fishers would fish with Genya)	Bad (makes water cold)
Ogingo(wind)	Dangerous	Very risky or bad	Bad	Poor fishing	Good because it brings a lot of fish	Fair
Komadhi(wind)		Good	Fair		Very good for fishing (used to take boats to fishing grounds)	Fair (warm water for good fish catch)
Yandha (wind)	Good		Fair		Good - it is believed to bring fish close to the shore and it is used by fishers to return to the shore	Fair
Ongwengo(fog)		Poor visibility cause boats to lose direction			Bad – poor visibility is bad for fishing	
Adiel Muzi and Okunga (birds)				Good		
Olambo(wind)	Good			Good		
Rain	Risky		Bad if heavy rain	Poor		Bad in heavy rain
Sego(wind)	Good			Good		
Lightning/thunder			Bad			Bad – scares away fish
Sunshine			Good			Good
Nimbus clouds	Good because they warn fishers of danger				Bad for fishing	
Nyalambwe(wind)			Good			Bad – (makes

						water cold, which reduces the catch)
Kwasi (bird)	Good	Good it warns fishers of looming danger but sometimes it crows and the wind does not change	Bad	Bad	Irrelevant	-
Sam (small flies)		Bad – proceeds a strong wind			Good because it comes with fish	
Low wave height	Good			Good		
High wave height	Dangerous			Bad		
No rain	Good			Good		

How do they obtain this information?

The fisher folk gain local knowledge through apprenticeships on the boats. Some go fishing with their fathers and learn how to read the signs over time. Some join the boats as crew and with time they learn to read the signs. The boats have a captain who is the final decision maker but he consults with the rest of the crew members on how to proceed.

Who is the authority behind the supply of this information?

Fishing is a way of life for lakeshore dwellers and they have traditional ways of passing on skills and knowledge. Local knowledge is passed down through generations from the elders to the younger generation. The older fishermen are the most experienced and are the custodians of this knowledge. It is normally not documented and is said to only be gained through apprenticeships. Many fishermen who own boats passed the trade on to their sons.

As indicated earlier, the fishers also use forecasts from KMD to make decisions on whether to go fishing or not. Scientific forecasts are produced by professionals employed by the government. The BMU officials receive the KMD forecasts and also observe the prevailing weather conditions at the beach before deciding what colour flag is raised; BMU chairmen and secretaries have been trained to do this. The rolling 24-hour impact-based forecast is divided into 6-hour timeframes, so the flag can be changed 4 times over a 24-hour period. The flags remain in place during the night. People can also make enquiries about the colour of the flag even if they are not on the beach and then make a decision to go or not to go fishing.

Boat owners are concerned about the safety of their boats and can sometimes warn the crew members not to go fishing. The BMU chair can also order a boat not to go fishing if the crew has been drinking.

What proportion of the fishermen are perceived to adhere to this?

Local knowledge has been with the community for many years and all fishers use it. However, they do this to varying degrees. Some do not pay much attention to the KMD forecast and go about their fishing as their ancestors did. This is a small proportion of the community estimated at 25%. There is another group that receives KMD forecasts but do not act on it alone and combine it with local knowledge. No fishermen rely exclusively on the KMD forecasts. However, ALL fishermen know that the forecasts exist.

Decisions made by fishermen based on local indicators

Using the local indicators identified by the group discussion, the facilitators sought to understand the decisions made by the fishermen and rated them for accuracy (*accurate very accurate, moderately accurate),*

Table 8 below indicates that 60%(6 indicators) of the indicators were considered very accurate, 30% (3 indicators) moderately accurate and 10% (1 indicator) accurate.

The local indicators presented do not give much lead time. All of them give less than 6 hours' lead time and some less than one hour. For Kiumba, 10 indicators were considered very accurate, 2 were considered moderately accurate, and 1 was considered accurate. Of the 23 indicators identified at Koguna, only 8 had their accuracy rated. Of these 5 were perceived as very accurate and 3 were considered accurate.

Of the 5 indicators common across all 3 sites (genya, ogingo, yandha, kwasi bird and cloud formation), 3 (kwasi bird, genya and ogingo) were considered 'very accurate' at all 3 sites. Yandha was considered 'accurate' at Lwanda Nyamasare and Kiumba and 'very accurate' at Koguna. There were also differences in the perceptions regarding the accuracy of cloud formation; Site 1 assessed it as moderately accurate, Site 2 assessed it as very accurate and Site 3 assessed it as accurate.

Table 7 Decisions made by fishermen based on local indicators

Local indicator	**Decisions on whether to fish**		
	Lwanda Nyamasare	**Kiumba**	**Koguna**
Genya (wind)	Don't go fishing	Don't go fishing	Don't go fishing
Ogingo(wind)	Don't go fishing		Go fishing with caution
Komadhi(wind)		Go fishing	Go fishing
Tarai (wind)		Go fishing	
Yandha (wind)		Don't go fishing	Go fishing
Ongwengo(wind)		Don't go fishing	
Adiel Mbuzi and Okunga (birds)	Go fishing		
Olambo(wind)	Go fishing		
Rainfall	Don't go fishing		
Sego(wind)	Go fishing		
lightning and thunder	Go fishing with caution	Go fishing with caution	Go fishing with caution
Heavy cloud cover/ Nimbus clouds	Go fishing with caution	Go fishing with caution	
Sunshine			Go fishing

Nyakisumo(wind)	Go fishing with caution		
Nyamaseno(wind)	Go fishing with caution		
Kwasi bird	Don't go fishing	Go fishing with caution	Go fishing with caution
Nyakoe/water spout		Don't go fishing	
High wave height	Don't go fishing		
No rain	Go fishing		

STEP TWO- Ascertain fisher folk confidence in IK indicators identified in Step One

Table 8:-Perceived Accuracy and Lead time of local indicators

Cross-site comparison of the perceived accuracy and lead time of local indicators						
Local Indicators	**Perceived Accuracy**			**Lead time**		
	Lwanda Nyamasare	**Kiumba**	**Koguna**	**Lwanda Nyamasare**	**Kiumba**	**Koguna**
Genya	3	3	3	1 hour	1.5 hr	1 hour
Ogingo	3	-	2	3 hours	-	3 hours
Komadhi	-	3	3	-	15-20 mins	1-2 hours
Yandha (Kus)	3	3	3	6 hours	2-3 hour	2 hours
Ongwengo	-	2		-	2-3 hour	
Olambo	3	-		12 hours	-	
Rainfall	1	-	1	0.5 hour	-	1-2 hours
Sego	1	-		Difficult to tell		
lightning	1	3	2	2-3 hours	None	0.5-1 hour
cloud cover	1	-	-	2-3 hours	-	-
Nyakisumo	2	-	-	1 hour	-	-
Nyalambwe	-	-	3	-	-	0.5 hour
Kwasi bird	3	2	1	0.5 hour	0.5 hour	0.5 hour
wave height	2	-		1 hour	-	
Opijah	2	-		0.5 hour	-	
Nyakoe/water spout	-	2		-	1-2 hour	
Key: 1 = Slightly accurate, 2 = moderately accurate, 3 = very accurate						

Participants observed the lead time for local indicators is often shorter than for scientific forecasts.

KII Question 6: Which sources of weather information do you consider most reliable? And why?

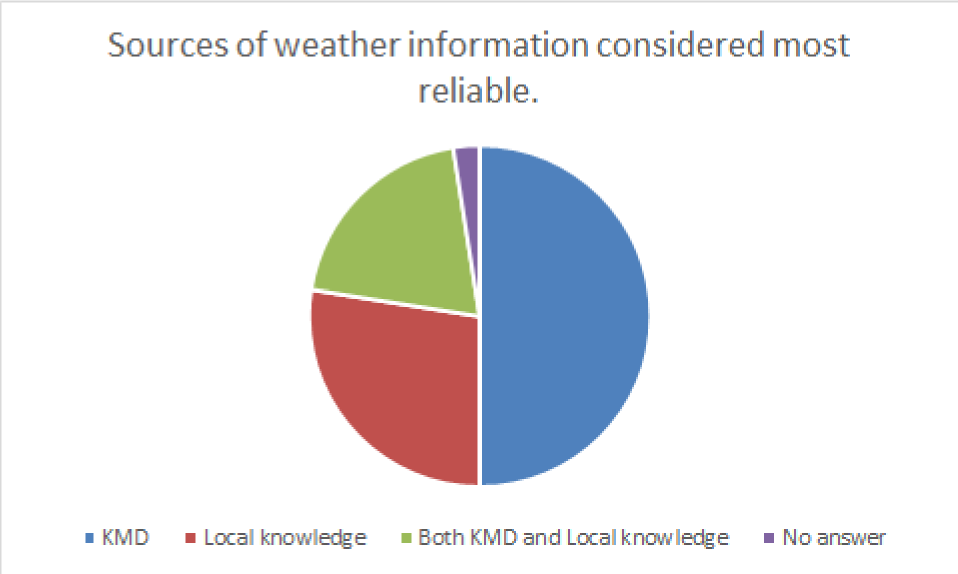

Figure 5:-Sources of weather information considered most reliable by participants across all three sites

Weather-Related Deaths

Why do fishermen still die yet participants say that their indicators are accurate?

The discussion group at Lwanda Nyamasare beach indicated that continued weather-related deaths were caused by the following factors:

1. Poverty - The need to earn something to sustain the family will drive some boats into the lake even when the weather forecast is not good.
2. Introduction of the motor-driven engine has reduced the dependency on winds so some fishermen especially the young ones become less keen on monitoring the wind systems. They are sometimes caught off-guard by bad weather.

3. Business opportunity. Due to unemployment there are many young people who seek employment on the fishing boats. They do not have the experience required to interpret the indicators and thus expose themselves to danger. Apprentices work under experienced fishermen for many years before they can take charge of a boat. People seeking employment will hire boats and go fishing even when they have limited experience.

4. Sometimes fishermen go out to fish even when the forecast and indicators were not good because they are very poor and the pressure to provide for the family pushes them to take risks.

5. The local indicators provide very short lead time and sometimes the fishermen do not have enough time to get back on land before the storm. Strong and dangerous winds, such as Genya, have a short lead time.

6. Indiscipline - There are fishermen who drink while out fishing and impair their capacity to make sound judgement. They often miss or ignore the warnings. This is common with the younger fishermen.

A survey of 36 beaches in Homabay indicates that there has been a decrease of weather related deaths on the lake since the introduction of scientific weather forecasting and increased awareness of weather elements by fishermen. It established that boat size and type contributed to weather related deaths. The smaller boats were less resilient in bad weather and often capsized. Boats fitted with motorized engines could change direction at will; when they saw a storm brewing, they were able to go back to the shore. However, sail boats could not do the same because they must wait for a wind blowing in the right direction.

Table 9:-Collated deaths in 36 beaches of Homabay County between 2010 and 2019. Source: Stakeholder interviews.

Year (and Month if known)	How many deaths were reported in this year?	How many of the deaths in the year were related to weather?
2010	67	38
2011	61	49
2012	71	52
2013	63	45
2014	65	36
2015	74	47
2016	19	16
2017	20	11
2018	25	20
2019	25	16

Reasons for the recent decrease in weather-related deaths

In responding to Step 2.2 question 4, on whether participants think that the number of weather-related deaths among fishermen has increased or decreased in the last 5 years, participants across all three sites observed that deaths have decreased for a range of reasons. These included:

- Use of local and scientific knowledge
- Increased access to scientific forecasts. For example, information on weather conditions is provided on the radio.
- The flag on the beach at 0400 before going on the lake
- Larger sizes of boats
- Use of life jackets.
- Use of motorized boats instead of sail boats
- Inspection of all boats leaving the land site

STEP THREE- Introduce or re-familiarize fisher folk with flag based impact based forecasts from science

The KMD representative introduced the impact-based forecasts for Lake Victoria, developed under the HIGHWAY project. These are currently issued twice daily by KMD at 3am and 3pm and communicated via email and WhatsApp to fishery officials, BMU chairmen, and local radio stations for sharing.

Figure 6 illustrates the matrix for the KMD impact-based forecast for Lake Victoria. The matrix combines level of probability with level of impact, to assign level of risk with guidance on whether to go fishing, not go fishing, or go fishing but remain alert. The colour coding aligns with guidance in Luo as to whether to go fishing or not. In Kenya approximately 210 intermediaries[6] have been trained in understanding, communicating and using the impact-based forecasts.

Explain the content, format and probabilistic nature of the KMD impact-based forecasts, and that both local indicators and scientific forecasts are not 100% certain

The initial piloting identified the need to ensure participants understand the probabilistic nature of scientific forecasts over time and geographic scales, alongside presenting the format and content of the impact-based forecast. It was recognized that enhancing uptake of the scientific forecast is dependent on ensuring that lakeside communities appreciate that it is not completely certain but, if the forecasts have sufficient skill and are used consistently, over time the forecast will be an important source of information. If the probabilistic nature of

[6] The intermediaries trained include fishery officials from 82 beaches in Homa Bay County that face the Open Lake, Chairmen of Beach Management Units (BMUs) in Homa Bay, Busia, Kisumu, Migori and Siaya Counties, County Disaster managers in Homa Bay and Kisumu, County Director of Fisheries in Homa Bay, Kenya Fisheries Service in Kisumu, Kenya Marine and Fisheries Research Institute (KMFRI) Kisumu, Water Bus Company operating from Mbita to Mfangano Island among others, variety of local radio stations and TVs including Sunset FM in Homa Bay, Gulf Radio FM in Homa Bay, Ekialo Kiona FM in Mfangano Island, Victoria FM and Nam Lolwe FM in Kisumu, Bulala FM in Busia, Dala FM in Siaya among others.

forecasts is not fully understood, people will perceive the forecast as inaccurate on the occasions when conditions do not occur as predicted.

At each site the KMD representative presented and explained the scientific impact-based forecast. They then presented four examples of where the forecast was and was not matched by local observations to demonstrate that the scientific forecast is sometimes not accurate at a local level. As the scientific forecast covers a wide geographic area, from Kisumu's Winam Gulf up to Mbita, observed conditions may vary at a local level.

It was felt that step 3 could be further strengthened through:

- Adding a counterpart consideration of local indicators, providing examples of where the predicted conditions did and did not occur. This would allow participants to appreciate that both local indicators and scientific forecasts are not completely certain.
- Sharing the assessed skill of the scientific forecast across lead times and geographic scales. This would facilitate participants in comparing the accuracy of local indicators and scientific forecasts.

The knowledge timeline approach[7] offers a useful method that could be incorporated and adapted for use within future complementary research. As such, it is included in the methodology in Annex 1. In Knowledge Timelines, facilitators and participants identify a major recent weather event. Participants are asked to identify which local indicators were observed in advance of this and at what lead times. A representative of the national meteorological agency explains the types and timeframes of scientific forecasts available in advance of such a weather event and then clearly communicates the skill of the scientific forecasts across timeframes and geographic scales. The participants then similarly assess the accuracy of their local indicators.

[7] https://www.humanitarianfutures.org/wp-content/uploads/2014/05/CS2-Timelines.pdf

STEP FOUR. Explore different combinations of IK and science based forecasts

Participatory impact-based forecasts

This step supports discussions on how local indicators and scientific forecasts can be used together, using a template similar to the scientific impact-based forecasts, but where the probability is instead replaced by a series of local indicators.

Probability	High level of certainty			
	Average level of certainty			
	Low level of certainty			
		Go fishing/Green	Go fishing but stay Alert/Amber	Don't go fishing/ Red
		Impact		

Figure 6:-KMD Impact Matrix

1. Remind people of the HIGHWAY 24-hour impact-based forecast, and what the colour coding means.
2. Review the local forecast indicators from the earlier exercise and identify local indicators that correspond with KMD forecasts
3. Then draw out a table for participants to consider the presence and absence of local indicators in three different scenarios – where the KMD impact-based forecast has resulted in there being a red flag, an amber/yellow flag and a green flag.

Table 10: Lwanda Nyamasare: Combining local indicators with KMD impact-based forecasts

Local indicator	Green	Amber	Red
Nyandwara (wind)	Do not go fishing	Do not go fishing	Do not go fishing
Genya(wind)	Do not go fishing	Do not go fishing	Do not go fishing
Olambo (wind)	Go fishing	Go fishing but stay alert	Go fishing
Kwasi crows	Go fishing but stay alert	Go fishing but stay alert	Do not go fishing
Ogingo(wind)	Do not go fishing	Do not go fishing	Do not go fishing
Lightning	Go fishing but stay alert	Go fishing but stay alert	Go fishing but stay alert
Heavy Clouds	Go fishing but stay alert	Go fishing but stay alert	Go fishing but stay alert
Sego (wind)	Go fishing	Go fishing	Go fishing

Table 11: Kiumba: Combining local indicators with KMD impact-based forecasts

Local indicators	Green/ adhi lupo	Amber / adhi katang	Red / ok adhi
Genya winds blowing	No fishing	No fishing	No fishing
Komadhi winds blowing	Go fishing	Go fishing but stay alert	Go fishing
Ongweng'o (fog)	Go fishing but stay alert	Go fishing but stay alert	No fishing
Sulwe (stars)	Go fishing	Go fishing	Go fishing but stay alert
Kwasi bird cries	Go fishing	Go fishing but stay alert	No fishing
Heavy Clouds	Go fishing but stay alert	Go fishing but stay alert	No fishing
Polo mil (lightning)	Go fishing but stay alert	Go fishing but stay alert	No fishing
Nyaosingo winds blowing	Go fishing	Go fishing but stay alert	Go fishing but stay alert
Storm approaching	Go fishing but stay alert	Go fishing but stay alert	No fishing
Ogingo winds blowing	No fishing	Go fishing but stay alert	No fishing
Nyamaseno winds blowing	Go fishing but stay alert	Go fishing but stay alert	No fishing
Nyarmanyala winds	No fishing	No fishing	No fishing
Falling rain.	No fishing	No fishing	No fishing

Table 12: Koguna: Combining local indicators with KMD impact-based forecasts

Local indicator	GREEN Go fishing	Amber Proceed with caution	RED No fishing
Nyaolambwe	Go fishing	Go fishing	Go fishing
Genya	No fishing	No fishing	No fishing
Ogingo	No fishing	No fishing	No fishing
Komadhi	Go fishing	Proceed with caution	Proceed with caution
Polo mil	Proceed with caution	Proceed with caution	No fishing
Polo okuot	Proceed with caution	Proceed with caution	No fishing
Nyamaseno	Go fishing	Proceed with caution	Proceed with caution
Yandha	Go fishing	Go fishing	Proceed with caution
Nyasakwa	Go fishing	Go fishing	Proceed with caution
Kwasi crows	Go fishing	Proceed with caution	Proceed with caution

In the second Pilot there was review the local forecast indicators that people in earlier exercises have assessed as accurate and particularly those that may be at similar timeframes to the scientific forecasts – and select the top 2 or 3 of the local indicators that are at a similar timeframe

Participants from Lwanda Nyamasare beach assessed the following local indicators as very accurate, (see table 8) with lead times as indicated in the table 13 below:

Table 13:-Lwanda Nyamasare beach-decision to go fishing and lead time

Local indicators	Decision on whether to fish	Lead time
Olambo (wind)	Go fishing	12 hours
Ogingo(wind)	Don't go fishing	3 hours
Genya (wind)	Don't go fishing	1 hour

Participants then discussed to reach consensus on the integration of local indicators and scientific indicators:

Table 14:-Lwanda Nyamasare beach-decision to go fishing and KMD forecast

Local indicators	Scientific forecast		
	Green flag	Amber flag	Red flag
Olambo (wind)	Go fishing	Go fishing	Go fishing
Ogingo(wind)	Do not go fishing	Do not go fishing	Do not go fishing
Genya (wind)	Do not go fishing	Do not go fishing	Do not go fishing

When participants were asked to recall the respective lead times for the local indicators and scientific forecasts, participants that made several revisions as follows:

Table 15:-Lwanda Nyamasare beach-Decision to go fishing after factoring in lead time

Local indicators	Scientific forecast		
	Green flag	Amber flag	Red flag
Olambo(wind)	Go fishing	Go fishing	Go fishing but stay alert
Ogingo(wind)	Go fishing but stay alert	Don't go fishing	Don't go fishing
Genya (wind)	Go fishing but stay alert	Don't go fishing	Don't go fishing

Particular attention needs to focus on discussion where local indicators and scientific forecasts differ: where the local indicators that indicates good fishing conditions where the impact-based forecast assesses dangerous conditions, and vice versa, where the local indicators indicate dangerous fishing conditions where the impact-based forecast advises fishing. For example no one will go fishing when Ogingo and Genya winds blow even if the scientific forecast indicates that they can go.

The exercise made clear that when bringing together others. The probability and impact of the scientific forecast are combined in the risk matrix, while the assessed skill of the impact-based forecasts is not yet shared.

- When reviewing the accuracy of scientific forecasts, while people generally considered these as fairly accurate, there remains a call for their greater localization. Here local indicators may be able to inform the localization of scientific forecasts covering a large geographic area.
- When reviewing the respective lead time of each, discussion clarified that the scientific forecast is covering a longer time period than the local indicator.

local indicators and scientific forecasts:

- It is important to highlight that neither local indicators nor scientific forecasts are completely certain. Some local indicators are recognized to have greater accuracy than

STEP FIVE-Mapping Information Ecosystem.

Participants together identified the channels through which they currently get weather information (mass media, social media, social network etc). Across all three sites the top three most used channels were radio, TV and WhatsApp. It emerged that although KMD has a designated WhatsApp group for Homa Bay county, most fishermen do not have smart phones.

KII Question 3: What weather information do you currently have access to?

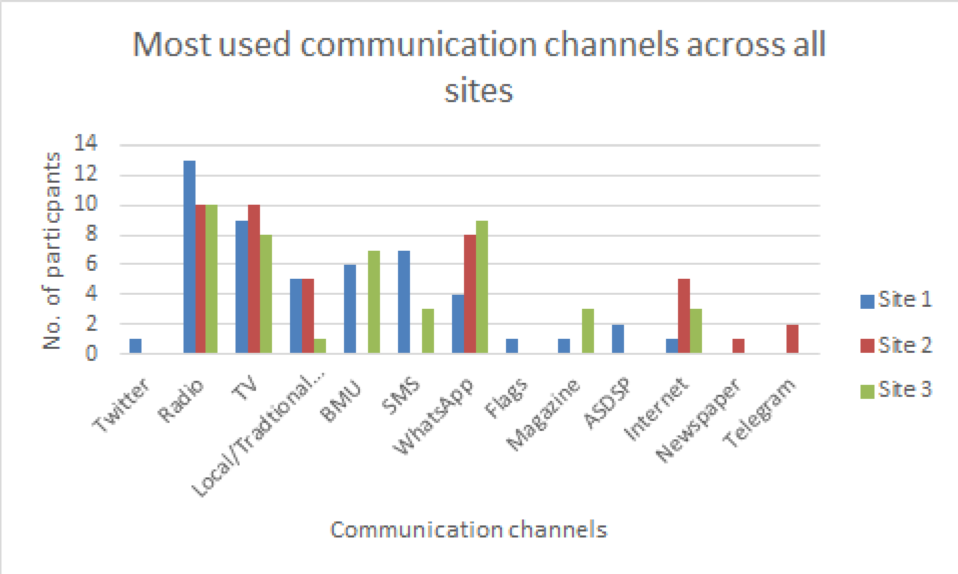

Figure 7:-Most used communication channels across all sites

Mapping the flow of information between the channels:

The BMU is a key link point in communicating weather forecasts. The chairman receives the information from KMD and shares with members in the assembly. The flow of information is one way. WhatsApp and SMS are also identified as one-way links to the fisherman[8]. KMD is also considered an important link because it generates the information which is then communicated through various channels. The flow of information is one way; from KMD to other media and other actors including BMUs. This was the same at site 1 and 3 since the institutional landscape is one. Site 2 did not create a linkages diagram for their communication channels as they were fatigued given this was the last task of the day. is one. Site 2 did not create

[8] Note that some fishermen do feedback to the KMD through WhatsApp, therefore information travels both ways through this channel; fishermen monitor the daily weather and provide the KMD with what was observed and the level of accuracy of the forecast.

a linkages diagram for their communication channels as they were fatigued given this was the last task of the day.

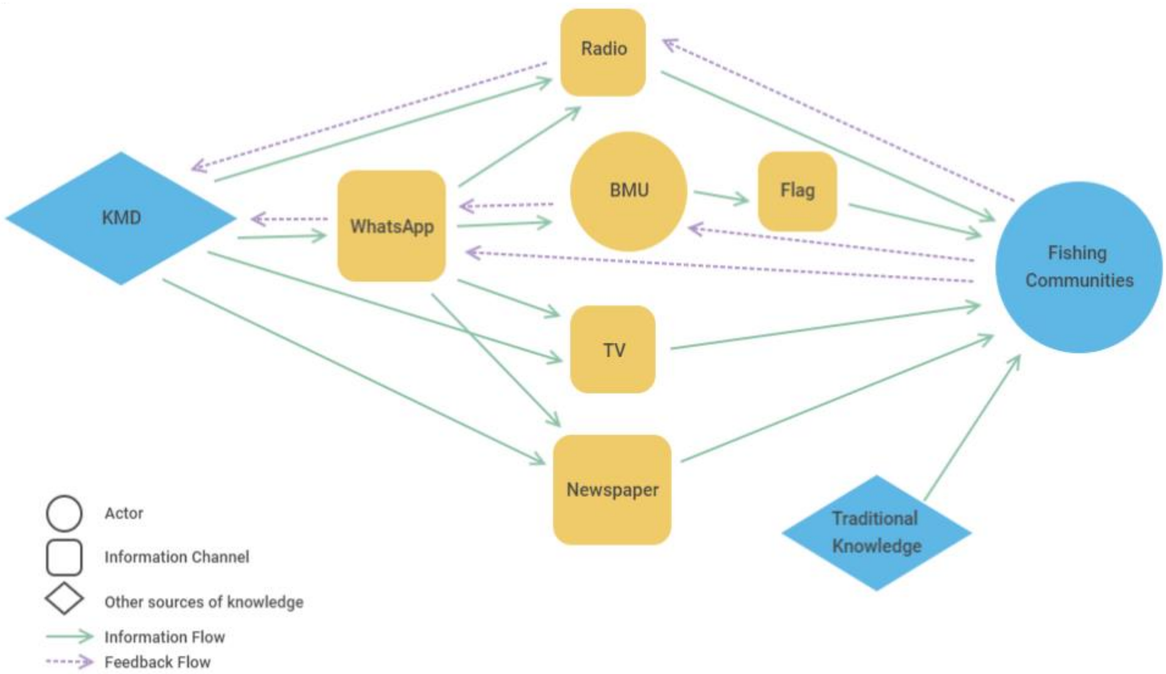

Figure 8:-Information Ecosystem Network in Koguna Beach

Terms of Reference for a Research Network on Weather, Climate and Fishing for the Lake Victoria Basin

Summary Narrative

A Network drawing together regional expertise to share knowledge and build partnerships in addressing weather- and climate-related risks for Lake Victoria's fishing communities.

Background

This initiative stems from research undertaken during the WISER HIGHWAY (HIGH impact Weather lAke sYstem) project which sought to address the need for an improved, accurate early warning system to prevent deaths and damage due to severe convection and strong winds on Lake Victoria. HIGHWAY aimed to establish a Regional Early Warning System (EWS) for the East Africa Region by working through mandated institutions from the international, regional and national levels, including the National Meteorological Hydrological Services in Kenya, Uganda, Tanzania and Rwanda; the Lake Victoria Basin Commission (LVBC) and the East African Community (EAC).

HIGHWAYS supported a Research and Fellowship project, bringing together academic and research capabilities across the Lake Victoria region, to facilitate the increase in uptake and use of impact-based weather warnings amongst fishing folk, assessing if more relevant and useable forecasts can be developed through closer integration of local and scientific knowledge. A workshop in January 2020 brought together regional capacities in meteorology, fishing, environment and social sciences with Beach Management Unit and media network representatives. Workshop participants discussed the potential for establishing a network of expertise for the Lake Victoria basin. These Terms of Reference (TOR) draw on the inputs of the workshop participants as well as comments received from a circulated draft.

WISER
Weather and Climate Information Services for Africa

What is this network for?

1. Collating a database of, and providing a resource for accessing, regional expertise across disciplines and sectors concerning weather, climate and fishing in the Lake Victoria basin;
2. Undertaking and supporting research on weather and climate and their effects on Lake Victoria fisher communities;
3. Assisting coastal communities to document and share their weather- and climate-related experiences
4. Providing feedback from across network members (encompassing representatives from across the fishing sector, academic and policy professionals) on particular climate products and models;
5. Informing local, national and regional policy, supporting harmonization of policies impacting on the fishing sector;
6. Responding to calls for funding, identifying opportunities for developing partnerships and collaborative proposals;
7. Offering training on scientific and Indigenous Knowledge (IK) forecasting;
8. Offering weather- and climate-related expertise to the general public and the media; and
9. Supporting sharing of weather and climate information in the EAC.

Criteria for membership

The initiative seeks to establish an inclusive network, bringing together practical, operational, policy and academic expertise related to weather, climate and fishing in the Lake Victoria Basin. Members are invited in a representative, rather than in an individual, capacity. Member institutions will be responsible for identifying and enabling their selected representatives to participate in the network.

Governance

With the aim of supporting regional equity, the network will seek to establish a website with the Lake Victoria Basin Commission (LVBC).

Executive

- Drafting the TOR for the network, seeking members’ feedback and agreement.
- Promoting the establishment of the network.
- Proposing a calendar of activities and membership roles within these.
- Drafting a budget to support network working and activities.

Members

- Actively supporting network activities.
- Ensuring institutional representation.
- Promoting the network within their institutions and wider interactions.

Membership of the Network

Table 16:-Membership of Network for Weather, Climate and Fishing for the Lake Victoria Basin

BMU Heads/Official	*1.* Homa Bay County (Kenya);	Name of BMU *(BMU with the largest number of members in the county)*
	2. Muleba District; (Tanzania)	Name of BMU *(BMU with the largest number of members in the county* BMU KIMOYOMOYO
	3. Kalangala District (Uganda)	Name of BMU *(BMU with the largest number of members in the county)*
Boat Owners	*4.* Homa Bay County (Kenya);	Name of BMU *(Name of Boat Owner with the largest fleet)*
	5. Muleba District; (Tanzania)	Name of BMU *(BMU with the largest number of members in the county* BMU KIMOYOMOYO
	6. Kalangala District (Uganda)	Name of BMU *(BMU with the largest number of members in the county)*
Indigenous Fisherman	*7.* Homa Bay County (Kenya);	Name of BMU *(BMU with the largest number of members in the county)*
	8. Muleba District; (Tanzania)	Name of BMU *(BMU with the largest number of members in the county)*
	9. Kalangala District (Uganda)	Name of BMU *(BMU with the largest number of members in the county)*
Fish Traders	10. Homa Bay County (Kenya);	*(*Name of a person considered by the fishing community to be the most successful local fish trader in the BMU*)*
	11. Muleba District; (Tanzania)	Name of BMU *(BMU with the largest number of members in the county* BMU KIMOYOMOYO
	12. Kalangala District (Uganda)	Name of BMU *(BMU with the largest number of members in the county)* (Kananaasi Fish Landing Site)
Fish Processors	13. Homa Bay County (Kenya);	Name of the dominant fish processing plant in the county.
	14. Muleba District;	Name of the dominant fish processing plant in the

	(Tanzania)	District.
	15. Kalangala District (Uganda)	Name of the dominant fish processing plant in the district
Fisheries Managers	16. Homa Bay County (Kenya);	Director of Fisheries, Homa Bay County
	17. Muleba District; (Tanzania)	District fisheries In-charge Muleba District.
	18. Kalangala District (Uganda)	Director of Fisheries Kalangala District.
Fisheries Researcher	19. Kenya	Director, Kenya Marine and Fisheries Research Institute (KMFRI), Kisumu
	20. Tanzania	Tanzania Fisheries Research Institute (TAFIRI), Mwanza Center
	21. Uganda	National Fisheries Resources Research Institute, Jinja ,Uganda
Meteorologist	22. Homa Bay County (Kenya);	Kenya Meteorological Department (KMD)
	23. Muleba District; (Tanzania)	Tanzania Meteorological Authority (TMA)
	24. Kalangala District (Uganda)	Uganda National Meteorological Authority (UNMA)
Maritime/Transport	25.	Consult with LVBC
Disaster Managers- Coast Guards	26. Homa Bay County (Kenya);	Director, Disaster Management,Homa Bay County
	27. Muleba District; (Tanzania)	
	28. Kalangala District (Uganda)	
GIS Experts	29. Maseno Univesrity Alumi	
Local/ Central Administrations	30. Homa Bay County (Kenya);	Director, Communications (County Information/Liaison officers)
	31. Muleba District; (Tanzania)	District Information/Liaison officer
	32. Kalangala District (Uganda)	District Information/Liaison officer
LVBC	33. Lake Victoria Basin Commission(LVBC)	Principal Resource Mobilization Officer East African Community- Lake Victoria Basin Commission
NEMA Officials	34. Homa Bay County (Kenya)	Director, NEMA Homa Bay County
	35. Muleba District; (Tanzania)	NEMC -Lake Zone Mwanza
	36. Kalangala District (Uganda)	NEMA Rep.Kalangala District-

Public Universities	37. Kenya	Maseno UniversityKenya
	38. Tanzania	Sokoine University of Agriculture, Tanzania
	39. Uganda	Makerere University,Uganda
Media (to be expanded)	40. Media (Uganda)	NECJOGHA
	41. Media (Kenya)	Nam Lolwe FM
	42. Media (Kenya)	Gulf Radio FM, Kosele, Homa Bay County
	43. Media (Kenya)	Ekialo Kiona (EK) FM, Mfangano Island

Organizational Structure

Table 17:-Organisational structure for Network

Name of the network	**Research Network for the Lake Victoria Basin**
Steering Committee	Maseno University Sokoine University Makerere University KMD UNMA TMDa
Terms of Service-Guidelines	Quarterly information sharing/Newsletter by the Executive The newsletter will be electronic and will report on the ✓ Co-production approaches in forecasts ✓ Monitor uptake of forecasts by fishermen Obtain feedback from fishermen ✓ Triangulation of issues in forecasting ✓ Comparative analysis on use of local indicator verses modern impact forecasts.
Calendar/ form of engagement	The Executive committee to set come up with a tentative itinerary for the network
Practical steps - sharing emails, establishing WhatsApp group, website	Setting up 2 WhatsApp groups, one for the Executive committee and one for entire network Email listing for the entire network
Who will host the website	We will request LVBC to host the website The network will link with Students/Alumni of Maseno University to develop the website. All members of the network will submit information quarterly to update the website. Updating the website will be the responsibility of the Executive
Propsals	The network will purpose to look for relevant calls for proposals and respond to them.

Conclusions and Recommendations

Conclusions from the first Pilot

Local indicators

The fishing calendar laid a strong foundation for discussions on scientific forecast and local indicators. While the majority of local indicators identified are localised there are some indicators common across sites. Some are shared across sites but are assessed as having different levels of accuracy between different locations. Weather information, such as sunshine, fog and rainfall, particularly during the day are of great importance to Omena business and this needs to be further considered within the development of forecasts for the fishing folk on Lake Victoria. More focus should be paid to the lead times of the local indicators. In many cases local indicators and impact-based forecasts may not conflict as they may not be available at similar timeframes. This point needs to be highlighted for inclusion in the exercise, as proposed within the original methodology.

Exploring different combinations of IK and science based forecasts

In combining local indicators and scientific impact-based forecasts:

- When local indicators and scientific forecasts align, there is no difficulty. When for example the yandha wind blows and the impact-based forecast is green, both sources of information align for advising that it is good to go fishing. Or when the genya wind blows and the impact-based forecast is red, both sources of information align for advising that fishing conditions are dangerous.

- When local indicators and scientific forecasts do not align, participants prioritised some but not all local indicators perceived as having high levels of accuracy above scientific forecasts. For example, when the impact-based forecast assess that conditions are ok to go fishing/the green flag is flying, but the genya or ogingo winds are blowing – local indicators considered as having high levels of accuracy and indicating dangerous fishing conditions – then participants in all sites were in agreement that the advice should be not to fish. However, where the impact-based forecast is green/good for fishing but the kwasi crows – an indicator considered to be highly accurate and which also indicates dangerous fishing conditions – participants decided in 2 sites (Kuimba and Koguna) that the guidance should be to fish, and in one that fishing should proceed with care (Lwanda Nyamasare).

- When local indicators and scientific forecasts do not align, participants prioritised some of the local indicators that are associated with a good catch. For example, at Lwanda Nyamasare participants agreed that with the Olambo wind and green flag flying it was good to go fishing and with the presence of the amber flag they would go fishing with caution. However, when the impact-based forecasts assess that conditions are bad to go fishing/the red flag is flying, and the Olambo wind was blowing participants considered it good to go fishing. According to the workshop discussion, the amber flag meant the weather can change abruptly at any time, therefore, they would go with caution. However, with the red flag fishers said they would take this warning to be false given that the Olambo is a gentle wind. Participants highlighted that scientific forecasts only have a 70% chance of happening and as the Olambo wind is present the forecast of a red warning is false. Additionally, the Olambo wind is associated with a good catch, therefore fishers said they would take the risk. A similar response can be seen in the case of the Komadihi winds in Kiumba. Here it is clear that while fishers may take both SF and local indicators into consideration when making fishing-related decisions, in some cases, when the SF is contrary to the local observation they will use local indicators to make decisions, even when the SF is indicating it is dangerous to go fishing.

- In some cases, the local indicators can temper, rather than reverse, the impact-based forecasts. In considering cloud formations and lightning in case of an impact-based forecast indicating that conditions are good for fishing, participants in Koguna advised that fishing proceed with care.

Combining local indicators and impact-based forecasts needs to be undertaken at a local level to:

- Identify local indicators
- Engage local assessment of the levels of accuracy of different local indicators
- Enable participatory discussion and agreement on how impact-based forecasts may inform decisions made with local indicators.

However, the methodology employed in this research can be shared with those institutions identified as intermediaries to receive, communicate and support use of impact-based forecasts, for them to lead localisation of impact-based forecasts.

Mapping Information Ecosystem

Results from mapping Information Ecosystems across all three sites indicate that the top three most preferred channels or sharing of forecasts were radio, TV and WhatsApp. However, when looking at the sites separately there are some notable differences, with varying preferences for SMS, BMU and local knowledge as channels for information. When looking at the flow of information it is clear from discussions that the KMD is a key source of information for multiple channels. The BMU is also a key channel of information feeding information from the KMD onto other channels. In Koguna, local knowledge also feeds into the BMU and then on to fishing communities.

Triangulation of research with Key Informant Interviews Step 6

The KIIs enabled research to hear views from a wider range of people, as well as cross-reference findings emerging from the workshop exercises. In many instances KII responses backed up workshop findings. For example, KII responses mirrored workshop data regarding the complex web of sources and channels through which people receive their information and with which national meteorological agencies need to engage if they are to successfully communicate their forecasts. The KIIs have also identified additional information in a number of areas. This has included the different livelihoods that are combined with fishing, as well as the wide-ranging ways in which weather and climate affect specific types of fishing as well as fishing boats, buildings, infrastructure, farms and homes, transport and trade, through both recent flooding and storms.

KII data has highlighted that more than half of interviewees obtain their information from both KMD and local knowledge, and that 90% are receiving information from KMD. 50% of interviewees considered KMD forecasts as the most reliable source of weather information, over 25% others viewed weather information gained through local knowledge as most reliable, while 20% interviewees viewed both KMD and local forecasts as reliable. Participants who viewed weather information from both KMD and local knowledge as reliable suggested that local knowledge was used to confirm scientific forecasts and vice versa. A number of interviewees recognised that neither could be completely accurate. Reasons for lack of trust in KMD forecasts varied including wanting information not included in the forecast, insufficient understanding of the basis on which forecasts are developed and constraints in access. One respondent noted issues with KMD forecasts not being shared by officials.

Reasons for considering KMD forecasts as more reliable varied. While some highlighted that the observational basis to local knowledge meant that lead-times were shorter than for KMD forecasts, another interviewee noted local forecasters produce seasonal rather than the short-term forecasts required for fishing decision-making.

In terms of general use of KMD forecasts amongst the wider community, an eighth of interviewees estimated that 0-25% of their community accessed KMD forecasts, and a further fifth that over 76% accessed KMD forecasts, while 40% estimated that 50-75% accessed KMD forecasts. Most interviewees felt similar proportions of people accessed and used the forecasts, while some felt that there are different levels of use amongst those who receive the forecasts.

Just over half of interviewees suggested lack of understanding as one of the reasons that people do not use KMD impact-based forecasts, in part due to low levels of literacy and lack of understanding regarding the weather icons used in forecasts. Additional reasons included lack of trust, local or activity specificity and easy access to weather information.

There is a need to sharpen a number of questions to focus on the information most vital to this research. Revision may include:

- Reducing the length of the interview. In particular, the supplementary questions associated with question 2 (such as asking about the community size) could be asked to just one or two interviewees (such as BMU members) to provide an overall background for the research.
- In question 3, clarifying the lead time of the different sources of weather information that people use.

Recommendations for KMD to support communication and use of impact-based forecasts particularly highlighted increasing the number of people to whom forecasts are sent and further training on the communication and use of forecasts, particularly amongst the BMU, with which KMD's engagements should be institutionalised.

Conclusion from the second pilot

While most of the findings from the second piloting reinforced findings identified from the initial research, the revised methodology provided a more streamlined and forensic approach. The greater efficiency of the revised methodology is extremely important given the time constraints of those dependent on fishing for engaging in participatory research. Greater precision in the revised methodology clarifies where there is potential for conflict between local indicators and scientific forecasts, and how these sources may be aligned. It remains to be seen whether supporting alignment between the two knowledge sources may enhance uptake of scientific forecasts, and so support the lives and livelihoods of lakeshore populations.

The revised methodology provided more detailed findings on participants' perceptions of the impact of weather on fishing boat safety and fishing potential and the accuracy and lead times of local indicators. Greater detailing of the accuracy and lead times of local indicators enabled more informed consideration of how these can be used alongside scientific forecasts.

The methodology made clear that:

- Neither local indicators nor scientific forecasts are completely certain.
- While most participants considered scientific forecasts as fairly accurate, there remains a call for their greater localization. Here local indicators may be able to inform the localization of scientific forecasts covering a large geographic area.
- When reviewing the respective lead time of each, discussion clarified that the scientific forecast is covering a longer time period than the local indicator.
- Some indicators of fishing conditions are provided by either scientific forecasts or local indicators, but not by both. The areas where sources of information overlap are related to wind speed, wind direction, wave height and visibility.
- Information from local indicators is mostly available with only a short lead time apart from information on currents and temperatures, which some key informant interviewees indicated was available up to a day in advance for an extended period of up to a week. KMD forecasts are available with a lead time of 4 hours for the coming 24 hours.**I**

Recommendations from second pilot

Analysis of findings from the second piloting identifies areas where the methodology could be further strengthened. These include:

- An overall need to clarify key terminologies, including ‘lead time’, ‘stay alert’, as well as the basis for assessing forecasts effectiveness (in terms of their accuracy or as an indication for boat safety or fishing potential).
- Strengthening Step 3 through adding consideration of the accuracy of local indicators alongside that of scientific forecasts, to enable appreciation that both local indicators and scientific forecasts are not completely certain.
- Strengthening Step 3, through sharing the assessed skill of the scientific forecast across lead times and geographic scales. This would facilitate participants in comparing the accuracy of local indicators and scientific forecasts.
- There is a need to clarify the methodology for Step 4 and whether this employs local indicators assessed as being accurate or with varying levels of accuracy. A mixture of the two was employed in the second piloting. If local indicators with varying levels of accuracy are employed to emulate the scientific impact-based forecast, it could be useful to match both the levels of accuracy/probability and impact to the scientific impact-based forecast.

In terms of strengthening the communication of KMD impact-based forecasts, discussions from the workshops and key informant interviewees highlighted the need to:

- Further access to scientific impact-based forecasts: suggestions included providing smart phones to BMUs to ensure access where mobile coverage is limited and/or members are in other locations.
- Extend training on the scientific impact-based forecasts, to strengthen understanding of their content and meaning.
- Include information that can inform other livelihood activities of the lake shore populations. Participants welcomed receiving information that could inform fish drying and trading, as well as farming and poultry keeping.

There is potential to undertake a similar process to consider the implications for fishing decisions of local indicators and scientific forecasts on seasonal timeframes, similar to a Participatory Scenario Planning exercise.

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