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Climate change adaptation and the African fisheries: evidence from the UNFCCC National Communications

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Abstract Climate change can cause significant (un)foreseen changes in the fisheries sector. However, adaptation has the potential to moderate some of the impacts. This paper explores the challenges faced by both freshwater and marine fisheries sector in addressing climate change and teases out intervention measures from 21 African countries. The paper uses document analysis and draws selected analysis parameters from the grounded theory. The data are obtained from the United Nations Framework Convention on Climate Change National Communication reports. Among the key adaptation measures emerging from the analysis are: fish breeding, integrated coastal management, putting in place appropriate policies, water and flood management as well as research and development. The study concludes that adaptation in the African fisheries sector should be prioritised, an aspect that could also apply elsewhere in the world to enhance food security.

Keywords Adaptation · Africa · Climate change · Fisheries · Sustainability · UNFCCC

1 Introduction

Climate change is perceived to have substantial long-term impacts on the fisheries sector (Brander et al. 2015; Hilmi et al. 2013). The changing climate will accelerate the already stressed status of the African coastal areas (IPCC 2007), posing a considerable degree of uncertainty with regard to fish population distribution (Kirby et al. 2009). The African population's dependence on fish protein in diets makes the fisheries sector one of the most important sectors to look after sustainably (Hansen et al. 2015).

Cochrane et al. (2009) reiterate that fisheries are also essential in income generation and nutrition. In addition, the sector provides employment to about 43.5 million around the

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globe with the highest number in Africa. In Senegal, fish provides dietary protein proportion as high as 75% (Ndiaye 2003). The same is evident in Ghana and Sierra Leone where the proportion of dietary protein is about 63% (Be'ne and Heck 2005; Be'ne et al. 2007). In Mauritius, fishing provided about 13% of total employment in 2006 (CSO 2007).

Given the forgone, this paper attempts to answer the following question: What adaptation measures exist in the African fisheries sector in response to the changing climate as reported in the UNFCCC National Communications? The paper comes in five main sections. The first section is made up of the introduction and addresses the problem of the study. The second section focuses on reviewing previous studies on the impacts of climate change and adaptation measures on fisheries. The third part explains the method and materials used in the study with the fourth section presenting data and discussing the main findings. The last section is the conclusion.

2 Literature review

This section reviews relevant literature from previous studies with specific focus on documenting adaptation measures in the fisheries sector. The section comes up in twin subsections: one covering the impacts of climate change on fisheries and the other focusing on emerging adaptation strategies from the literature. This profiling is interfaced with the analysis of data and findings.

2.1 Climate change impacts on fisheries

Climate change impacts on fishery resources are evident in most African lakes and have become common sense in the early 2000s (Marshall 2012). There is sufficient regional and global research pointing out that many (although not all) of these climate change impacts may be negative. According to Lam et al. (2012), the annual landed value of fish for Africa is projected to decline by 21% by 2050 (under an A1B scenario), resulting in a nearly 50% decline in fisheries-related employment and a total annual loss of US$311 million to the region's economy. In addition, some of the highlighted impacts include ocean acidification that can lead to reduced sperm motility (Pratchett et al. 2013), reduced olfactory response and increased fish boldness (Munday et al. 2013), ocean warming as a result of sea temperature increases (Johansen et al. 2014), as well as sea-level rise and habitat degradation (Wen et al. 2016). Allison et al. (2009) carried an analysis of climate change impacts on fisheries for 132 countries and found that two-thirds of the most vulnerable countries were in Africa. Among these countries were Angola, Democratic Republic of Congo, Mauritania and Senegal.

Cinner et al. (2009a) reiterated that climate change may cause both short- and long-term impacts on all coastal ecosystems. However, not all of the effects will modify the biotic and abiotic environment negatively. For example, at moderate to low temperatures, fish species often compensate for metabolic increase demands by increasing food intake (Nowicki et al. 2012; Johansen et al. 2015). Where food is a limiting factor, moderate increase in temperature may render very little effect on individual fish performance. Individual performance of ectotherms can be improved by small increase in temperature (Tewksbury et al. 2008), for which internal body temperatures are generally reflective of ambient temperatures. However, abrupt increases and exposure of fish species to high

temperature often lead to decline in performance and fitness due to increased metabolic demands and inherent limitations in oxygen (Neuheimer et al. 2011). Brander (2007) emphasise that marine ecosystems are under pressure due to ocean acidification and warming as well as climate-induced habitat loss. Such changes are expected to negatively impact on behaviour, biology and ultimately, catchability and availability of fish. Other human-induced activities such as eutrophication and water pollution also come into the picture-making ecological systems more fragile (Hansen et al. 2015).

Lower sea pH levels subsequently change the ion balance of the carbonate–bicarbonate equation (Moy et al. 2009). However, fish can sustain carbon dioxide induced acidosis by the regulation of acid–base relevant ions (primarily bicarbonate and chloride) (Heuer and Grosell 2014). Nevertheless, additional physiological costs due to higher ambient partial pressure of CO_2 (pCO_2) may be imposed and this could affect their performance (Ibid.). These changes may affect the neuroreceptor function in marine fishes (Nilsson et al. 2012) causing abnormal behaviour (Munday et al. 2012) and impaired sensory discrimination (Munday et al. 2009). In addition, such modifications may often lead to early post-settlement and increased mortality of fish larval (Ferrari et al. 2011).

Ocean acidification on fish species results in changed auditory preferences, olfactory and loss of learning ability (Nagelkerken and Munday 2016). Other effects often lead to fish migration which in turn may affect production phases of their life cycle (Rahel and Olden 2008) as well as harvest patterns in communities. However, as temperature increases, other fish species (those produced in freshwater ponds like the Nile tilapia (Oreochromis niloticus) grow faster. To this end, there are positives in that at such high elevations, aquaculture can be made possible. In addition, high rainfall events may also allow fish ponds to be established even in locations where conditions for freshwater aquaculture were marginal.

In the context of small-scale fisheries and aquaculture, artisanal fishers may often encounter challenges exacerbated by the changing climate identified by Cinner et al. (2009b). Such challenges include loss of alternative employment, weak governance, inappropriate incentives and ultimately poverty. However, such challenges are different from the large-scale fishers who have good institutional structures to promote sustainable fisheries, adequate financial support to implement adaptation options and can access insurance and obtain loans to cushion them against climate change and variability. Although small-scale fisheries usually have fewer resources to help them adapt, flexible fishing schemes and diversifying supplies as well as conservative fishing practices are reported as good adaptation options (Bell et al. 2013).

2.2 Resilience and adaptation to climate change in the fishery sector

Resilience is the ability of socio-ecological systems to adapt with, and shape change (Folke 2006). It is desirable to promote a resilient fisheries sector from the impact of climate change to allow the ecology and society to be capable of bouncing back after undesirable shocks. Coastal communities are more vulnerable to the impacts of climate change (Allison et al. 2009). Therefore, improving adaptive capacity of coastal communities is regarded as an essential policy objective in various countries as such communities depend on seafood for their livelihoods.

After the tsunami disaster in 2004, boats in Seychelles utilised trawl nets to make use of new fishing methods and vessel and fishing practice (Decomarmond et al. 2008). Hence, seafood emerging economies are developing end-to-end and ecosystem models of adaptation (South Africa Smith et al. 2014) as in the Mozambique Channel of Madagascar

(Wendland et al. 2010). Projecting fish larval dispersal is made through the use of oceanographic models for some hot spot regions (Roberts and Mullon 2010). This is done through high-resolution global ocean models running to the year 2099 (Popova et al. 2016).

Other new adaptation measures emerging include exploitation of new gears (CMFRI 2014) and the identification of fish species that can resist high temperature like *Silver Pompano* (Shyam et al. 2014a). In addition, adoption and investments in new technologies and innovation are of paramount importance. Such include the integration of climate resilient technologies like *pokkali cum fish* farming and multi-trophic farming (Shyam et al. 2014b).

Weather-based index insurance (WBII) has been piloted as one of the appropriate intervention measures to avoid losses in the agricultural sector like managing droughts in Ethiopia. Through WBII, climate change-related disruptions are avoided by making communities get access to credit and loans timely. While such WBII adaptation measures are being scaled up in the agricultural sector with a view to assist farmers to adapt to the changing climate-induced disasters (Skees et al. 2007), little attention has been given to the fisheries sector. As Secretan et al. (2007) and Van Anrooy et al. (2006) pointed out, other interventions such as safety nets, food aid or cash transfers as means to enhance adaptation of the fisherfolk should be promoted.

Education and training have been identified as essential adaptation measures (Perry and Sumaila 2009) of interest to the fisheries sector too. Education and awareness creation may help fisherfolk to make informed decisions and choices in employing appropriate adaptation measures (Toya and Skidmore 2005). Walker and Salt (2012), Biggs et al. (2012) and Pope et al. (2014) are of the view that improving access to forecasting, early warning systems and climate information can reduce the fisheries sector's vulnerability to the changing climate. Employing the use of traditional ecological knowledge management systems as an adaptation measure proves to be very useful as it imparts additional knowledge and perspectives based on locally developed practices such as fish species management. A typical example in southern India, as Coulthard (2008: 31) highlights, is how households employ local ecological traditional systems in managing fisheries—padu system. Padu is embedded within certain cultural and religious belief and is a way of life in many areas across India.

Allison et al. (2007) argue that diversified livelihood systems increase opportunities for enhanced adaptive capacity to the changing climate. Although not an entirely new adaptation means, diversification leads to various income-generating activities outside fishing and also livelihoods diversification within the fisheries sector (Bruge're et al. 2008). In Malawi, for example, fishing families around Lake Malawi diversify into farming (Russell et al. 2008) to cope with drought. Such activities should be scaled up. Promoting livelihoods diversification in the fisheries sector does not only address climate change impacts, but also support sustainable fisheries management and poverty reduction (Conway et al. 2005). The next section will now focus on the materials and methods used in generating data and analysing the findings.

3 Materials and methods

This paper answers the research question: What adaptation measures exist in the fisheries sector in response to climate change in African countries as emerging from the UNFCCC National Communications documents? This was done through auditing adaptations

measures from 21 African countries based on their National Communications to the UNFCCC. The countries include Botswana, Egypt, Eritrea, Gambia, Ghana, Guinea-Bissau, Kenya, Lesotho, Malawi, Mauritius, Namibia, Nigeria, Rwanda, Sierra Leone, South Africa, Sudan, Swaziland, Seychelles, Uganda, Zambia and Zimbabwe. The countries were purposefully sampled based on twin key criteria: (1) those with the most updated National Communications in the form of either the second or third National Communication report submitted to the UNFCCC and retrievable from this website and (2) English-speaking countries as the authors can only read and understand English. From the preliminary analysis, 23 categories of adaptive measures in the fisheries sector emerged and these were later organised into six thematic areas. Details of the themes and categories in each of the themes are presented in Table 1.

Following Corbin and Strauss (2008) and Rapley (2007), the study employed a nuts-and-bolts methodology to document analysis including drawing some analysis elements from grounded theory. From grounded theory, we came up with in vivo categories leading to themes within the main framework of document analysis. Document analysis entails a systematic method for evaluating and/or reviewing documents, which could be both electronic and in print. Documents were examined and interpreted in order to elicit meaning, gain understanding and develop empirical knowledge (Corbin and Strauss 2008). A thorough procedure of finding, selecting, appraising (making sense of) and synthesising data contained in the submitted national reports documents was employed. The retrieved National Communication reports were subjected to document analysis resulting in the yielding data in the form of excerpts, entire passages or quotations. Such data were then organised into major themes and categories and followed by case examples later explained in detail in the results section specifically through content analysis (Labuschagne 2003).

Document analysis further helped to provide background information as well as insights into adaptation options being implemented or planned for by the selected countries. Theoretical issues were tested against the analysed information to enhance understanding of the data. Through document analysis, words from the National Communication reports were distilled into content-related categories. Words, phrases and other information sharing the same meaning were classified into the same categories (Cavanagh 1997). The objective was to attain a broad description and condensed phenomenon of categories as outcomes of the analysis.

A number of advantages were observed using document analysis; namely, the method is less time-consuming and therefore more efficient than other research methods; method required data selection, instead of data collection (Bowen 2009); method was less costly; and many documents were already in the public domain. This made document analysis an attractive option for qualitative research as the one under consideration (Merriam 1988).

The emerged themes captured the essence of measures and experience drawn from varied country submissions and contexts instituted to make the fisheries sector climate compatible in as far as adaptation is concerned. The retrieved themes were then examined and interpreted to give meaning and draw conclusions through skimming (superficial examination), reading (thorough examination) and interpretation (Fereday and Muir-Cochrane 2006; Strauss and Corbin 1998). Pertinent information was identified and separated from that which is not pertinent (Corbin and Strauss 2008). Results from the document analysed are presented in the next section.

Table 1 Emerging themes and categories of the reviewed adaptation measures. *Source*: Authors

Theme	Categories
Research and development	Promote, strengthen and reorient research and development of fisheries research institutions to take into account climate change Promotion of monitoring, control and surveillance of fishing grounds and fish stocks for sustainable exploitation
Fish breeding	Promoting exploitation of pelagic fishes through breeding Breeding adapted species of fish in lakes, ponds and rivers Enhancing the protection of breeding areas, for example spawning sites and fishing nursery areas Raising salt-tolerant fish breeds
Water and flood management	Dredging of rivers and harbours Protection of water resources and aquatic ecosystems Conservation of water, particularly during droughts through careful use and good agricultural management practices
Integrated coastal management	Promotion of integrated fish farming through the implementation of integrated development plans of watersheds and the use of fish—farming techniques with high yield Restoration of fish stocks where possible Protection of biodiversity Development of private initiative and professionalisation of the fish sector Effective management of fish breeding sites Provision of financial resources and institutional capacity Regulation of technically oriented construction to protect the coast
Technology and policies	Protection of the aquatic areas and wetlands by prohibiting farmers from growing crops within 50 metres from the lake shores and within 10 m from the banks of rivers in order to avoid sedimentation due to crop growing on hill slopes Mainstream climate change considerations into account in the fishery sector planning process Provision of financial resources and institutional capacity Classic measures such as total allowable catch or global quota, fishing effort and gear limitations, and closed seasons to introduce sustainability in yields and resilience in both fishing companies and fish stocks to inter-annual and long-term variations in environmental conditions Adoption of a closed season—when fish is under threat of either over exploration or adverse effects of climate change. This option allows for the restoration of either the degraded habitat or recovering of the fisheries The creation of marine protected areas and marine parks and the introduction of closed seasons for certain fisheries and for commercial fishing to protect and conserve the marine biodiversity Protection of biodiversity through the development of private initiative and professionalisation of the sector fish
Weather-based index insurance	Establishing fisheries disaster insurance scheme

4 Results

The objective of this section is to present and highlight the key findings from the study. The study established a number of adaptation measures drawn from the review exercise of the National Communications comprising six thematic (adaptation) areas. Following careful auditing of the National Communications, it further emerged that 14 of the 21

countries were either implementing or considering to implement the adaptation measures from the thematic areas identified (Table 2), while the remainders were silent.

Although some of the findings from the UNFCCC National Communications reports mirror traditional ways of dealing with fisheries, these have continued to be used and scaled up with the understanding of adaptation in the era of climate change. Further details regarding the findings and discussion are now presented as per the themes in the following subsections.

4.1 Artificial fish breeding

The adaptation measures that emerged under this theme are: promoting exploitation of pelagic fishes; introducing non-indigenous species, climate resilient species of fish in lakes, ponds and rivers; effective protection of spawning sites; and fishing nursery areas and raising salt-tolerant fish species. The sampled African countries are carrying out fish breeding initiatives as a way of adapting to the changing climate. A good example is the breeding programme that the government of Rwanda initiated in 2004. The government introduced adapted species of fish in lakes, ponds and rivers. The adapted fish species are able to withstand sudden changes in temperature ranges of between 10 and 15 °C. This helps to make food available throughout the year under the changing climate (Ministry of Natural Resources 2012). Malawi is spearheading the breeding of adapted fish species through research and scientific innovations. The government is conducting training

Table 2 Summary status regarding the implementation of adaptation measures. *Source*: Authors

Country	Categories					
	Fish breeding	Integrated coastal management	Technology and policies	Water and flood management	Research and development	Weather-based index insurance
Gambia	++	+	++	+	++	
Lesotho	++		+	++	+	
Malawi	++	+	++	++	++	
Mauritius	++	++	++	+	++	
Nigeria	++	+	+	++	++	
Rwanda	++	+	+	+	++	
South Africa	++	++	++	+	++	
Seychelles	++	++	++	+	++	++
Uganda	++		+	++	++	
Zambia	++		++	++	++	
Egypt	++	++		++	+	
Guinea-Bissau	++	+	++	+	+	
Eritrea	++	+	++	++	++	
Sierra Leone	++				++	
Namibia	++	++		+	+	

Key: ++ (implemented); + (in consideration)

programmes for fish to develop heat shock proteins. This is particularly important as the adapted fish species (*Opsaridium microlepis* (Mpasa), Ntchila, *Tilapia rendalli* and the more popular *Oreochromis* spp (Chambo) are heat tolerant and are able to withstand high temperatures. The proteins are induced when temperatures increase by 6 and 12 °C higher than the required (Jobling 1995). Other fish species are also adapted to resist other environmental stressors such as heavy metals, xenobiotics and radiation (Government of Malawi 2011). However, introducing invasive species may have other unintended consequences like changing the habitat chemically or physically as well as indirectly or directly (Wallentinus and Nyberg 2007). In such cases, it is difficult for the native fish species to survive and flourish, especially if invasive species monopolise the area. Invasive species can perturb ecosystem structure and energy flows including the accumulation of waste (Ruesink et al. 2006).

The government of Malawi is also re-stocking vulnerable fish species through hatchery-bred stocks. The practices for fish breeding in captivity are available and government launched in 2005, the Presidential Initiative on Aquaculture (PIA) to provide the necessary impetus for such studies. There was no evidence in the Malawi National Communication report that the PIA has realised its outcomes and community participation in fish breeding is still minimal (Government of Malawi 2011).

The government of Nigeria is addressing threats to sustainable fish production specifically in the Sudano-Sahelian areas with a focus on adopting and breeding hardier and early maturing fish species. The initiative will ensure increased fish production even during harsh weather conditions. The government is supporting breeding programmes of research institutions through funding their relevant fish-based research and development and dissemination of findings (Ministry of Environment 2014). Moreover, other initiatives include the breeding of salt-tolerant fish species in areas around the coast. This adaptation measure is particularly in response to the ongoing rising and expanding sea level, high concentration of salt water of the coastal areas and flood plains. These initiatives are being implemented through partnership between local communities, research institutions and government. Breeding salt-tolerant fish makes it possible for fish to reproduce under the increasingly emerging saline coastal areas to enhance food security and sustainable livelihoods for the affected communities. However, lack of financial resources is hindering the progress on breeding salt-tolerant and high-yielding fish varieties. The government need support in order to fund appropriate studies and disseminate the results to a wider community. For successful implementation, there is need to involve individuals, local communities and research institutes. To be more sustainable, the government is now spearheading community-based management arrangements to ensure the participation of rural communities (who depend on the fisheries for livelihoods) in the management and control of this natural resource. The involvement of local communities ensures sustainability of the fishery sector (Ministry of Environment 2014).

4.2 Integrated coastal management

Adaptation categories that emerged under this theme as contained in the reviewed country reports include promoting integrated fish farming; restoration of fish stocks; the development of private initiative and the professionalisation in the fish sector' effective and productive breeding grounds; and the promotion of technically oriented construction to protect the coast. South Africa is carrying out sound integrated coastal management practices to protect the marine and coastal biodiversity from the changing climate (DEA 2011). Other measures include creating conditions for integrated and coherent management

of multiple ocean uses, so each one does not run in conflict with the other things being done with ocean resources in the same area. The government is employing a suite of tools including marine zoning, marine protected areas (MPAs), permit systems, land-use control, fisheries management and conflict resolution and planning. Most of these tools are either under consideration or implemented, with others at the centre of lively debates regarding their appropriateness and efficacy. These measures and concepts are being introduced progressively as integrated coastal management programmes (Ibid.). However, externally funded projects have generally been the main means of implementation of integrated coastal management. The dependence on external financial and technical assistance creates the potential for unsustainable institutions and policies as projects are terminated and support staff and funding are withdrawn.

In Mauritius, the government is implementing an aquaculture master plan as an adaptation measure. The master plan looks at creating marine protected areas and marine parks and introducing closed seasons mainly for certain fisheries (Government of Mauritius 2010). This helps to protect and conserve the marine biodiversity, making favourable conditions for sustainable fish production. A good example of the initiative spearheaded by the government is the voluntary buy-back scheme. The voluntary buy-back scheme of nets was introduced in 1996 and further reviewed in 2004 to allow the fishery to be sustainable and to rehabilitate the marine ecosystems. Net fishing licence holders were encouraged to surrender their net licence on the basis of an inducement package made up of financial compensation, conversion and training to join other fisheries. The introduction of the Fisheries and Marine Resources Act in 1998 made provision for a reduction in large nets from 33 to 10 and grill nets from 20 to 5. The whole idea is in line with the government policy to promote sustainable management of the fishery resources. In addition, there are certain reserve areas which prohibit the use of fish nets (e.g. nursery grounds for fish). The reserves are located at *Poudre d'Or, Trou d'Eau Dounce, Port Louis, Flacq, Mahebourg* and *Back River*. The fishing nets are not allowed from operation from the first of October to the last day of February with the aim to protect fish during the major spawning season. Moreover, in protecting the small size fishes, the minimum mesh size of large nets is set at nine centimetres and that of gill nets is at 11 centimetres (ibid). Despite these significant interventions, the government is undertaking, the fishery sector suffers coral bleaching, warmer seas and loss of scores of fish species. Such impacts prompted the government to intensify transplantation and coral farming, enhance the sustainable management of coral reef ecosystem, establish monitoring and evaluation systems and strengthen mangrove propagation programmes.

Similarly, Rwanda is promoting integrated fish farming through diversifying fish production with piggery, poultry over fish ponds as source of fertilisation. The integrated system can produce high yields and sustainable fish production. The government is protecting wetlands and aquatic areas including prohibiting farmers to grow their crops within 10 metres from the banks of rivers and 30–50 metres from lake shores. The idea is to avoid harmful chemical reaching lakes that can affect fish production. However, the initiative is still in experimental trials in Rwanda and the implementation is slow due to lack of resources (Ministry of Natural Resources 2012). The main fish species cultured in Rwanda include *Tilapia melanopleura (or T. rendalli) and T. macrochir. Tilapia nilotica and common carp*. The government is developing and implementing watersheds development plans and other high-yielding fish farming techniques such as pond fertilisation (organic or inorganic fertilisers). However, the use of chemical fertilisers is hindered by the increase in its price making it unaffordable by the communities. Other adaptation measures that the

government is carrying out include the restoration of fish stocks and developing private initiative and professionals in the fish sector (Ministry of Natural Resources 2012).

4.3 Technology and policies

Facilitating the diffusion of improved technologies and creating an enabling environment is important for climate change adaptation initiatives in the fisheries sector. South Africa is spearheading a number of policies in fisheries management under climate change. These policies include fish quota rights, sustainable ecosystem management and setting regulations in the fisheries sector such as the total allowable catch or global quota, gear limitations and fishing effort, and closed seasons. In fact, these measures are specifically to enhance the sustainability of the fish resources, fishing companies and livelihoods and associated economies (DEA 2011). The changing climate can modify the fish distribution and yields by causing either a decrease or increase over a long period of time (ibid). In this regard, climate change adaptation is essential to ensure fish production even during periods of varying environmental conditions. The measures are in place to ensure fish yields sustainability and resilient under the changing climate.

Gambia formulated the Fisheries Policy and Strategic Action Plan (2012–2016) to deal with climate change challenges. The policy stipulates principles of sustainable fish production under the changing climate. In addition, the policy supports aquaculture programmes to improve the nutritional status of the local communities. The specific aquaculture programmes include fish production, oyster and shrimp fish farming at community level. The government laid strict control and protection measures to reduce the degradation of the fishery sector. These controls include fishing licensing to be granted to foreign vessels, improving surveillance and placing an embargo on fishing operations during the fish spawning season (Ministry of Fisheries and Water Resources 2012). In addition, the Gambia is improving its technology in conserving fish food and fish products in a way to promote increased supply chain. The measures include installing operations for fish plant processing and preservation. Furthermore, post-harvest technologies are being employed in the country to improve fish conservation and products. The same is being exercised by the government of Guinea-Bissau, where the fisheries sector is considering transfer of technology in fish packaging systems, sophisticated systems of fish conversation including improved technology for the fisheries transformation. Eritrea considers the fisheries as an important sector, and the government is establishing improved technologies in fish preservation and landing, considering value-adding fish processing facilities, and equips the small-scale farmers with improved technology around their communities.

In Malawi, technological advances are being practised to enhance its fishery sector under the changing climate. Unsustainable fishing practices are pushing many fish stocks to the point of collapse through illegal fishing, poor regulatory enforcement in fisheries and pollution. The government is amending the Fisheries Act to come up with a climate change adaptation statement in the Act. The focus is on technologically sustainable practices that conserve ecosystems and sustain livelihoods to ensure food security. For example, the country employed advanced fishing gears that include gill nets, beach seine nets, open-water seine nets, hooks and fish traps (Njaya and Kachilonda 2008). Use of improved technologies to prevent post-harvest fish losses are also being implemented such as screens against insects, improved 'chorkor' smoking kilns and mesh trays to elevate the fish off the ground can reduce these losses significantly, resulting in greater food security for consumers and increased incomes for processors and traders (Sumaila and Alder 2001).

The Egypt government approved new regulations to include integrated coastal zone management (ICZM) into developmental plans needed for better management of coastal resources and protection against impacts of climate change. The idea was the need to formulate a strong institutional monitoring capability. However, adaptation options are site dependent and often involve multi-criterial analysis to assess levels of technology, impact assessment, cost and maintenance (El Raey et al. 2000). In realising integrated coastal management, the government is considering the following adaptation options at the local level El Shennawy (2008), developing wetlands in sites that are susceptible to climate change impacts as a result of sea-level rise in low-lying areas. In this regard, Lake Burullus and Lake Manzala are two examples of such areas for such adaptation option systems: advancement in fixing and protection of natural sand dunes systems which are essential in natural protection; Mohamed Ali Wall is being considered by the Shore Protection Authority as first line of defence of protection and enforcement the low lands south of Abu-Qir Bay, strengthening the international road that act as a second line of defence for the protection of the northern zone of the Delta along the Mediterranean coast. In this regard, the northern side of the road is being reinforced as a sea wall through the use of Al-Salam Canal banks. In addition, the government is establishing the National Coastal Zone Management Committee to develop an integrated coastal zone management plan.

The Malawi government established Lake Malawi National Park in 1982. The idea is to consider up to 10% of the lake under protection, supported by best practices and scientific evidence from other recent international studies (Sumaila and Alder 2001). Although such adaptation-related practices have been implemented elsewhere around the world outside climate change, with the fisheries sector benefiting from those restoration programmes, scaling up will be needed under climate change. Malawi is further considering such programmes. Namibia through the prevalence of Benguela current has one of the most productive fishing grounds. The government is promoting its aquaculture and fisheries through sustainable development of fisheries and aquaculture (marine and freshwater aquaculture), utilisation and development of the coastal zone and its resources.

4.4 Water and flood management

Adaptation categories that emerged under this theme include dredging of rivers and harbours, protection of water resources and aquatic ecosystems, and water conservation during droughts. The government of Uganda is promoting water conservation during drought periods through regulated water harvesting techniques and sustainable agricultural practices. Rain water is being harvested to form reservoirs for storing water for use in fish production (Ministry of Water and Environment 2012). Nigeria supports the expansion of small-scale water harvesting practices for the fishery sector in the dry areas. It built water harvesting infrastructure for watering in the Sudano-Sahelian areas known for its long dry seasons (Ministry of Environment 2014). In Lesotho, the government is undertaking improved water resources management through harvesting and storage of water in containers attached to houses as well as surface artificial dams for breeding resilient fish species (Ministry of Energy, Meteorology and Water Affairs 2013). Improved water supply enables fish production during dry periods and thus promoted all year-round household food security. The protection of water resources and aquatic ecosystems remains one of the traditional adaptation measures across the continent as this feature prominently in countries is prone to prolonged droughts.

4.5 Research and development

The key adaptation measures that emerged under this theme are: promoting, strengthening and reorienting research development in the fisheries. This includes the development of efficient monitoring, control and surveillance of fishing grounds and fish stocks through research. In South Africa, best adaptation approaches in the fishery sector lies in planning and research-based activities. DEA (2011) highlighted studies carried out in the country in promoting fish production under the changing climate. Studies by Midgley and Thuiller (2005), Theron (2007) and Theron and Rossouw (2008) suggest that South Africa need best approaches in research such as programmes utilising satellite mapping of favourable fish living conditions. The aim of the earth observation is also to verify, ascertain and map out the climate change impacts on fisheries. The government is developing geographical information systems (GIS) that identify fish hot spots vulnerable to climate change, determine coastal erosion and drawing up shoreline management plans. Siera Leone government is promoting research development in fishing nursery and spawning sites. The idea is to control, monitor and surveillance of fishing grounds and fish stocks for sustainable exploitation. Through research, educational awareness and related education programmes are being considered at national level and downscaled into local levels.

Uganda is taking climate change considerations into the fishery sector through strengthening the research capacity of the Department of Meteorological Services to enable it to provide timely and accurate weather and climate information to support adaptation to impacts of the changing climate (Ministry of Water and Environment 2012). Scientific evidence-based programmes on fisheries are dealing with: formulation of fish feed (dry and live feed); setting up fish pathology laboratory to monitor fish health; breeding hybrid (*Tilapia and monosex culture, catfish and Tilapia)*, production of seed; integrated fish farming, aquaculture socio-economic research programmes; and research on newly adapted fish species. The government developed a programme with the aim of rehabilitating infrastructure of the Kajjansi Aquaculture Research Station. In a bid to enhance the research, the government established fish pathology and biochemistry laboratory to be used at the station. A model hatchery was constructed for induced breeding of giant African catfish. The establishment and expansion of the research activities at the Kajjansi Aquaculture led to the design of fish pond adopting modern aquaculture construction. Sustainable on-farm modern demonstrations are being carried out at the research station for improved fish production. These fishing practices include developing fishing ponds, selection of seed, fish stocking, sustainable pond preparation, management and harvesting (ibid).

Zambia is enhancing its research on sustainable fish management and production. The government is promoting community participation in fisheries management. Research programmes undertaken in Zambia provide (1) technical advice to small-scale fisheries to choose ideal ponds and their construction, seed selection and stocking optimum fish stocking densities, use of both organic and inorganic chemicals to fertilise fish ponds and monitoring fish health; (2) promote small-scale and large-scale fisheries providing training and credit facilities; (3) providing loans to fish feed producers; and (4) rehabilitating demonstration and fish production centres. The production centres are promoted in order to produce brood stock and fish fry for re-stocking purposes. In Zambia, research and modelling programmes are carried out to show the relationship between rainfall and fish catch. The programmes are carried out in areas, namely *Kafue flood plain fishery, Lukanga, Kariba, Upper Zambezi, Mweru-wa-ntipa, Itezhi Tezhi, Tanganyika, Bangweulu, Mweru-Luapula and Lake Lushi-washi*. The results show a strong relationship total agreement on droughts and fish catches. In

the period of droughts, fish catches are reduced quite considerably as compared to wet periods (Ministry of Lands Natural Resources and Environmental Protection 2014).

4.6 Weather-based index insurance

The government of Seychelles established the Seychelles Agriculture and Fisheries Insurance Fund (SAFIF) involving the fisheries sector. The main aim of the fund is to provide insurance protection to fisherman against climate change-related disasters. Following the December national tsunami disaster in 2004, the government spearheaded research into private sector insurance solutions for the agriculture and fisheries sector. A task team was created to establish the risks and benefits of an insurance scheme to the fisheries sector. Following 2 years of progressive consultations by the task force, a working paper with the findings was produced and proposed the establishment of an Agriculture and Fisheries Insurance Scheme for the Seychelles. This weather-based index insurance (WBII) scheme was facilitated by the government through the public–private partnership arrangement. This initiative yielded the formation of the private insurance sector (State Assurance Company of Seychelles Ltd and Harry Savy Insurance Company Ltd). The Seychelles Farmers Association, the Seychelles Fishing Authority and the Seychelles Boat Owner Association are actively involved in the Disaster Insurance Scheme for Agriculture and Fisheries.

The insurance scheme support small-scale fishing community by providing inputs (fish feed) on credit against a well-defined shock, technical support and marketing. Moreover, the livelihoods, assets and properties and their health are cushioned against the devastating losses. The WBII is helping the fishing community to be able to withstand catastrophic and other risks such as cyclones, droughts, diseases and floods that can affect sustainable fish production. The WBII provides fisheries with timeously access to funds during the occurrence of an insured climate-related disaster to regain their livelihoods. In addition, WBII plays an essential role in protecting local coastal communities from catastrophes, thereby enabling them to venture into riskier initiatives, but equally profitable and sustainable fish farming practices. The importance of focused-index insurance is realised when it opens avenues for lucrative fish business markets, highly adaptable and contextual modern inputs and technologies, updated information related to agriculture, credit facilities and other financial services (Government of Seychelles 2012).

The government of Seychelles is promoting compulsory insurance to all licensed and registered fishing vessel owners as defined in their Agriculture and Fisheries Incentive Act (2005). The insurance covers loss or damage caused to fishing vessels, Group Personal Accident insurance for all fishermen or crew working on the vessels and third-party liability arising out of loss or damage caused by insured vessels against another party. Due to the compulsory participation of the fishery sector in the insurance scheme, the government subsidised the premium rates. In this regard, it is suggested that Seychelles' Government provide a premium subsidy of 50% plus allowing exemption from payment of GST and Trades Tax on SAFIF insurance premiums. The subsidy will outweigh any possible resistance by the fishing industry to the insurance scheme.

5 Conclusion

This study reviewed adaptation measures contained in the UNFCCC's National Communications from 21 selected African countries of which 10 explicitly indicated adaptation measures under the themes that emerged. The results indicate that there are a number of

adaptation measures instituted by such countries in the fishery sector to make it resilient to the changing climate. Key adaptation themes that emerged are: research and development, fish breeding, water and flood management, integrated coastal management, adaptation policy development and weather-based index insurance schemes.

From the analysis, it emerged that some countries are implementing adaptation options, whereas others are still considering implementing adaptation measures. The themes that have received closet implementation include research and development, fish breeding as well as water and flood management. Artificial fish breeding is being implemented by Malawi and Rwanda through the promotion of exploiting pelagic fishes. Nigeria is considering implementing fish breeding initiatives through adopting and breeding hardier and early maturing fish species. The government is also supporting breeding programmes of research institutions through funding their relevant fish-based research and development and dissemination of findings.

Integrated coastal management is being implemented in Mauritius, South Africa and Seychelles. This is not surprising given the extent of the coastlines for these countries. The countries are employing a suite of tools including marine zoning, marine protected areas (MPAs), permit systems, land-use control, fisheries management and conflict resolution and planning. These measures and concepts are being introduced progressively as integrated coastal management programmes. However, externally funded projects in South Africa have generally been the main means of implementing integrated coastal management. Rwanda and Malawi are still in the phase of considering integrated coastal management through diversifying fish production with piggery, poultry over fish ponds as source of fertilisation and establishing parks and protected areas as a common practice. Technology and policies adaptation options are implemented in Gambia and South Africa. A number of policies in fisheries have been developed to ensure sustainable coastal management under climate change and setting regulations in the fisheries sector such as the total allowable catch or global quota, gear limitations and fishing effort, and closed seasons. In Malawi, technological advances are being practised to enhance its fishery sector under the changing climate.

Although there is a wide spread of implementing improved water and flood management that include the protection of water resources and aquatic ecosystems, and water conservation during droughts, Lesotho, Malawi, Nigeria, Uganda and Zambia have done well. Nigeria is considering the expansion of small-scale water harvesting practices for the fishery sector in the dry areas such as the Sudano-Sahelian areas. Furthermore, research and development programmes such as development of efficient monitoring, control and surveillance of fishing grounds and fish stocks are integral elements of many adaptation interventions in the countries sampled. South Africa is considering research programmes that include utilising satellite mapping of favourable fish living conditions developing geographical information systems that identify fish hot spots vulnerable to climate change, determine coastal erosion and drawing up shoreline management plans. Weather-based index insurance schemes are implemented in Seychelles. The schemes provide insurance protection to fisherman against climate change-related disasters. The insurance supports small-scale fishing community by providing inputs (fish feed) on credit against a well-defined shock, technical support and marketing.

Overall, countries implementing the identified adaptation options reported various benefits from the implementation of such measures. These benefits include increased food production even during dry periods, improved nutritional status among the local population, all year-round household food security, improved human health, and sustainable water resources management, low input costs, increased profit margins, reduced coastal

and marine degradation, improved capacity of fisheries, diversified livelihoods options, improved marketing and export opportunities. Some of the outstanding adaptation programmes implemented include the Seychelles Disaster Insurance Scheme for Agriculture and Fisheries, and the Gambia's Fisheries Policy and Strategic Action Plan (2012–2016). However, countries also reported challenges that can hinder or slow down the adoption of adaptation measures such as financial constraints, unfavourable policies, limited knowledge, and slow diffusion of technology and innovation, limited diversified protein sources, costly fishery feeds, non- and limited scientific information on aquatic resources, and human perceptions.

The study shows that adaptation should be part of the bigger and ongoing climate change agenda in the fishery sector. Effective stakeholder engagement should be exercised that involves decision and policy makers, researchers, private sectors, relevant stakeholders and government officials and scientist in ensuring that adaptation measures reach farmers and fishing artisans at grassroots level. In addition, governments should create an enabling political and policy environment in order to boost opportunities for sustainable adaptation to climate change.

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