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CASE STUDY

Fishers' perceptions of climate change, impacts on their livelihoods and adaptation strategies in environmental change hotspots: a case of Lake Wamala, Uganda

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Abstract Fisheries resources support livelihoods of fishing communities but are threatened by over-exploitation, habitat degradation, pollution, invasive species and climate change. Unlike the other threats, climate change has received limited consideration and reducing its risks requires appropriate adaptation strategies. This study used quantitative and qualitative methods to generate knowledge on fishers' perceptions of climate change, changes in climate variables and their impacts on livelihoods, adaptation strategies, constraints to adaptation and required interventions to promote adaptation strategies that would enable fishers to build resilience to sustain their livelihoods. We found that fishers were aware of changes in climate conditions manifested by unpredictable seasons, floods and droughts. Fishing remained the main livelihood activity. However, the dominance of fishes had changed from Nile tilapia (*Oreochromis niloticus* L.) to the African catfish (*Clarias gariepinus* Burchell). Floods and droughts were associated with damage to gears, boats, landing sites and changes in fish catches and sizes, income from fishing and fish consumption. The fishers adapted by increasing time on fishing grounds and changing target species and fishing gear among other things. Some innovative fishers diversified to high-value crops and livestock. This increased their income beyond what was solely earned from fishing which provided an incentive for some of them to quit fishing. Livelihood diversification was enhanced by use of communications technology, membership of social groups, increasing fishing days and fishing experience. Adaptation was, however, constrained by limited credit, awareness and access to land, which require interventions such as improving access to credit, irrigation facilities, appropriate planting materials and awareness raising. We identified adaptation strategies, which if promoted and their constraints addressed, could increase resilience of fishers to the influence of climate change and sustain their livelihoods.

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1 Introduction

Fish contributes about 15 % of average animal protein intake for 4.3 billion people worldwide (FAO 2014). In Uganda, it contributes 12.5 % to agricultural GDP, 2.5 % to national GDP, employs about 1.2 million people, generates >US$150 million in export earnings and provides animal protein for >50 % of the population (MAAIF 2012). However, fish stocks are threatened by over-exploitation, habitat degradation, pollution, invasive species and climate change. Despite this, climate change, which has intensified since the 1970s (IPCC 2013), has received limited attention in Uganda and elsewhere.

Changes in water temperature influence productivity of aquatic ecosystems and fish yield (Behrenfeld et al. 2006; Cheung et al. 2009), ultimately impacting on livelihoods of fishers. Average global combined land and ocean surface temperature increased by 0.62 °C above the twentieth century average by the end of 2013 (NOAA 2013). Impacts of climate change on livelihoods are manifested in livelihood assets, activities and outcomes (Jallow et al. 1999; Balgis et al. 2005; Elasha et al. 2005). Evidence of impacts on livelihoods of fishers by climatic events, similar to those expected to intensify due to global warming, has accumulated. For example, the number of fish species in Lake Chad decreased from 40 to 15 between 1971 and 1977 following a drought (Leveque 1995). Fish yield in Lake Chilwa decreased to zero in 1996 following desiccation of the lake (Allison et al. 2007; Njaya et al. 2011). The yield of *Limnothrissa miodon* Boulenger in Lake Kariba decreased at an average of 24 metric tons per year between 1974 and 2003, associated with changes in rainfall and water levels (Ndebele-Murisa et al. 2011). In Uganda, the contribution of a less economically valuable small fish species, *Rastrineobola argentea* Pellegrin in lakes Victoria and Kyoga and that of *Neobola bredoi* Poll and *Brycinus nurse* Ruppel in Lake Albert have increased to 40–80 % of the commercial catches (Ogutu-Ohwayo et al. 2013). This is in line with the FAO (2010) prediction that climate change will shift fisheries to small fast-growing, opportunistic species. Floods, droughts, tsunamis and hurricanes associated with changes in climate variables are reported to have damaged landing sites, boats and gear, disrupted fishing activities and displaced lakeside communities leading to economic losses and loss of lives (Aiken et al. 1992; Broad et al. 1999; Jallow et al. 1999; Westlund et al. 2007; Birkmann and Fernando 2008; Trotman et al. 2009; Ogutu-Ohwayo et al. 2013).

Available literature shows that fishers have adapted to the impacts of climate change in various ways to sustain their livelihoods. On Lake Chilwa, some fishers diversified to farming and pastoralism, while others migrated in response to the decrease in fish catches (Allison et al. 2007; Njaya et al. 2011). On lakes Victoria, Kyoga and Albert, fishers shifted from gillnets to mosquito seine nets with increases in catches of the small fish species (Ogutu-Ohwayo et al. 2013). However, adaptations are location specific and influenced by local conditions, and local specific knowledge is required to guide planned adaptation to build resilience and sustain livelihoods of affected communities.

This study was intended to generate such knowledge for fisher communities around Lake Wamala, a designated environmental change hotspot that has experienced changes in water levels and fish yield associated with changes in climate variables (Goulden 2006; UNEP 2009). We examined fishers' perceptions to changes in climate, changes in climate variables, impacts of the changes on livelihoods and adaptation strategies, constraints to adaptation and the possible required interventions to reduce constraints to adaptation around the lake.

2 Materials and methods

2.1 Study area

The study was conducted around Lake Wamala in central Uganda (Fig. 1). The lake is one of the six most important sources of fish in Uganda, supporting livelihoods of about 785 fisher households in about 25 landing sites. It is designated as a major environmental change hotspot in Africa due to human-induced environmental changes including climate change (UNEP 2009). The lake area shrunk to about half between 1984 and 1995, increased between 1995 and 2008 but had not fully recovered to its original size with water gauges previously under water remaining on land by 2014. The mean depth of the lake decreased from 4.5 to 1.5 m between 1977 and 1995, increased to 4.5 m after the El Niño of 1997/1998 and dropped to 3.5 m in 2005. The mean depth increased to only 3.8 m in 2013 and 2014, an indicator that the lake had not regained its original mean depth of 4.5 m (UNEP 2009; Natugonza 2015).

The fishery of Lake Wamala includes the African catfish (*Clarias gariepinus* Burchell), the lungfish (*Protopterus aethiopicus* Heckel) and Nile tilapia (*Oreochromis niloticus* L.). Annual fish yield increased from about 1000 tons annually in 1960 to a peak of 7100 tons in 1967, dropped to 500 tons in 1982 (Okaronon 1993), increased to about 4500 tons in 2000 and dropped again to 1200 tons by 2013. These changes have been associated with changes in rainfall and lake depth (NaFIRRI unpublished catch statistics). The contribution

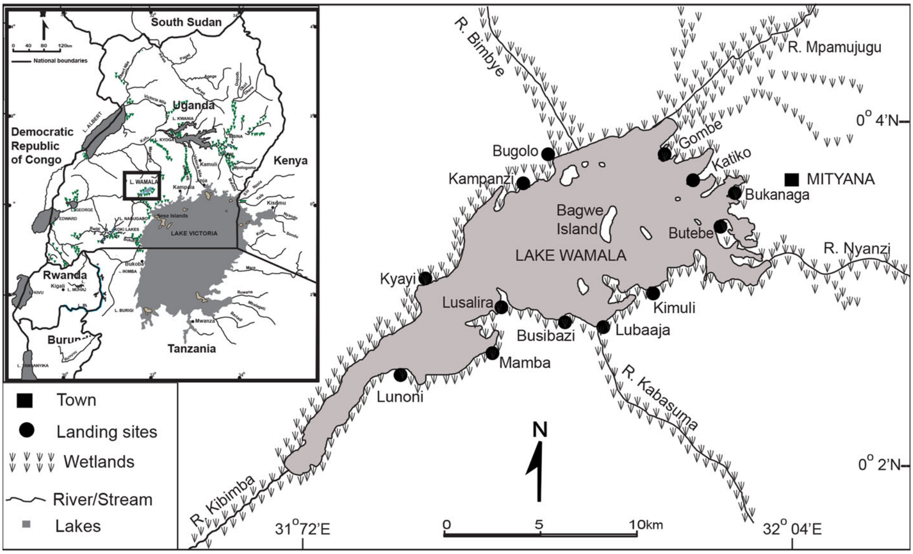

Fig. 1 Location of Lake Wamala indicating landing sites (including studied sites) with inset location map of Uganda

of individual fish species to fish yield has changed with climate variables. The contribution of the Nile tilapia increased from <10 % in 1960 to 78 % by 1975 following the El Niño rains of 1961, then decreased to 57 % by 1989 following a drop in rainfall from 1600 to 900 mm and a drop in depth from 4.5 to 1.5 m (Natugonza et al. 2015). It increased again to 90 % by 1999 following El Niño rains of 1997/98 but dropped to 20 % by 2012. Experimental catches indicated that Nile tilapia contributed <1 % to fish catches by 2013 (NaFIRRI unpublished catch statistics). Meanwhile, the contribution of the African catfish increased from about 5 % in 1975 to 20 % in the 1990s and was 85 % by 2013 (NaFIRRI 2003 unpublished fishery assessment report; NaFIRRI unpublished catch statistics). These changes in fish yield and contribution of fishes to catches associated with rainfall and lake depth have affected fishers and other human riparian communities, making it necessary for them to adapt to sustain their livelihoods.

2.2 Data collection

Annual temperature (maximum and minimum means) and total rainfall data for the years 1980–2012 for Mubende station near Lake Wamala were obtained from Uganda National Meteorological Authority and used to examine changes in climate variables. A household survey was conducted using a semi-structured questionnaire administered to 54 fisher household heads, randomly selected from five landing sites, namely Katiko, Butebi, Gombe, Lubaaja and Lusalira (Fig. 1). The survey was conducted in 2013 during the implementation of a climate change project around Lake Wamala (http://www.firi.go.ug/climate_change/index.php). The landing sites were selected at random from those in the project intervention area. The selected landing sites were estimated to cover 155 fishing households, and therefore, the selected households (54) represented 35 % of the fishing households on the landing sites. The data collected included: fishers' perceptions of climate events and their occurrence; demographic characteristics; fishery-related livelihood activities; climate impacts on livelihoods such as the influence of floods and droughts on target fish species, fishing gear, boats, landing sites, income from fishing and fish consumption; adaptation strategies including data on diversification to crops and livestock; fishers' perceived constraints to adaptation; and the interventions required to enhance adaptation. The fishers' perception of climate change was assessed by asking fishers if they were aware of changes in climatic conditions and events that are known to have increased or will increase with increasing climate change, namely changes in timing of seasons and in flood and drought events. A total of 15 key informant interviews were carried out with fishers or former fishers (innovators)[1] who improved their income and food security through a variety of non-fishery livelihoods (innovations). The interviews identified the innovations and their benefits from which other fishers and lakeside communities could learn. Written consent could not be obtained from the fishers due to low literacy levels, but verbal consent was obtained from participants before conducting the household surveys and key informant interviews.

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[1] In this study, innovators refer to fishers or former fishers who had diversified to growing crops and rearing livestock, consequently improving their income and food security beyond what they earned from fishing alone. The innovators were identified through consultations with local leaders. The crops and livestock they had acquired are referred to as their innovations.

2.3 Data analysis

A Mann–Kendall test (Mann 1945; Kendall 1975) was used to ascertain trends or patterns in the climate variables. Rainfall and temperature anomalies were determined to analyze the match between fishers' perceptions and climatic trends, as departures from 1981 to 2010 average, the most recent 30 year period for calculating climate normals (Fathauer 2011). Data from the household survey were analyzed using descriptive statistics (relative proportions and mean), while some qualitative information from the key informant interviews is provided in the form of key respondents' experiences. Diversification among the fishers to crop and livestock was examined using a diversification indicator (Kristjanson et al. 2011; p. 4), which is a measure of the different types of crop and livestock products produced by the fishers. The indicator is created by adding up the total number of the different crops or livestock produced, where 0 products = no production diversification; 1–4 products = low production diversification; 5–8 products = intermediate production diversification; and more than 8 products = high production diversification. The diversification indicator was individually created for crops and livestock, and then, an overall diversification indicator was created for crops and livestock combined.

A logistic regression model was used to examine the influence of some of the fishers' demographic characteristics as predictor variables on diversification to non-fishery livelihood activities. A dummy dependent variable, probability of the fishers to diversify (DV), was created and took the value of one if a household diversified and zero if not. The model between DV and the demographic characteristics was as follows:

$$\mathrm{DV} = \beta_0 + \beta_1 + \beta_2 + \cdots + \beta_n + \mu$$

where β_0 is the intercept; β_1, β_2,… are coefficients associated with each of the following demographic characteristics: age (continuous, 20–71 years)—the age of the household head; education (0 = No, 1 = Yes)—whether household head had some level of formal education or not; fishing experience (continuous, 2–51 years)—number of years household head had spent fishing; technology (0 = No, 1 = Yes)—whether the household head used technologies such as mobile phone and radio or not; social groups (0 = No, 1 = Yes)—whether the household head belonged to any social group(s) or not; timing of seasons (0 = No, 1 = Yes)—whether the household head had knowledge of when seasons occur; and fishing days (continuous, 0–7 days)—weekly number of days a household head fished in dry or wet seasons; μ is the error term; and β_n indicates that there can be multiple (n) demographic characteristics.

3 Results

3.1 Fishers' perceptions of climate change and changes in climate variables

All fishers interviewed were aware of variations in climatic conditions. Most fishers (70.4 %) reported that the timing of the wet and dry seasons had become less predictable. Most fishers (68.5 %) reported decreased drought, while a lower proportion (48.1 %) reported decreased floods. A higher proportion of fishers (61.1 %) were aware of a year when drought occurred than that of fishers who were aware of a year when a flood occurred (57.4 %). Of those who reported droughts, 92.6 % reported major droughts in 1994 and 1995 and 87.0 % of those who reported floods, stated that they had occurred in 1997/1998 and 2011/2012.

The perception of decreased droughts reported by the fishers was confirmed by the analysis of rainfall data that showed increased rainfall by 9.65 mm annually since 1980 and predominantly above-average rainfall anomalies since 1988 (Fig. 2). Fishers' perception that the years 1997/1998 and 2011/2012 experienced floods was supported by the observed above-average rainfall in those years (Fig. 2). The years 1994 and 1995, which according to the fishers experienced droughts, had below-average rainfall and slightly above-average rainfall, respectively (Fig. 2). Generally, rainfall around Lake Wamala exhibited a significant increase since 1980 ($p < 0.001$) and the anomalies (Fig. 2) demonstrated above-average rainfall for 18 years and below-average rainfall for the remaining 15 years. Analysis of the temperature data showed that mean maximum temperature (Fig. 3a) and mean minimum temperature (Fig. 3b) around the lake had increased by 0.01 °C per year and 0.02 °C per year, respectively, since 1980. However, only the trend for the mean minimum temperature was significant ($p = 0.02$). For the mean maximum temperature (Fig. 3a), the anomalies showed erratic maximum temperature from 1980 to 2000 and predominantly above-average maximum temperature since 2001. For the mean minimum temperature (Fig. 3b), the anomalies highlight erratic temperatures from 1980 to 2008, after which minimum temperatures around the lake were mainly above-average suggesting a warming trend.

3.2 Fishery livelihoods

Fishing was the main fishery livelihood during the wet (78.7 %) and dry (81.4 %) seasons. Other fishery activities included fish trading, renting gear and renting boats, which constituted 14.8, 3.3 and 3.3 %, respectively, in the wet season and 11.9, 3.4 and 3.4 % in the dry season. The African catfish was the main target species (38.6 %) followed by lungfish (33.9) and Nile tilapia (27.4 %), with the African catfish contributing the most to daily catches during the wet seasons (52.0 %) compared to the dry seasons (38.0 %). On average, fishing was conducted for 5 and 3 days per week during the wet and dry seasons, respectively. Most fishers (58.1 %) reported increased catches of the African catfish and decreased catches for the Nile tilapia (52.1 %). Fishing gear used by the fishers comprised of gillnets (51.9 %) and hooks (48.1 %). The mesh sizes of gillnets ranged from 38.1 to 127.0 mm with 101.6 mm mesh size being the most dominant (86.2 %). Hook sizes ranged from numbers 4 to 14 (the higher the number, the smaller the hook and vice versa), but were dominated by numbers 7 (31.4 %) and 10 (31.3 %). Large proportions of the gillnets (93.2 %) and hooks (44.4 %) used on the lake were of illegal[2] sizes.

3.3 Impacts of climate events (floods and droughts) on livelihoods

Droughts were mainly associated with reduced fish catches and sizes, damaged boats and loss of lives, while floods were mainly associated with increased fish size, loss of gear, increased fish catches, damaged gear and landing sites (Table 1). Reduced fishing days, number of traders and effort were only associated with floods. The African catfish was reported to dominate catches during floods (71.2 %), followed by Nile tilapia (17.3 %) and lungfish (11.5 %). Nile tilapia dominated the catches during drought (40.0 %) followed by African catfish (32.0 %) and lungfish (28.0 %). A higher proportion of fishers reported

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[2] Illegal gillnets were those with mesh sizes below the minimum mesh size (114.3 mm) currently recommended on small lakes such as Lake Wamala in Uganda. Illegal hooks were those with numbers smaller than the minimum (number 9) currently recommended on small lakes in Uganda.

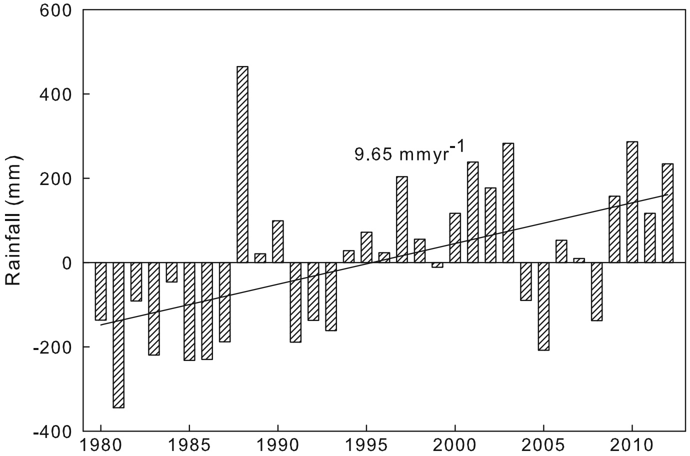

Fig. 2 Time series annual rainfall anomalies (mm) on Lake Wamala, Uganda with respect to the 1981–2010 average

decreased income from fishing during floods compared to droughts (Fig. 4a, b) and a higher proportion reported increased income during droughts compared to floods (Fig. 4a, b). Almost equal proportions of fishers either did not know or did not respond to how their income was affected by floods and droughts. Income from fishing was higher during droughts, ranging from US$10 to US$14 per week, compared to US$6–8 during the floods. A higher proportion of fishers reported increased fish consumption during floods compared to droughts (Fig. 4c, d) and a higher proportion reported decreased consumption during droughts compared to floods (Fig. 4c, d). Fish consumption was higher (1–4 kg per week) during the floods than during drought (1–2 kg per week).

3.4 Adaptation strategies

The adaptations to the influence of climate change that the fishers reported, in order of importance, were mainly diversification to non-fishery activities, increasing time on fishing grounds and changing fishing grounds and target species (Table 2). The non-fishery activities that the fishers diversified to were, in order of importance, crop (45.5 %) and livestock (36.4 %) agriculture, retail trading (11.1 %)—mainly dealing in agricultural products, and informal employment (3.0 %), with 4.0 % carrying out none of these activities. The crops that the fishers diversified to were mainly sweet potatoes, cassava, maize and beans and the livestock were mainly pigs and chickens. The diversification indicators (Table 3) showed most of the fishers with low and intermediate diversification to crops and low diversification to livestock. Overall, most of the fishers had intermediate and low diversification (Table 3). Crop and livestock agriculture were reportedly also influenced by climate variability and change to which the fishers had to adapt. The adaptation measures related to crops included changing planting dates and cultivating early maturing crops while those related to livestock included grazing near lake shores and collecting fodder (Table 4).

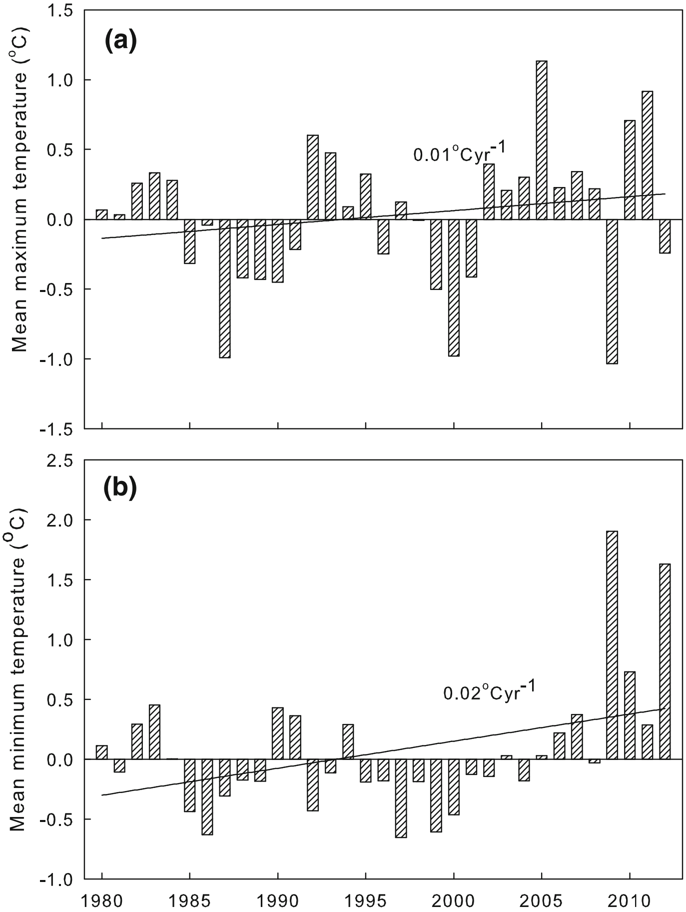

Fig. 3 Time series annual mean maximum (**a**) and mean minimum (**b**) temperature anomalies (°C) on Lake Wamala, Uganda with respect to the 1981–2010 average

3.5 Innovations

Innovators were fishers or former fishers who diversified to high-value crops and livestock to increase income, food security and employment. These grew crops like tomatoes, cabbages, pepper, oranges, pineapples and bitter berries which fetched more income compared to other crops. These were sometimes inter-planted with other crops like bananas or grown under irrigation during dry season and drought. The livestock including cattle, goats, pigs and chickens that were reared also provided manure for the crops. The annual income from the innovations was estimated at US$3400 compared to US$1400 from fishing alone. This increased income acted as an incentive for some of the fishers to quit fishing, probably reducing pressure on the lake. A fisher stated that:

> He liked fishing and had benefited from it by buying land. However, he acknowledged that it could not help him in future to educate his children and decided to invest money from fishing into buying cows and chickens and growing oranges. He

Table 1 Relative proportions (%) of respondents reporting different impacts of climate change (floods and droughts) on livelihoods on Lake Wamala, Uganda

Impact	Floods	Droughts
Reduced fish catches	5.8	23.2
Reduced fish size	0.9	12.0
Damaged to boats	4.9	11.3
Loss of lives	11.2	13.4
Loss of gear	13.9	9.9
Damaged gear	13.0	9.9
Increased fish size	16.6	9.2
Increased fish catches	13.0	6.3
Damaged landing sites	11.7	4.9
Reduced fishing days	8.1	–
Reduced number of traders	0.5	–
Reduced effort	0.5	–

> used manure from the cows and chickens to improve soil fertility. He stated that income from fishing alone was not enough but when combined with income from oranges, milk and eggs, he was able to send his children to good schools.

A former fisher stated that:

> He has lived most of his life as a fisherman, but the income from fishing was hard to get as fishing was associated with many problems like reduction in fish catches making fishing less rewarding than before. He could not quit fishing completely at first but by diverting money from fishing to on-farm activities, he eventually quit fishing completely to the on-farm activities and his living standards had improved.

3.6 Demographic characteristics and their influence on diversification

The demographic characteristics of the fishers are summarized in Table 5. The logistic regression model (Table 6) showed that the demographic characteristics explained 45 % of the diversification of the fishers ($R^2 = 0.45$). The coefficient values (B) showed that technology (use of radio or mobile phone), social groups, fishing experience and wet season fishing days increased diversification although only technology and the wet season fishing days were significant ($p < 0.05$). Age, education, timing of seasons and dry season fishing days decreased the likelihood of diversification, though this was not significant ($p > 0.05$). The odds ratios (Exp(B)) showed that technology, wet season fishing days and social groups had the highest chances of increasing diversification and a unit increase in each could increase diversification by 11.45, 3.32 and 3.13 times, respectively (Table 6). Conversely, age had the highest chance of reducing the likelihood of diversification and a unit increase in age would result in 0.96 times reduction in likelihood of diversification.

3.7 Constraints to adaptation and required interventions

The fishers reported that adaptation was limited by credit facilities (26.4 %), awareness (21.9 %), land availability (21.4 %), appropriate planting materials (11.7 %), inadequate law enforcement (10.7), lack of affordable irrigation facilities (5.1 %) and high dependence on fishing alone (2.8 %). They suggested that interventions required to overcome the

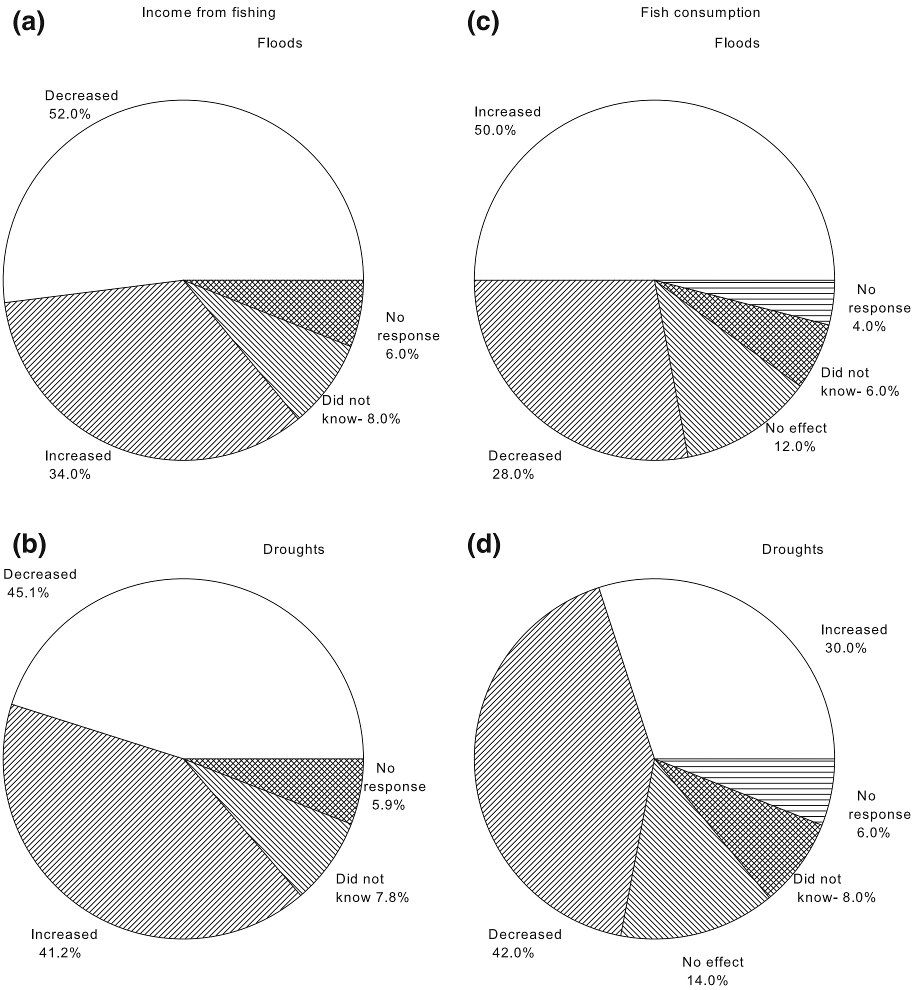

Fig. 4 Relative proportions (%) of impacts of floods and droughts on income from fishing and fish consumption on Lake Wamala, Uganda

constraints included: provision of low-interest credit facilities (28.6 %), increasing awareness (26.8 %), provision of affordable irrigation pumps (16.1 %), appropriate planting materials (16.1 %) and enforcement of existing laws and regulations (12.5 %).

4 Discussion

This study was intended to generate knowledge on the extent to which the fishers perceived changes in climate, the impacts of the changes on their livelihoods, how they had adapted to the impacts, the constraints to adaptation and required interventions to guide planned adaptation.

Table 2 Relative proportion (%) of adaptation strategies of fishers to perceived floods and droughts around Lake Wamala

Adaptation measures	Relative proportions (%)
Diversification to non-fishery activities	20.9
Increased time on fishing grounds	16.8
Changed fishing grounds	15.8
Changed target species	13.6
Changed fishing gear types	9.4
Used more gear	7.6
Decreased fishing days	7.0
Increased fishing days	4.7
Decreased time on fishing grounds	2.0
Changed landing sites	1.6
Exited the fishery	0.6

Table 3 Diversification indicators of fishers around Lake Wamala, Uganda

Production diversification indicator	Percentage of fisher household		
	Crop	Livestock	Overall
No diversification	18.5	35.2	14.8
Low production diversification	40.7	63.0	29.6
Intermediate production diversification	38.9	1.9	38.9
High production diversification	1.9	–	16.7

Table 4 Relative proportion (%) of adaptation strategies of fishers in relation to crop and livestock agriculture around Lake Wamala

Crop related strategies	Relative proportion (%)	Livestock related strategies	Relative proportion (%)
Changing planting dates	38.3	Grazing near lake shores	23.8
Cultivating early maturing crops	22.4	Collecting fodder	19.0
Diversifying crops	12.0	Collecting water for livestock	14.3
Irrigation	11.0	producing fodder	14.3
Farming near the lake shore	9.4	Reducing number of animals reared	9.5
Growing drought resistant crops	7.0	Zero grazing	9.5
		Buying feed stuffs	9.5

The results showed that the fishers were aware of changes in climate, manifested through less predictable seasons, floods and droughts, with some of their perceptions related to changes in rainfall around the lake. This awareness reaffirms observations of Howe and Leiserowitz (2013) that rural communities dependent on climate sensitive resources such as fisheries have capacity to recognize changes in local climate. Since knowledge of climate change promotes adaptation and mitigation (Leiserowitz 2007), the awareness among the fishers around Lake Wamala suggests capacity to practice and participate in interventions to promote adaptation. However, perception of local climate change can be subjective (Nursey-Bray et al. 2012; Howe and Leiserowitz 2013), thus

Table 5 Summary of demographic characteristics of fishers around Lake Wamala, Uganda

Characteristics	Relative proportion (%)/ years/persons
Fishing experience (mean)	13 years
Sex	
Male	100 %
Age (mean)	37 years
Education	
No formal education	14 %
Incomplete primary	59.3 %
Complete primary	22.2 %
Secondary	3.7 %
Marital status	
Married	83.3 %
Not married	16.7 %
Household size (mean)	5 persons
Residence status	
Permanent shelters	94.4 %
Migratory shelters	5.6 %
Membership to social groups	
Credit groups	27.9 %
Fisheries	11.5 %
Religious	9.8 %
Agricultural	6.6 %
No membership	44.3 %
Use of communications technology	66.7 %

Table 6 Summary of results of the logistic regression model

Variables	Coefficients (*B*)	*p* value	Odds ratio (Exp(*B*))
Age	−0.05	0.549	0.96
Education	−0.53	0.686	0.59
Fishing experience	0.11	0.334	1.12
Technology	2.44	0.046	11.45
Social groups	1.14	0.365	3.13
Timing of seasons	−2.71	0.122	0.07
Wet season fishing days	1.20	0.040	3.32
Dry season fishing days	−0.57	0.166	0.56
Constant	2.68	0.463	14.63
R^2			0.45

Coefficients provided the relationship between the probability of diversification and the predictors; the odds ratio show changes in odds for diversification for each unit change in the predictors; Significance was at 0.05 probability level explaining some of the dissimilarities of fishers' perceptions observed in this study. The observed increase and predominantly above-average anomalies for temperature are comparable to climate change assessments for Uganda (USAID 2013). However, USAID (2013) reported decreased rainfall over Uganda and the increasing trend of rainfall observed around Lake Wamala, suggests non-homogeneous rainfall patterns over the country, which emphasizes the need for location specific observations.

The comparable relative proportions of the fishery based activities and average fishing days on the lake in both the dry and wet seasons demonstrate the importance of fishery activities to the fishers. The results also demonstrated a shift from the dominance of the Nile tilapia to the African catfish, in line with commercial and experimental catches on Lake Wamala that show increased contribution of the African catfish and decreased contribution of the Nile tilapia (NaFIRRI unpublished report). The fishery of the African catfish can be considered an "emerging fishery" as the Nile tilapia dominated catches from the 1960s when the lake was first opened for commercial fishing up to 1999 when it contributed about 90 %. Since then, the contribution of the Nile tilapia to the catches has been decreasing and was <1 % by 2013, while that of the African catfish has been increasing to about 85 % (NaFIRRI unpublished catch statistics). The decline in the contribution of Nile tilapia could be linked to reduced lake levels since the 1980s due to droughts (UNEP 2009), which may have created unfavorable conditions that reduced the volume and area of open water habitat, causing overcrowding, competition for food, and increased susceptibility to fishing gear and reducing breeding and nursery areas (Lowe-McConnell 1958). Conversely, the increase in the contribution of the African catfish could have been enhanced by its capacity to utilize marginal wetlands with low water and oxygen levels for breeding, feeding and decreased susceptibility to fishing (Van der Waal 1998). Recent research on the lake also suggests that, whereas the condition factor (measure of robustness and well-being of fish) of the Nile tilapia has decreased with decreasing lake levels associated with changes in climate variables, that of the African catfish appears not to have been affected (Natugonza et al. 2015; NaFIRRI un published report). This suggests that changes in climate variables will shift fisheries to those that can survive under the changed conditions which will change the types of fishes available for harvesting.

The shift from the Nile tilapia to the African catfish on Lake Wamala presents different fishing opportunities. The first lies in the capacity of the African catfish to survive under conditions of low oxygen and water levels, characteristic of wetlands that would otherwise limit the production of other fish species such as Nile tilapia. The African catfish in Lake Wamala presents a fishery which is more resilient to droughts with better capacity for resurgence during floods. Similar observations have been reported on Lake Chilwa where the populations of the African catfish, compared to those of species closely related to Nile tilapia such as *Oreochromis shiranus chilwae* Trewavas were shown to decline less severely and later during lake drying phases and to recover earlier during refilling (Furse et al. 1979; Njaya et al. 2011). Secondly, the condition of the African catfish has been shown to be less affected by severe climatic conditions, with its individual average weight in commercial catches in Lake Wamala ranging from 1.2 to 4.3 kg compared to 0.3–0.7 kg for individual Nile tilapia which is affected more severely by climatic changes (Natugonza et al. 2015; NaFIRRI un published report; Okaronon 1993). Since small fish have low consumer preference and low commercial value (FAO 2005), the shift to the African catfish presents better consumption and market opportunities to the fishers.

Similar shifts in fish species have been experienced in other lakes. In lakes Victoria, Kyoga and Albert, small cyprinid and characin species have increased to 40–80 % of commercial catches (Ogutu-Ohwayo et al. 2013). In Lake Chilwa, the fishery has been dominated by more resilient *Barbus* spp., with the ability to breed in marshes and river mouths (Njaya et al. 2011). These shifts are in line with the FAO (2010) prediction that fisheries will shift to those able to persist in new conditions created by the changing climate.

The shift in fish species on Lake Wamala has been accompanied by a shift in types and sizes of fishing gear. Okaronon (1987) reported that gillnets were the dominant fishing gear, with the minimum mesh size being 88.9 mm and hooks were not widely used on the lake. However, during this study, the mesh size of gillnets had dropped to 38.1 mm and hooks were extensively used. The increased use of hooks appear to have emerged with increased contribution of the African catfish, while the smaller mesh size gillnets seem to be associated with reduced size of the Nile tilapia.

The effects of floods and droughts on livelihoods (Table 1) have been reported elsewhere among fishing communities. These events have been associated with loss of lives in Indonesia (Westlund et al. 2007) and damage to boats, fishing gear, landing sites and other community infrastructure as well as disrupting fishing activities in The Gambia and Côte d'Ivoire (Jallow et al. 1999). However, loss of lives associated with floods and droughts around the lake is apparently due to strong winds experienced on the lake that lead to increased severity of waves causing drowning and death. The reduction and increases in fish catches reported on Lake Wamala during droughts and floods, respectively, can be attributed to recessions and recovery in water level associated with these events, as have been observed in other lakes such as Chilwa (Njaya et al. 2011). The lower income from fishing during the floods reported by fishers may be linked to the corresponding higher fish catches. Higher catches have been demonstrated to result into higher fish supply and reduced demand, preventing fishers from realizing increased income from increased fish catches (Broad et al. 1999). Conversely, low fish supply resulting from reduced catches during droughts increases demand, and results in higher prices, enabling fishers to achieve higher income. However, this benefit could be short lived if prolonged droughts resulted into severe reduction in catches. The more fish available for consumption during floods compared to droughts was apparently due to higher catches associated with the floods and vice versa.

The fishers on Lake Wamala have demonstrated capacity to adapt to the changes in the fishery and their livelihoods as result of droughts and floods. Their adaptation strategies are typical of fishers' response to risks (Allison et al. 2007; Turner et al. 2007; Brugere et al. 2008). Diversification to non-fishery activities could be the most beneficial adaptation strategy for the fishers as it successfully contributes to income, food security and employment (Brugere et al. 2008) and fisher households with diversified farming activities have better well-being than those without (Bene 2009). In combination with fishing, non-fishery activities ensure more sustained livelihoods for fishers because income from fishing can be invested in on-farm activities such as crop growing, fishing can provide income when crops are growing, and crops can generate income to support fishing (McGrath et al. 2007). In addition, some fishing communities have been reported to invest income from fishing and growing crops into livestock (McGrath et al. 2007), which acts as a safety net against household emergencies. Such values of diversification out of fisheries are also demonstrated in this study for the innovators who increased income and food security beyond what was earned from fishing and the quitting of fishing activities thereafter by some of them.

The fishers' strategies of decreasing fishing days, decreasing time on fishing grounds and quitting the fishery could improve income and food security if time created is diverted to productive non-fishery activities. However, the diversification indicators (Table 3) showed low diversification to crops and livestock and overall intermediate diversification, suggesting that specific efforts are required to promote diversification, especially to high-value crops. On Lake Wamala, the innovators could serve as role models from whom others can learn.

The adaptation strategies of the fishers like increasing time on fishing grounds, increasing fishing days, and changes in gear, characterize diversification within fisheries that involves strenuous activities fishers adapt especially under declining fish yield (Cinner et al. 2011). Such strategies may be beneficial in the short term but could enhance unsustainable fishing practices that can reduce the resilience of the ecosystem, degrading its capacity to contribute to livelihoods (Smit and Wandel 2006). The upsurge of illegal gear observed on the lake is probably a consequence of such adaptation strategies. Similarly, other adaptation strategies such as grazing and cultivating up to lake shores that the fishers reported in relation to crop and livestock agriculture can contribute to unsustainable practices such as deforestation and degradation of critical fish habitats. These have been shown to contribute to reduction in water quality, photosynthetic activity and habitat available for aquatic invertebrates and fish, ultimately reducing fish production (Junk et al. 2000; McGrath et al. 2007). Other crop and livestock associated adaptation strategies are considered innovative ways to respond to stressors including climate change (Kristjanson et al. 2012).

Results of the logistic regression model (Table 6) showed that fishing experience, technology, social groups and wet season fishing days increase the likelihood of diversification to non-fishery activities, in line with what has been demonstrated in other studies where by more experience in agricultural activities was found to increase probability of uptake of adaptation strategies (Nhemachena and Hassan 2007). Increased use of technology like mobile phones and radios enhanced access to information needed for adaptation (Yirga 2007). Membership of social groups held communities together providing sense and purpose for adaptation (O'Riordan and Jordan 1999). Fishing provides finances to support on-farm activities (McGrath et al. 2007; Njaya et al. 2011), and more fishing days could enhance diversification when fishers use their income from fishing for on-farm activities. The observation that age, education and knowledge of the timing of seasons decrease likelihood of diversification to non-fishery livelihoods around Lake Wamala, contradicted what was expected as they are commonly known to enhance adaptation efforts (e.g., Maddison 2006). However, increasing age may hinder diversification out of fisheries as older fishers have been shown to be less willing to adapt to changes, explore and later on take on new activities outside of fisheries (Silva and Lopes 2015). The model provides ideas on how the demographic characteristics influence diversification out of fisheries but is not conclusive since the best combination of the characteristics explained only 45 % of the diversification, with most of them being non-significant. However, the coefficient values of the non-significant demographic characteristics maintained in the model, demonstrate the direction (positive or negative) of their relationship with the capacity of the fishers to diversify outside fisheries, thus providing information useful in guiding adaptation interventions.

The fishers' considerable knowledge of constraints of adaptation and the possible interventions to reduce them is remarkable. The constraints that were reported are mainly associated with limited physical infrastructure and access to basic services like credit that characterize most fisher communities (Olago et al. 2007; Iwasaki et al. 2009; MRAG 2011). Therefore, providing these services can address the constraints. However, the interventions that the fishers reported such as improved awareness and membership of social groups that build up resilience against disaster and make communities more prepared to adapt (Adger et al. 2005), should be also considered by development agencies. As an example, increasing awareness has enabled communities to recognize the necessity of adapting, acquire knowledge about available options, have the capacity to assess them and implement the most suitable ones (Fankhauser and Tol 1997).

5 Implications for planned adaptation, policy and management

This study indicates that adaptation strategies can have both positive and negative consequences. Efforts are needed to promote the positive strategies and to discourage the negative ones. Positive adaptation strategies especially diversification to non-fishery activities should be encouraged because it is acclaimed as an indispensable way for coastal communities, including fishers, to build resilience to environmental changes such as climate change (Adger et al. 2005; Mcclanahan et al. 2008; Cinner et al. 2011). However, it may not always be beneficial and can be accompanied by practices that can degrade the resilience of aquatic systems (Smit and Wandel 2006). Policy should provide diversification opportunities for fishers as well as addressing the constraints for adaptation, with priority given to fishers' proposed interventions like providing awareness and credit. As diversification out of fisheries resulted in some fishers quitting fishing, it has potential to reduce fishing effort and should be used as part of other fisheries management tools. Management efforts are needed to control the illegal gear and develop a lake-specific management plan for the emerging African catfish fishery. Uganda's Fish Act provides for minimum mesh and hook sizes for all lakes in the country and, if implemented, could reduce the use of the illegal gear. To implement the Act, 28 cm has been set as minimum total length of Nile tilapia to be harvested, but no size limit exists for the African catfish, which could benefit from policy changes to include its size limits. There exists a provision to protect 200 m of shorelines as buffer zones on all lakes in Uganda and this should be implemented to partly manage the negative consequences resulting from diversification to crop and livestock agriculture, such as encroachment on wetlands and grazing and cultivating up to the lake shores. There are also other policy provisions targeting protection of wetlands and promoting tree planting that can be beneficial if implemented. Planned adaptation is necessary and possible and its implementation should promote positive adaptation strategies and discourage negative ones. With a boost of the policies to regulate illegal fishing practices, address constraints to adaptation and promote demographic characteristics that enhance diversification out of fisheries, the livelihoods of the fishers will be sustained. The results of this study indicate that fishers have some knowledge on changes in climate and impacts on their livelihoods and have been able to adapt to some of the impacts to sustain their livelihoods. As required in other counties dependent on fisheries resources such as the Pacific Island countries (Bell et al. 2013, 2015), there is need for more studies to predict the direction and consequences of the increasing variability and change in climate in Uganda to guide policy for planned adaptation to build resilience of affected communities.

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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